Environ. Sci., Hokkaido University	12 (1)	17~26	June 1989

Model Reference Adaptive Theory on International Technology Transfer (I)
—— Transfer of Coal Mining Technology into Hokkaido ——

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Abstract

About the history of Japanese Civil Engineering, *Hirozo Ogawa* said that it is clear that when the Japanese culture came into contact with the cultures of advanced countries, the work of civil engineering exalted the part of the period. It seems, the period, in which Japanese Civil Engineering exalted coincided with period when civil engineering technology was introduced by advanced countries as a model, and actually with adaptation here and there, the technology became accepted by Japanese. In other words, this process can be said to be an attempt by Japanese to adapt to a foreign technology.

This paper discusses the necessity of the effort process and consideration about the process of adaptation upon the introduction of coal mining technology into Hokkaido.

Key words: Model Reference Adaptive Process, Coal mining technology into Hokkaido.

1. Introduction

Recounting the history of Japanese Civil Engineering, *Hirozo Ogawa* once remarked as follows:

"The contact of the culture in the society gives actually great impact upon the changes of the theme of the period. As it is well, known the introduction of rice gave its benefit to the culture of the Joumon period (the Stone age), and even, the introduction of metalware from Korea peninsula gave an improvement to the society. The phenomenon of the opening the Kofun period (the civilization of ancient burial mounds) could be said as the foundation to the next history. But in 6th century or the beginning of 7th century, the progressive Chinese culture did actually have a great impact upon Japanese culture. In a similar way, it is possible to compare the Azuchi -Momoyama period(16th century) with Meiji period. Historians often classify Japanese history into 5 periods. The four boundary of period are the Taika Renovation (7th century), the formation of the Kamakura-Shogunate (12th century), the Azuchi -Momoyama period (16th century) and Meiji restoration. The middle of the Taika Renovation (7th century) was the period when contact was made with the Chinese

culture. The Azuchi-Momoyama period (16th century) represents the period when the Japanese culture came into contact with the cultures of Spain and Portugal and finally Meiji era was the period when there was Japanese contact with industrial revolution via the cultures of Europe and America. The formation of the Kamakura−Shogunate is characterize as the conclusion of long process to suppress the Tohoku area, and complete the formation of one society, one language, one religion and one country. Under all the historical periods enumerated above (with the exception of the Kamakura-Shogunate period) Japanese Civil Engineering activities expanded. At the same time, under a unified country, not surprisingly, the power of the country became stronger and the society lived with fresh mind. Adaptation of foreign culture, the unity of a country, the work of civil engineering, this history depicts the continuation of the relationships among those three factors."

It seems, the exaltation of the work of Japanese Civil Engineering is a period when there was the adaptation of foreign cultures and the introduction of civil engineering technology from advanced countries as a model. This process certainty can be said to be a trial of Japanese adaptation capabilities. Stated differently, this process can be likened to the model reference adaptive process. In the 6th century or the beginnings of the 7th century, China can conveniently be referred to as the advanced country. In a similar manner, Portugal and Spain can be labelled as the reference during the Azuchi-Momoyama period while Europe and America can also be referred to as the reference in the Meiji period.

The main aim of this paper is to show how civil engineering technology was accepted in the Meiji period, and in relation to adaptive processes, we focus on the introduction of coal mining technology into Hokkaido.

In the direction of the process of coal industry development, a variety of new machines have been introduced from Europe and America, and when considering technology for coal mining, it can be found the plenty progress has been made in coal mining technology. It was also found that the development of coal transportation technology was supported by the construction of railroads and harbors, and this actually gave a great impetus to the development and progress in civil engineering technology.

The progress made in coal mining activities can only be meaningful when it is linked to its prospecting, mining and excavation which involved the application of diverse and sophisticated civil engineering technologies. In addition there was also the construction of Gunkan island in Nagasaki.

2. The Traditional Technology of Coal Mining

The traditional technology of coal mining is usually characterized by small market, poor in experience and the scale of production is relatively small. Nevertheless, this technology has been extended and accumulated for more than hundred years. The method of mining production from 17th century to the middle of 18 th century is usually called as traditional because the method used at that period was mainly to mine bare head coal or simply to dig a hole to get a coal.

From the end of 18th century however, there has been a gradual improvement upon the technology of coal mining. That is to say, the knowledge on geological features, in particular in exploiting the coal mining, has gradually increase, and about the tunnel, it can be clearly seen the improvement of three methods namely, Shaft, Transverse, and Oblique helped considerably. Shaft is called as a well bucket canal (at first, you make an arrow shape in the canal and then dig the hole in the lower part). Transverse means, entering through the side of the lower part of the root of the mountain, while Oblique means making a hole and then entering the sideways of the tunnel via the proper coal.

