Roles of Transportation Systems in the Formation of Ashio Copper Mining Town in the Era of Japanese Industrialization
- Considering Aspects to Assess Historical Heritages related to Transportation Facilities-

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Abstract: Mining industries were one of main sectors that played key roles in the process of Japanese industrialization. Ashio copper mine was one of representatives from Japanese mines for the large amount of products and for early challenges for injurious from mining. The paper deals with transition of transportation infrastructures and their roles for formulating the mining town in order to assess historical heritages related to transportation facilities in Ashio copper mine. Next to giving the brief preview of Ashio copper mine, Historical reviews of introducing new transportation technologies and of developing transportation network are described. Influences of transportation infrastructures on functional and areal transition of production bases through the period, when the special structure has been constructed are discussed. Based on above mentioned reviews, Aspects of assessing historical transportation heritages are proposed.

Key Words: Ashio Copper Mine, Production Base, Transportation Technology, Transportation Heritage

1. PREFACE

Japan is the first country in the world, except western countries, that achieved industrialization. In the process of Japanese industrialization, mining industries played key roles such as in producing exportation to get foreign currencies, in formulating industrial conglomerates that leaded industrial investments, and in progressing in starting up electric industries (Takeda, 2003). Ashio copper mine was one of representatives from Japanese mines with the large amount of products and with early introducing environmental technologies for environmental pollution from mining. Ashio copper mine is worthy of conservation as industrial heritages in order to understand the process of Japanese industrialization that developing countries might be interested in to compare the process with their own. The mining that is a typical industry depending on its resources is located, in many cases, at the disadvantaged point on accessibility. So both internal and external transportation systems of logistics are inevitable infrastructures for production. This means that transportation systems give large influences also on the physical structure of the mining town.

Next to giving the brief preview of Ashio copper mine, historical reviews of introducing new transportation technologies and of developing transportation network are described. Next, the paper deals with roles of transportation infrastructures for formulating several kinds of production bases in which facilities for production are accumulated and into which so many workers are gathered. Ashio Copper Mining Town was composed of several districts developed around the production base. Influences of transportation infrastructures on the
transition of production bases regarding function and location are discussed within the period from 1887 until 1926, when the special structure of the town has been constructed. Based on above mentioned reviews, aspects of assessing historical heritages related to transportation facilities are discussed.

2. THE OUTLINE OF ASHIO COPPER MINE

2.1 The Topography of Ashio and Local Resources

The former Ashio town (now merged into Nikko city), shown in Figure 1, is situated on the source of the Watarase river. At the center of the area enclosed by this river (which also includes the Matsugi river) and its branch the Koshin river stands the Bizen Tateyama mountain, stretching 3.2 km east to west and 4.4 km north to south, with the copper ore bed at its bottom. Ashio Mining town was situated surrounding the Bizen Tateyama mountain, alongside three-abovementioned rivers. Other than copper ore, the area contains several other resources that were widely used in copper production. Those include the waters of the Watarase and Daiya rivers (an electric power resource), timber from the surrounding area (fuel and building material) and caustic lime (neutralizer). The location of the copper production facilities depended on location and distribution of these resources.

2.2 Growth of Production Volume and Population Size

In 1877 (Meiji 10), Furukawa Ichibei bought the exhausted Ashio copper mine and began managing it. In the period between that time and 1917 (Taisho 6), the production volume increased from 47 tons to 16,000 tons (Figure 2). Though several fluctuations of the production can be seen, there was a continuous rise during these 40 years, and the production eventually multiplied up to 340 times. Ashio proudly had occupied the leading place in the country on copper production volume more than thirty years (Takeda, 2003). The continuous increase in copper production in Japan was mainly due to two factors. The first is the growth of the world market with Japan occupying 5% share of world production in 1887 (Meiji 20), and Japan maintained a status of primary exporter until the end of the First World War (Takeda, 2003). The second is the growth of domestic market, especially at the time of the
first World War after which copper production answered the demands of the electricity and communication industries. It can be said that privately owned mines such as Ashio copper mine made aggressive efforts increasing copper product. National industrial policies, such as mining regulations and governmental mines that employed Western experts (Takeda, 2003) helped effectively private mines actively to seek the introduction of advanced western technologies, alongside the development of original techniques according to different conditions of each mine.

