From shipbuilding to automobile manufacturing

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This paper deals with the engineering capability of a developing country. But what is the engineering capability of a country? Here we tentatively define the term as the social capability of a country to design and construct various machinery and systems constituted from machinery. Modern industrial technology is largely embodied in a system of machines, each of which embodies a subsystem of the technology.

Usually the transfer of manufacturing technology to a developing country starts with the importation of a full-line manufacturing plant—a system of machinery—and the training of workers to operate this line under the guidance of foreign engineers. Even at this stage, a minimum degree of local engineering capability is required for the maintenance and repair of the plant.

Along with the assimilation of transferred technology, efforts will shift towards the production of raw materials and components. This stage usually requires importing more foreign technology and consequently more machinery systems, and necessarily attracts attention to the need for higher local engineering capability to improve the balance of international payments. In this way, the process of technology transfer—especially its assimilation and further development—proceeds concomitantly with the growth of local engineering capability.

Therefore, the question of how and in what industry a latecomer country acquires basic or primitive engineering capability, as well as the manner in which it upgrades itself, is crucial for late, or late late industrialization.

The shipbuilding industry played a key role in the process of building engineering capability in prewar Japan. However, when Japan tried to construct an automobile industry, it experienced serious difficulties, and had to postpone its plans until the postwar period. This was partly due to the fact that the engineering capability built up on the experience of shipbuilding was insufficient for the mass production of automobiles; but even more important was the fact that major Japanese engineering firms were forced to be involved in war production.

Part One of this paper briefly describes the difficulties which the modern

young shipyards faced in Meiji Japan. Part Two traces the rise of the modern shipbuilding industry in the first decade of the century, and the role of the Mitsubishi Nagasaki Shipyard. It then examines how the early history of the shipbuilding industry influenced the structure of prewar Japan's social capability in engineering, and identifies a hierarchical structure in this capability. Part Three discusses Mitsubishi's plan for automobile production in the 1910s and why it was abandoned. It then goes on to consider the significance of this decision.

Part 1 : Early trials for modern shipbuilding technology in Japan

The Japanese modern shipbuilding industry established its firm base in the first decade of the 20th century. Some fifty years had passed since 1850s, when an intensive effort to introduce Western shipbuilding techniques started under the leadership of some strong *han* (feudal clans) and the *Bakufu* (Shognate government).

Many years had been spent on the assimilation of Western shipbuilding technology. In this period, a combination of the circumstances particular to this moment in technology and the conditions indigenous to Japan as a latecomer to industrialization concerted to engrave unique features on the Japanese engineering industry—some of which still remain. Let us start by briefly describing this period in two stages : before and after the Meiji Restoration.

Before the Meiji Restoration : 1850~1867

In the 1850s there was a boom in Western-style armaments as influential feudal lords scrambled to defend themselves against Western fleets. There were three main targets: building steam warships, casting iron cannons, and manufacturing muskets. This boom involved a feverish movement to mobilize all traditional crafts and the knowledge of *Rangaku* (Dutch learning) which had accumulated since the middle of the Edo period.

For instance, the lord of the Satsuma han asked a famous Ranguku scholar to translate a Dutch textbook on steamships. Then he gathered skilled craftsmen and ordered them to construct a model of a steamship based on the translation. After confirming that the model actually moved by steam, he organized two teams to construct one small steamship each. Though one team failed utterly, another successfully completed a steamboat with a small brass steam engine, and a traditional Japanese wooden hull. However, its performance fell far short of their expectations, while the cost was tremendous. They learned from this experience that Western-style shipbuilding was impossible without resorting to mechanical engineering, and required abundant financial resources.[1]

Thus steamship building was soon abandoned and most *daimyôs* began to buy them secondhand in Shanghai and Hong Kong.

Meanwhile the Bakufu was considering technology transfer from Holland, the only Western country with which Japan had kept trade relations throughout its period of isolation. It was only the Bakufu, as the central government of feudal Japan, which was capable of carrying out this task.