These all are the methods used in tunnel, and the facts showed that on one hand, the knowledge of topography has increased in coal bed, and on the other hand, the technology of coal mining has reached a high point due to the concretions of the method of regulation. The method of coal mining is, to make the main road of the tunnel inside the coal be, however because the right and left side along the tunnel still persists, it is very important to use a method to support the tunnel. To maintain the tunnel, pillars were used at that moment so that, while the coal was picked up a pillar was made in a special place called a coal face.

The biggest problem of this traditional technology is that, as the tunnel got deeper, spring water was sometimes found inside the tunnel, and it certainly increased per unit cost of production. A method used to overcome this problem was, in Shaft, all the spring water is drained using a well bucket, while in the Oblique only the fluctuation of spring water is drained using a hand pump. Furthermore, since the road of the tunnel got deeper, the drainage hand pump made the drainage system difficult, so that it called for the use of the drainage tunnel. In the case of Transverse, under the water level, tunnel was continuously dug and the method used was to drain the spring water outside the tunnel. The relation between drainage method and exploiting the tunnel had become a center of coal mining technology. About the ventilation system in coal mining, natural ventilation was commonly used.

The conveyance system used in coal mining as that coal was put inside the well bucket in Shaft but for Oblique and Transverse coal was placed inside the bamboo basket, and the basket was moved by pushing or using a shoulder. It was brought out of the surface by using four wheel vehicles.

In the beginning of 19th century, the market of coal was wider, the technology of coal mining still accumulated, in particular, in the advanced regions, resulting in the improvement of coal mining technology. In the end of Tokugawa period, the drainage technology used is hand pump and water mill. In Shaft the technology used was a roll up machine, and up to now the Shaft has 6-9m depth of throne, and even there is the possibility that the depth of throne is around 30m. This fact showed that there was an introduction of technology of gold mining in the improvement of coal mining technology. The attention of coal mining technology in the end of Tokugawa period was that the big coal plantation should be linked to the quality of coal location and the profitable condition of a region. Among the coal mines was Takashima coal, a solitary island separated 15 Km from Nagasaki where the capacity of production was around 3,800 ton per annum.

In 1885, three coal mines could produce 235,000 tons with a work force of about 400

miners, and to overcome the drainage problem, a large water mill was used. Furthermore, Takashima coal mine was a big one, and in accordance with coal mining technology, it had to be supported by skilled as well as contract workers. In 1871, a mine engineer from Britain, *F. Potter,* conducted a study on the Takashima coal mine, and the study on coal bed and topography utilized the traditional technology, and this resulted in an increasing knowledge of this technology by domestic workers.

The history of the development of coal mining in Hokkaido, began in 1854 with the opening of Hakodate port and this may be steamship. In 1856, Japanese feudal government assumed a direct control over Shiranuka coal mountain. From the point of view of coal mining technology prevailing at that time, a tunnel was continually dug at water level in the road within the tunnel. One was about 18m and the other was about 15m. To prevent the sudden fall of a tunnel a perch was used in the ceiling part, and a Kandelaar was used inside the tunnel. In kyushu area, the accumulation of coal ming technology resulted in the application of diverse coal mining technologies. The production of coal was around 865 ton, and all were sent from Hakodate to fuel foreign steamship. Production, however stopped due to the bad quality of coal.

To replace the Shiranuka, coal mines immense coal deposits were found and developed near Hakodate in 1856 and in 1857 the production of coal at the site began. After that, Japanese feudal government employed some foreign engineers. In 1862 for example American geologists, *R. Pumpelly* and *W.P. Blake* did a geological study. In the same year, they established a School of Mining Technology in Hakodate. The mechanization of Japanese coal industry at that period was undertaken by *Takato Oshima, Yasuzo Yamao, Hisaburo Takeda.* In 1867, Japanese feudal government employed *H.M.Gower* from Britain, and this resulted in the production of high quality of coal, even though the production of coal never reached 100 tons and in fact there were no machines inside and outside the tunnel.

3. Introduction of Foreign Technology During Meiji Period

To increase national prosperity and strengthen the defense of Northern Japan, the Meiji government took some initiatives to develop the backward region, Hokkaido and to exploit its abundant resources. One of the development priorities was the development of coal mining. It can be said that the development of coal mining technology pioneered by Japanese is actually a result of adaptation of progressive technology. The Japanese feudal government was represented by a leader called *Enomoto,* a past Shogunate retainer. He left the School of Navy in Nagasaki after studying steam machine and chemistry. He also studied about weapons, steam machine, voyage, etc., and the necessity of knowledge in the development of mines at the School of mining and chemistry in the Netherlands. Related to the technology of mining *Enomoto* is regarded as the first Japanese who did a study on the ingredient analysis of coal using chemical analysis. Besides *Enomoto,* Meiji government used three other scholars such as *Ikunosuke Arai, Takato Oshima and Hisaburo Takeda* with past Shogunate retainer who finally fought against the Meiji government in the Hakodate war.