Between 1877 (Meiji 10) and 1913 (Taisho 2), the number of miners in Ashio copper mine grew from 215 to 11,963, and later began to decrease. The ratio of miners in the local population (Figure 2) provides an important insight into the progress of urbanization. In 1897 (Meiji 30) miners constituted approximately 30% of the population, the rate has been held afterward but not been increased. It can be said that the copper production industry has been a driving force behind the development of the urban system and that Ashio mining town has been stayed at the step of reaching the threshold of urbanity.

2.3 Challenges for mining pollution

Furukawa started to deal with environmental pollution legitimately in 1897 by following “the Third Order on Prevention of Environmental Pollution from Mining” that was the comprehensive program equipped by the central government as the first attempt to meet environmental pollution from mining. Water pollution from mining in the lower Watarase river region was getting improved as the result of the projects of water purification plant conducted by Furukawa but in spite of various experiments to increase smoke problems, desolation of forests owing to smelting smoke couldn’t be improved (Editorial Committee of Tochigi History, 1984), because of lack of the technologies, until autogenous smelting methods were established in 1956. Restoration of forests has been conducted afterward continuously in Matugi valley.

2.4 Furukawa’s administrative policies both on copper production and on solving mining pollution

Ashio copper mine has been achieving rapid increase of copper product. Environmental pollution from mining stemmed from the increase. Two objectives, namely increasing copper products and meeting environmental pollutions, make the competitive relation to each other. Furukawa attempted to achieve the two objectives by extension and continuous redevelopments of production bases by introducing the wide range of new technologies from foreign countries and improving them to fit for Japanese conditions including feature of ore, geography and figure of Japanese labor (Japan Business History Institute, 1976).

3. INTRODUCTION OF TRANSPORTATION TECHNOLOGIES AND FUNCTION OF TRANSPORTATION MEANS

3.1 Transitions of transportation means by rapid introductions of new technologies

Transition of Transportation means in Ashio copper mine is represented in Table 1. It can be summarized in following items.

Decauville and man cars; Furukawa struck bonanza (Jinbodhi) at near Honzan in 1881. Furukawa needed transportation means in order to transport a lot of copper ores from the
bonanza to production bases (Shigeno, 1937). And so transportation means of tracks such as Decauville which was invented by a Frenchman (Paul Decauville) to carry grapes along slopes of vineyards and was known at Paris Exposition in 1878 were introduced. Man cars were also introduced from the West (Murakami, 2006).

**Horse tramways and gasoline cars;** In 1891, Horse tramways were installed for the transportation among production bases throughout the town. They have contributed to increasing the capacity of logistics among production bases to improve cars running on the track. Then, in 1926, gasoline cars were introduced as alternative means of horses (Editorial Committee of Tochigi History, 1984).

**Cableways;** In 1891, cableways were introduced to carry baggage along steep slopes (Shigeno, 1938). Afterward, they were constructed along many routes for connecting two points with different levels. In 1907, Furukawa developed a new type of cableway called “Tamamura cableway” by improving conventional technology. After that, a mechanical engineer (Tamamura) established the cableway company, by which the cableway produced became popular widely among Japanese mines (Murakami, 2006).

**Electric Trolley cars;** In 1890, Furukawa introduced water power plant to Mato which set a precedent of using electric power for mining in Japan. Next year, trolley cars were constructed from the end of the horse tramway to some facilities in Honzan. Since then, they were also introduced into the pits in Kodaki and in Honzan. In 1906 electric tram cars were introduced to tracks connecting Hosozan and Nikko Railroad (the Nikko line) station (Shigeno, 1938).