It established the Nagasaki Iron Works in 1857 with technical assistance from Holland. The works had a naval academy attached to it. Young samurais selected from influential hans studied naval engineering at the academy, and practiced at the works. When a Russian schooner wrecked off the Japanese coast, and its officers asked the Bakufu's permission to rebuild it in Japan, the Bakufu also organized a group to study schooner building from them. While both the Nagasaki Iron Works training and the study of schooner building were useful, the Bakufu was still not satisfied : its final aim was sea defense and the construction of warships which could compete with Western fleets. It began to construct slips in the Nagasaki Iron Works, and tried to modernize its own shipyard, the Ishikawajima Shipyard, with imported machinery. Further, the Bakufu approached France for help in transferring modern shipbuilding technology. Construction of a large shipyard—the Yokosuka Iron Works and its ancillary engineering shop, the Yokohama Iron Works—started in 1864 under the guidance of many French engineers and mechanics.[2]

Unfortunately this project was unfinished in 1867, when the Shogun returned his government to the Emperor in the revolutionary political change known as the Meiji Restoration. The feudal system was abolished in 1871, and consequently most of the enterprises of the feudal lords as well as those of the Bakufu were closed down, though the major ones were assumed by the new government.

How and in what respects did these feverish but incomplete movements under the feudal system influence Japan's subsequent industrial development? Historians have long disputed this problem. Some argue that these were noneconomic activities under the leadership of feudal lords, and consequently had little influence on the later development of industrial capitalism. Others insist that they played an important role in impressing a military character on subsequent Japanese industrial development.

However, my main concern is with the later development of Japan's engineering capability. Here three major contributions merit special notice :

1. Many authors stress the role played by government enterprises in the industrial development of Meiji Japan. However, except for the railways, the telegraph and a few manufacturing firms, most of these enterprises were

inherited from the Bakufu or some major han. In addition, the local engineers who worked in the government enterprises after the Restoration were all samurai engineers trained in these movements. In short, the pre-Meiji movements provided the new government with several well-equipped works and a group of experienced engineers. These were very valuable to the new government, which at that time was extremely poor, as we shall see below.

2. The Bakufu enterprises functioned as a training center for mechanical engineering. While the Bakufu monopolized the process of foreign technology transfer, it faced the urgent need to strengthen Japan's defense power. Therefore, as exemplified by the case of the Nagasaki Iron Works, it received samurai and craftsmen selected from any han and trained them in the Works as far as possible. If a han requested technical help, the Bakufu sent adequately skilled craftsmen from the Works. This constituted an important channel of technology diffusion. The channel was restricted to such fields as shipbuilding or cannon casting, because these fields were financially appropriate only to the Bakufu and a few wealthy han. Perhaps the most important case was gun manufacture. Most han employed a considerable number of gunsmiths for traditional matchlocks. Based on their skills, many han tried to take advantage of this channel for the diffusion of technology and to manufacture muskets, and in some cases, even rifles. Through such efforts, some techniques of mechanical engineering spread relatively widely, covering nearly all of Japan.[3]
3. A remarkable result of the above process was the birth of the first generation of mechanics in Japan. In Western-style armament movements, it was traditional craftsmen who actually constructed furnaces, cast cannons, built hulls and manufactured gunlocks. They read instructions translated from Dutch books, and mobilized all their experience and skill in their efforts, ultimately unsuccessful, to create the devices described. Afterwards they worked in the Bakufu works, or worked under the guidance of skilled mechanics sent from the Bakufu works, and gradually gained experience in mechanical engineering. Whether we can really call them modern mechanics or not is a moot point. Essentially they were traditional Japanese craftsmen with a little actual experience in engineering. In any case, it was they who provided the workforce of engineering firms after the Restoration. In this sense we may call them the first generation of Japanese mechanics.