To lay the foundation of coal development in Hokkaido, the first foreigner used by Meiji government was *H. Capron*. *Capron* was a governor of agriculture and later on, and expert on chemistry engineering, *T. Antisell,* together with an expert on civil engineering technology, *A.G. Warfield* joined Capron in 1871. One year later, the colonization Agency started functioning. The report on research of geological features and mineral resources had been given by *Blake,* and that report was used by *Warfield* as a reference to measure geological features, and was also used by *Antisell* for studying similar features.

In 1873, *B.S. Lyman* and his student, *H. Munroe* did a study on geological features and mineral resources for all Hokkaido and in particular a study on Horonai coal. This study was done several times and this led to the establishment of the foundation for coal development in Hokkaido. Around that time, as American expert on coal technology, *L. C.E. Gaujot, J. U. Crawford,* and some other experts from foreign countries were hired to develop the Kayanuma and Horonai coal mines. For coal development in Hokkaido, this was the first opportunity to use an American expert, and as assistants, the Japanese worker got the advantage of increasing their personal experiences in applying modern coal mining technology. The workers who helped *Lyman* in doing the geological research, together with the student from Colonization Agency, while working together with *Lyman* had the unique opportunity of putting into practical use the fundamental theories they had learnt at school. This process of geological research made them skillful in technology. These assistants formed an association of geological study, and the regular meetings on the research was also instituted. They also studied from foreign books which had relationship with geological study, and in January 1879, they published a monthly journal on earth. They also reported their research findings on geology and translated foreign books. Among the assistants, were the head of Mitsui Miike, *Junichi Shimada,* conductor of Meiji industry, *Tetsunosuke Inagaki,* and the concluded that coal development of Kyushu is important. On measurement technology, the *Ikunosuke Arai's* group acquired the triangulation technology from *J.R. Wasson.*

Concerning those who studied abroad, the governor, *Kiyotaka Kuroda,* using the experience he acquired during his observation tour in Europe and America, in 1871 together with *Keisuke Otori* taught at the School of the Colonization Agency, and contributed greatly to the development of Horonai coal. The number of students who studied abroad were 33 students, of this 8 studied at the School of Mining while 2 were at School of Engineering. From this it is clearly seen that a strong intellectual power had been involved in the development of coal mining. About the education in the field of technology, *Kuroda* in 1872 requested for increase in size of the School of Colonization Agency in Tokyo and in 1876, that of the School of Agriculture College in Sapporo. Furthermore he called for the training of those whose employment had relationship with technology, e.g.: School of Mining, School of Engineering, School of Agriculture, In addition for the lecturers to be able to operate the modern technology, he requested that they learn the fundamental theory of the real practice and application of technology.

(1) Introduction of foreign technology to the Kayanuma coal mines

In 1869, Meiji government started to produce from the coal bed of Kayanuma mines.

The work of *Gower* and his assistant, *Scout,* can be considered as an effort to consolidate the utilization of the equipment of conveyance. He introduced at that time a handcart one wheel vehicle inside the tunnel. An 80cm railway steel was also prepared for the conveyance outside the tunnel where the distance was around 2km from the mouth of the tunnel to the seashore, and a truck with 4 tons of cow power was also ready to be used. At first, coal vehicle was purchased from Europe and America, but soon, Japanese employees were able to produce by themselves, so that manufactured goods could be sufficiently supplied. But compared to the conveyance measure, the shaft was relatively in an old condition. The conveyance method used in the shaft as, from the coal surface within the main road of the tunnel and turned to the expiration hole, and from this place, the coal fell into the road tunnel, and then carried outside the tunnel using handcart of one wheel vehicle. This method was evolved under the guidance of foreigners hired in coal mining. The investment of facilities increased, so that to improve the coal mining, it became necessary to use large capital. Based on the round trip research of *Enomoto* and observation study done together by *Antisell, Lyman,* and *Keisuke Otori,* the government then, designed the improvement planning and development of the Horonai coal. In 1877, the conveyance mechanism as established and 170,000 yen was used to improve the harbor and conveyance facilities. In 1879, and expert on technology from America, *Gaujot* was invited to Japan and the real western coal technology was introduced then.