**Railroad;** Since 1888, Furukawa made railroad plans three times. But the first and the second plan were failed to implement owing to reject of the central government and lack of fund (Editorial Committee of Tochigi History, 1984). In1910, Furukawa got the license of the railroad (the Ashio line) from the central government and completed in 1914. It connected Ashio copper mine with a marketplace named Tokyo and refining plant at Hosozan directly. The Ashio line contributed to increasing the capacity of external logistics of Ashio copper mine.

### Table 1 Chronological table of transition of transportation means

<table>
<thead>
<tr>
<th>Year</th>
<th>contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1877</td>
<td>Roads and wooden bridges were maintained from Nikko to Honzan.</td>
</tr>
<tr>
<td>1881</td>
<td>Tracks were introduced in the pit of Honzan and the copper ores were transported by man car.</td>
</tr>
<tr>
<td>1884</td>
<td>Products of Ashio copper mine became the largest in Japan.</td>
</tr>
<tr>
<td>1885</td>
<td>Copper ores were transported from pit to dressing factory by Decauville in Honzan.</td>
</tr>
<tr>
<td>1885</td>
<td>Furukawa started to dig main adit named &quot;Tsudo&quot;.</td>
</tr>
<tr>
<td>1886</td>
<td>Coaches carried by cows were introduced in Ashio to get over Hosozan path.</td>
</tr>
<tr>
<td>1888</td>
<td>Roads were repaired in Mikochi to pass coaches carried by horses between Honzan and Mikochi.</td>
</tr>
<tr>
<td>1890</td>
<td>An iron bridge imported from Germany was set up in Hosozan.</td>
</tr>
<tr>
<td>1890</td>
<td>The first cableway was constructed between Hosozan and Mikochi for the transportation of cokes and blister copper.</td>
</tr>
<tr>
<td>1890</td>
<td>The road between Honzan and Mato was repaired from 2.7 meters wide to 7.2 meters wide.</td>
</tr>
<tr>
<td>1890</td>
<td>Furukawa bought a water power plant including associated technologies from Siemens AG in Germany and built the plant in Mato.</td>
</tr>
<tr>
<td>1890</td>
<td>Electric elevators were introduced in the pits as the first attempt in Japan.</td>
</tr>
<tr>
<td>1890</td>
<td>The Nikko line connecting Nikko with Tokyo was completed.</td>
</tr>
<tr>
<td>1891</td>
<td>A horse tramway was started to install between Honzan and Hosozan.</td>
</tr>
<tr>
<td>1891</td>
<td>A trolley car was introduced to Honzan as the earliest introduction in Japan.</td>
</tr>
<tr>
<td>1892</td>
<td>The second cableway was constructed between Mikochi and Furuminegahara to carry firewoods and lumbers.</td>
</tr>
<tr>
<td>1893</td>
<td>The third cableway was constructed between Hosozan and the East Mikochi as transportation means carrying firewoods and lumbers.</td>
</tr>
<tr>
<td>1893</td>
<td>The fourth cableway was constructed in Kodaki to carry firewoods and lumbers.</td>
</tr>
</tbody>
</table>
A cow tramway was constructed between Hoso and the Nikko station.

A trolley car made by Furukawa was introduced to Tsudo. Experimentally.

A trolley car imported from Siemens AG was used both underground and surface.

The main adit (Tsudo) reached Aniki main pit (Honzan).

The Third Order on Prevention of Environmental Pollution from Mining was published by the government.

Furukawa bought a lot of horses to transport materials of the facility for preventing environmental pollution caused by mining. And the horses were worked in Nikko and Hoso.

Trolley cars which were the first time ever in Japan as underground transportation were introduced in Honzan and Kodaki.

The sands and the slime which were discharged from Honzan, Kodaki and Tsudo started to be transported to the adjacent dump site each.

Trolley cars were constructed in the main adit of Tsudo.

Some cableways were constructed to carry a lot of refuses, lumbers and lime.

The second water power plant was built in Hoso.

Residents in Ashio were allowed to use the regular horse tramways.

The Ashio line was opened between Kiryu and Ashio.

The Ashio line was stretched from Watarase to Honzan.

The regular horse tramway between Kodaki and Watarase was disused.