Relating to the improvement of the stock of coal, *Gaujot* argued that to install an equipment along the corridor of a big tunnel, an open tunnel with vertical and horizontal system and characterized by steep slopes as deemed to be necessary. From this place, the coal beds can be lined along the tunnel to ensure penetration and easy access to this corridor. In this big coal mines as a result of the problem due to route of the tunnel corridor it became necessary to build a railroad for the conveyance which called for the selection of a surface access. On this line, there was a plan then to construct a railroad from Kayanuma to harbor. For the safety of coal mining, there was also a plan to improve the roads along the coal mines, and this resulted in the use of Shaft in Hokkaido for the first time to create fan using man power, electric fan using wood, build cottages for miners, and a factory for coal vehicles. In 1880, the cylinder for fresh road tunnel was established, and in 1881 coal quality selection procedures were established too. The various equipment used for coal mining had been replaced by modern equipment used for coal mining had been replaced by modern equipments, there was abundance of gas inside the tunnel, and dislocations were many. Besides that coal reserves were less than assumed, production of coal was under planning, and in 1882, coal industries discontinued to function. In the following year, this coal mining disposed to private enterprise. This western technology used in Horonai coal, though the result was fruitless.

(2) Introduction of foreign technology into Horonai coal

In 1873, both *Lyman* and *Enomoto* started to survey the Horonai coal deposits. According to them, the reserves of coal was in abundance. They also concluded that the quality of coal was high, excellent and pulse. After 1875, some distinguish bureaucrats, e.g.: *Keisuke Otori, Kuroda* governor, *Hiromi Ito, Aritomo Yamagata,* etc., after inspecting

the Horonai coal, made a plan for the government industrial policy. In 1878, 1,330,000 yen development fund from public loan earmarked. Relating to the decision made to the government on the industrial policy a business system was created, and foreign experts on technology were hired. In 1879, the construction of coal tunnel was ready and it started to operate. Because the know—how for improving the conveyance was not readily available, they hired two foreigners, *J. V. Crawford* and *Gent* to built this important railroad. They decided to plan the construction of railroad from Horonai to Temiya via Ebetsu, Sapporo, Otaru, and in 1880, the construction of the railroad began.

To purchase the railroad construction material, locomotives and other machinery, *J. V. Crawford* had to order the necessary materials from America. In the same year, the railway line linking Otaru, Temiya, Sapporo was constructed and a year later, the completion and opening of a 90km Sapporo-Horonai line. From the above, it can be realized that the means of conveyance to the Horonai Coal mines had then been completed.

Under the direction of *L.C.E. Gaujot,* who supervised the Kayanuma coal mines, the development of Horonai coal started in 1878 and a year later, the excavation of the main coal started. About the tunnel, its height was 2.1m and the width was 2.7m, 94m above the sea. One tunnel met the other at a right angle, and in 1881, the first coal bed was made at a point which was supposed to arrive at the original bed after two months. To be able to move freely on both sides of the road tunnel, it was deemed necessary that the two tunnels should run parallel to one another. For blasting and graver elasticity, they used a steam rock drill machine. In 1881, the Colonization Agency invited an engineer from Britain *F. Potter* guided the excavation of Miike coal. This guidance was from the road surface to the road along the coal bed, and in 1882 the realization of the road along the coal bed such as Takinosawa and Honsawa began.

The method of coal mining was that between the parallel excavation of road along the tunnel there were each 9m space blocks, and from this, they constructed a small road tunnel and space. To prevent the coal from falling, a pillar was used to support the ceiling and powder was commonly used. The transportation of the coal from underground to the surface involved the use of man of power by way of carried boxes or in the coal surface, the coal is brought to the road along the tunnel by a rotation. From this place, the coal is carried outside the tunnel through the main road tunnel by pushing four wheel vehicles. High quality coal usually composed of natural water, but the means or know-how for draining this water was non—existent coal ming. To generate plenty of gas for coal mining an electric power was often used. In 1885, conviction was used to get excellent products. In 1889, electric fan power was introduced so that the risky places inside the tunnel can certainly be reduced. And finally, in the government's sector coal mining, high quality coal containing no water was found.