A gasoline car made in Germany was introduced to underground transportation as the first attempt in Japan as transportation in pits.

Furukawa bought old model of engines made by Ford and made gasoline cars using it.

This table is made by authors from following data, Kozaankouwakai (1932), Shigeno (1938) and Editorial Committee of Tochigi History (1984).

3.2 Functions of each transportation means

The description of the process of introducing the transportation technologies, also present the growth of transportation network. The fields of logistics for copper production can be composed of following four categories, each of which has different functions and then needs different types of transportation systems. They formulate the total transportation network altogether connecting each other.

**External logistics:** Not only materials for production but also supplies for people’s daily life need to be imported from surrounding region and the products must be exported to domestic and international markets (Editorial Committee of Tochigi History, 1984). So the amount of copper product and the scale of Ashio mining town were depending on external logistics. Furukawa continued to take many efforts to equip external transportation facilities for logistics all through the period. The main route, except local external routes, changed three times with increasing its capacity according to transportation means. The first step was the reconstruction of road along the Watarase River from Kiryu to Ashio in order to carry cargos by horse or cow (Shigeno, 1937). The second was the connection with Nikko Railroad Station by coach running on the tracks and by cableway over Hoso pass. The third was the introduction of railroad named” The Ashio Line” from Kiryu to Ashio along the Watarase river. Smelting copper made at Honzan production base was carried to Hoso production base by the Ashio line (Onozaki, 2006). That made a detour by ten times longer distance than the former distance. Because its’ capacity was overwhelmingly larger than that of a cableway and a tramway.

**Internal logistics among production bases:** After maintaining roads in the town, tramways were equipped on the main road throughout the town along Watarase river from Kodaki to Honzan and man cars, coaches, electric cars and gasoline cars were introduced in order as carriers running on the tracks (Onozaki, 2006). After construction of Ashio Railroad, it functioned also as internal logistics among production base. Actually, it carried out crude ore
from Tsudo production base of dressing, to Honzan production base of smelting. After main pit was connected among Kodaki, Tsudo and Honzan, it also functioned as an internal transportation network among the production bases that was composed of tracks, elevators and so on.

**Internal logistics between the production base and other kinds of facilities;** Production bases were connected with various facilities such as lime-stone diggings, dump sites and sedimentation ponds. Cableways were adopted to logistics between the production base and above mentioned facilities to overcome the difference of vertical height (Onozaki, 2006). Firewood and timber were also carried from surrounding mountains by cableway for the same reason. So cableways as well as tramways functioned as transportation means for connecting production bases and related facilities.

**Transportation for digging;** The method of digging has been changed gradually from hand boring to mechanical boring introducing many kind of technologies (Murakami, 2006). That may be also the most important focus point for discussing the relation between the capitalist, namely Furukawa, and workers because the method decided power relation of both sides. The method includes transport of crude ore as major part. Electric power was utilized first for power of drainage and ventilation in the pit in order to meet lack of oxygen (Shigeno, 1938). Electric cars were also introduced at first to the pit for the same reason and then spread on the ground. Many kinds of instruments to overcome the difference of level were devised including lifts, elevators, belt conveyors and so on. Network of main pits composed of Ariki pit, Kodaki pit and Tsudo adit functioned to promote systematic digging to take under consideration of the total copper ore bed under Bizen Tateyama mountain.

**4. ROLES OF TRANSPORTATION SYSTEMS IN THE FORMATION OF ASHIO COPPER MINING TOWN**

**4.1 The physical structure of Ashio Copper Mining Town and production bases**

Ashio mining town was composed of six districts, namely Honzan, Mato, Watarase, Tsudo, Kodaki and Shuku since Taisho Era when the spatial structure of the mining town was completed. The structure has been nearly held today except Kodaki with the retreat. Shuku had been the center village of this area as lodging town before Furukawa started mining remaining the traditional central district now. Other districts having a production base at the center were developed rapidly by copper production though little inhabitants had been engaged in farming and forestry. In other words, Rapid transition of production bases in location and function made these districts spread by gathering people from surrounding areas who conducted commerce and businesses for increasing workers of copper production. So the formation of Ashio mining town can be recognized as the transition of production bases. The transition can be realized as inter-connection between progressing the terchinologies of copper production and developments of transportation facilities. Mainly, the former affected the function of production bases and the latter affected the location of them.

**4.2 Transition of production bases**

Transition of production bases can be divided into following five periods, namely, the first period: 1877-1887 (Meiji 10s), the second; 1888-1897 (Meiji 20s), the third; 1898-1911 (Meiji 30s and 40s), the fourth; 1912-1920 (The first half of Taisho) and the fifth; 1921- (after latter half of Taisho). The spatial structure of town was accomplished in the fourth period when the town was the most prosperous with the largest production volume.
Figure 3 Production bases at the first period 1877-1887

Figure 4 Production bases at the second period 1888-1897

Figure 5 Production bases at the third period 1898-1911

INDEX

- River
- Road
- Pit Mouth
- Smelting Factory
- Dressing Factory
- Main Pit
- Railroad
- Railroad Station
- Main Cableway
- Track
- Primitive Production Base
- Dressing Production Base
- Smelting Production Base
- Mechanical Production Base
- Management Production Base
- Traditional Central district
The first period (Figure-1): In this period, technologies for copper production, including dressing and smelting, remained so primitive that a large amount of investments need not be spent for the construction of production bases. So production bases which include all process of copper production called “primitive production base”, was equipped around each pit month in order to minimize the cost of logistics depending on man power and horse power. Same kind of production base was equipped around Ariki pit month in Honzan and Kodaki pit month, which were main pits at that time.

In 1885, Furukawa started digging main adit named “Tsudo” that has functioned main adit until closing the mine as it located at the lowest level of copper vein under Bizen Tateyama mountain (Itsukakai, 1926). It triggered also the rapid development of Ashio copper mine because of its effective location, from two aspects of copper production and developing the town, adjoining both Shuku district and large open space, which would utilized as sites of water purification plants and so on.

The second period (Figure-2): In 1891, Kodaki and Honzan was connected each other through Tsudo by track on the ground. In 1895, main adit, Tsudo, was connected with Ariki pit and Kodaki pit underground. These developments promoted to change digging methods from each independent system according to pits to whole system under consideration of total vein of copper.

On the other hand, as increasing copper product owing to aggressive introducing new technologies on dressing and on smelting, environmental problems both water pollution in the lower Watarase region and deterioration of forests around Ashio town (Editorial Committee of Tochigi History, 1984).
The third period (Figure-3); The third Order on Prevention of Environmental Pollution from Mining” issued by the central government meant legitimately beginning the challenge for mining pollution. It can be said that the challenge affected also the location of production bases. Smelting factory was concentrated to Honzan situated at the highest level along Watarase river of all production bases (Onozaki, 2006). Kodaki production base was changed to dressing production base from primitive production base. Parts and material of Kodaki smelting factory were reused for constructing Honzan smelting production base. From the aspect of efficient production, the concentration of smelting factories to Honzan production base is not favorable because it is better to locate the smelting factory at the lower level than the dressing factory. But the improved transportation network among production bases both underground and on the ground made that possible. The reason for the concentration maybe stemmed from meeting smoke pollution. But as the result of the concentration, smoke pollution was aggravated in Matugi river valley located next to Honzan to upper level along Watarase river (Editorial Committee of Tochigi History, 1984). All the people living there retreated within several years owing to failure of improving smelting process.

Developing technologies for copper production led production growth and made its process sophisticated and diversified. That progressed creating new types of production base. Maintenance department had been set up in the previous period to repair digging machines imported from foreign countries in Mato and it progress to mechanical department to produce many kinds of machines for digging (Murakami, 2006). Furthermore, the construction department and the chemical analysis laboratory were added afterwards. They grew a mechanical production base to back up copper production. After riot occurred by mining workers in 1907, management functions were gathered in Watarase. They formulated a management production base. These two production bases are located along the tramway throughout all other production bases.