(3) Introduction of foreign technology into Hokkaido coal mining industry

In 1889, the Meiji government disposed of the railroad and coal mining activities to Hokutan (Hokkaido coal railroad company). Hokutan bought some lines from Horonai and also took responsibility of the coal mines at Yubari and Sorachi, and began to excavate it. This inevitably meant the continuation of mechanization. Observing the technology

used to excavate the road tunnel, in 1895 the depth of Sorachi was 210m, while the depth of Horonai was 225m. This great depth of mining prevalent in these places reflected the fact that a big scale mode production was implemented. The presence of hard coal, black powder, carbonate, etc., in excavating the coal, necessitated the use of air compressor to cut the hard coal. In 1889, in both Yubari and Sorachi, waterline rock drill was used. In 1908, the mines at Yubari and Mayachiko bought 8 units of waterline rock drill. Because the scale was large, the introduction of power for operating that was most machines likely profitable and effective.

The progress of mechanization of coal mining was not so fast, however, long wall system tended to increase and a method of mechanization was employed. In 1990, Yubari coal introduced an air compressor cutter.

Concerning the conveyance, because man power was not used, a carriage was constructed to carry the coal using a coal vehicle over a rail. The rapid progress of the mechanization of main road tunnel still continues. Yubari for example, in 1893 produced a machine using steam, and a year later, endless rope steam had been produced. In 1895, Sorachi introduced a winding equipment. Yubari utilized a vehicle using air compressor in 1900 making it the first Japanese firm to have done so. In 1902, an electric endless rope was produced by Temiya factory, resulting in rapid changes in the use of electric power over steam power.

In 1901, Sorachi coal mines introduced a train from the mouth of the tunnel to the coal stock underground and a year later, the electric endless rope had been produced by Temiya. The mechanization progress was so fast, that by 1898 Yubari coal had started to use electric fan, and from 1900, small electric fans were introduced inside the tunnel.

Concerning drainage, because the underground mining was getting deeper, the mechanization of drainage seemed to be inevitable. A drainage pump was built and in 1909, Sorachi coal introduced an electric pump with 100 horse power. In 1896, both Yubari and Sorachi introduced a powder coal dressing. Because of this powder coal dressing, the quality of coal became better so that the various demand for coal could be matched and in addition the quality of the coal available to consumers was enhanced.

The combination between rapid progress of mechanization and the driving force that became available as a result of the transformation from steam power to electric power, Horonai coal immediately increased the energy of the electric fans to 7.5kw in 1898, and the construction of generator location was linked to the conversion made from steam power to electric power. To match the progress of mechanization both outside and inside the tunnel, the production of various machines still continued. At Iwamizawa and Temiya manufacturing plants where most of the productions had railroad related machine, some machines, e.g.: machine for coal dressing, machine for producing electric power, etc., were produced. In the subsequent years and in a similar fashion, the Japanese mining technology accumulated the methods of production on its own.

For the sake of modernizing the industry the Meiji government established the so-called legal public order as the basis for ensuring this modernization drive. In 1871 under the guidance of two miners who were also bureaucrats, *Toru Yoshii* and *J.G Godfray* from Britain, the draft of Japanese mining Act was under way and it was pronounced officially

in 1873. Section 33 chapter 8 of this Act regulated the public mining area and that one must have a permission from the government as a guarantee for conducting mining activities in government mining area. In addition, the government rejected all the coal mining management done by foreigners.

Nevertheless, considering the by−product of mining areas e.g.: dispersion, exhausted resources, destruction etc., of the mining area (the minimum area, according to the Act, was around 1500m-square) the government made a remarkable improvement of the Act in 1890. The new Act gave the possibility for large capital investment into big coal mining management and this certainly implied that the modernization of equipment for coal mining still continued.

4. Conclusion

In conclusion, it can be said that the coal mining technology has been introduced from foreign countries to Japan. In Edo period, European technology was introduced from Holland, and concerning the inexperience unsophisticated traditional coal technology, the accumulation of some technology also existed. Accumulation of technology also continued under the Meiji government, firstly, the development of coal technology was pursued by a leader, called *Enomoto,* and then was actively adapted by Japanese technicians. Many foreign experts were used, and assistants, the Japanese technicians enjoyed studying towards the improvement of technology, and even some technicians who studied abroad became a master in technology improvement techniques. Among them, the civil engineering techniques for construction of railroad was very notable. Around 1880, assistance given by foreign workers, a student who studied abroad, and among the graduated students solidly established the foundations and in 1889, relating to the coal mining technology, there were no foreign experts anymore. Moreover, private enterprise in Hokkaido paid a lower cost for coal, and up to now, every kind of coal machine can be sufficiently supplied through domestic production. It is clear, an effort to improve the European technology from Holland as a reference has been made during Edo and Meiji periods, a much concerted effort has been exerted in accordance with improving the inherited traditional technology by using European and American experiences, in particular the technology from Britain and America was used as a reference. Production of every kind of machinery for coal mining activities in Japan has improved over the years, and it is indisputable true that the adaptation process has been successfully done by Japanese.

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