The fourth period (Figure-4); The formation of production bases were almost completed, in this period, dealing with rapid increasing copper production amounts because of developing the new kind of ore vein. The Ashio railroad accomplished in 1912, strengthened not only the capacity of external transportation but also the connection of production bases. That promoted to make clear the functions of these five production bases as a part of total copper production process. For example, that concentrate ore dressed at Tsudo became to be able to be carried to Honzan for smelting by railroad made capacities of the both production bases increase by large steps. The central logistic terminal between the railroad and tramways was equipped in Watarase (Onozaki, 2006). In the area of lower side of Tsudo, which was largely increasing products of concentrate ore, water purification plant, supported by the complex network of tramways and cableways, continued to be developed throughout this period.

The fifth period (Figure-5); After the World War One, Great Depression struck the world and the Japanese situation in the world-wide copper market declined because of large developments of copper mine in America and etc (Takeda, 2003). They forced Furukawa to conduct the rationalization of Ashio copper mine. As the result, dressing factories of Kodaki and Honzan were transferred to Tsudo and three mining areas decreased to the two areas.

Afterward, the function of each product base has been fundamentally same as in this period until closing the mine. On the other hand, Gasoline cars running on the track were used for person trip as well as logistics and became popular among people, who called them “Teiji (Regular Schedule)”.
4.3 Roles of transportation systems to formulate Ashio copper mining town

At the primary stage, same production bases were equipped at each pit month because every facility for copper production was equipped around the pit month in order to minimize transportation. As production bases got more specialized and more diversified with introducing new production technologies, several types of production base were set up at different points. Logistics among production base has been reinforced with increasing the amount of copper product. Transportation technology as well as copper production technology contributed to transition of production bases. The physical structure of Ashio mining town is a typical example to show effects of developing technologies both of copper production and of transportation through the formulation of production bases. Combination of these technologies promoted developing Ashio mining town.

5. ASSESSMENT OF HISTORICAL HERITAGES RELATED TO TRANSPORTATION FACILITIES

Following three aspects to assess heritages related to transportation can be found through above mentioned historical reviews.

Technological and design side aspects; Technological and design side aspects are conventional items on industrial heritages. As mentioned in section 3.1, various transportation technologies were introduced from the west. Some of them are the first application in Japan and another improved fitting for Japanese condition in Ashio spread to many Japanese mines all over the country. Tamamura Cableway is the representative of that (Kozankonwakai, 1932).

Aspects of functions in the transportation network of Ashio copper mining; These aspects mean that the vales of transportation heritages are discussed from the view point of the growth of the total transportation network of Ashio mine. In section 3.2, after the network is divided into four parts, functions of transportation means were reviewed according to each part. That can be recognized as the process of formulating the network to fit for the topography of Ashio and the distribution of local resources. In other words, transportation heritages are assessed from the aspects of fitness to the locality. Kodaki Cableway Tunnel is the representative of the aspects.

Aspects of rolls for formulating Ashio mining town; The word of production base was proposed as the key concept to explain the formation of Ashio mining town and its transition was reviewed, in chapter 4, focusing on the effects of transportation means. Its transition is inevitable to understand the historical values of Ashio copper mine. Ashio Railroad is the representative of the values.

6. CONCLUSION

The paper deals with historical reviews of Ashio mining town from the view points of technologies, functions of transportation means in the transportation network and rolls for formulating Ashio mining town focusing on transition of production bases and proposed three aspects for assessing historical heritages related to transportation, Namely technological and design side aspects, Aspects of functions in the transportation network of Ashio copper mining and aspects of rolls for formulating Ashio mining town. The first is conventional one but the second and the third are new items for presenting the characteristics of Ashio copper
mine written in section 2.2 and 2.3.

These aspects are inevitable to assess the heritages related to transportation in Ashio. But actually, it is difficult how to decide the sphere of subjects and how to protect them from the second and the third aspects using the conventional institutions of cultural properties. We need more comprehensive, flexible and practicable concepts for protecting industrial heritages including transportation properties.

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