After the Restoration: from 1867 to 1885

After the Restoration the new government requisitioned all the shipyards and iron works of the Bakufu. It equalled the Bakufu in its enthusiasm to

transplant modern engineering to Japan. It established the Kôbusho (Ministry of Public Works) in 1870. The Nagasaki Iron Works became the Nagasaki Shipbuilding Department of the Kôbusho.[4] The government bought a shipyard constructed in Kobe by the Kaga han, and the Vulcan Iron Works (a shipbuilding firm run by an American). These two became the Hyôgo Shipbuilding Department of the Kôbusho. It also obtained the Yokosuka Iron Works, Yokohama Iron Works, and Ishikawajima Shipyard from the Bakufu, and put them under the control of the Navy.

The Navy did not think it economical to invest scarce capital evenly into three shipyards. It thus concentrated its efforts on the Yokosuka Shipyard (previously the Yokosuka Iron Works) which was the largest among the three, with two docks, three slips, and a well-equipped machine shop. The government found the other two unmanageable. Eventually Hirano Tomiji, who had been trained in naval engineering at the Nagasaki Iron Works, rented Ishikawajima Shipyard from the government and established the Ishikawajima Shipbuilding Company in 1876. Later he also took over the Yokohama Iron Works from the government.[5]

Meanwhile shipyards and iron works managed by Westerners were increasing at Yokohama, Kobe and Nagasaki. In 1870 ten such firms existed at Yokohama, of which six were devoted to shipbuilding. Around the same time, four such shipbuilding firms were confirmed in Kobe. In addition, a few Japanese shipyards employed Western technical advisors in order to construct small steamers.[6] With the growth of international trade between East Asia and Europe, demand for ship repair in East Asia increased. In response to this demand, shipyards and related iron works run by Westerners were growing in Shanghai, Hong Kong, and Singapore.[7] It was natural that their attention shifted to Japan when it opened its ports.

While the new government was eager to introduce foreign technology, they were not so open to foreign capital. Though in principle they wished to exclude direct foreign involvement in railways, telegraph, shipping, and shipbuilding, in reality it was impossible to build steamers without the help of foreigners. Such a situation resulted in a policy of not promoting foreign enterprises, and yet paying extraordinarily high salaries to foreign advisors. As a result, some of the early foreign shipbuilders closed their works and became the so-called *oyatoi gaikokujin*, namely foreign advisors of the Kôbusho. Nevertheless, other foreign shipbuilders continued their businesses and some of them prospered. The most successful example was the Kobe Iron Works managed by C. E. Kirby, who was the owner of the Kirby Trading House. It was estimated that the steamers built in the Kobe Iron Works were technologically superior to those built in the Hyôgo

Shipbuilding Department of Kôbusho.

Thus, five relatively well-equipped shipyards constituted the leading group of the modern shipbuilding industry in the early Meiji Period, namely: the Yokosuka Shipyard of the Navy, the Nagasaki and Hyôgo Shipbuilding Departments of the Kôbusho, the Ishikawajima Shipyard and the Kobe Iron Works. However, these modern shipbuilders faced harsh domestic market conditions. Let us concentrate, first, on the business of the latter two private shipyards in the early Meiji market, because the former three government-affiliated shipyards, which could count on public expenditures, are inappropriate for studying the business behavior of a firm in the market.

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During the Edo period, coastal shipping by traditional wooden sailing ships was well developed, and supported the Japanese economy at that time. This traditional coastal shipping system greatly helped the early stage of economic growth after the Restoration; at the same time, however, it also acted as an obstacle to the introduction of Western-style ships. Shipping traders were so accustomed to Japanese ships that they demanded exclusively traditional sailing ships.

As early as 1870, in an effort to modernize the traditional shipping industry, the new government promoted the use of schooners or barks as more efficient and consequently more economical sailing ships. The government one-sidedly regarded the traditional ships as backward, and the Western sailing ships as more advanced and efficient. Nevertheless, ship owners would not buy them because they were far more expensive than traditional ships (about twice the cost), and consequently by no means economical. Furthermore, few sailors could handle the Western sails.

Finally, the government banned the construction of large traditional ships after 1887. Coastal shipping traders coped with this situation by constructing the so-called *ainoko-bune* (a crossbreed ship) with Western sails and Japanese hull, a ship that was a schooner in appearance, but which was actually traditional Japanese.[8] In any case, Western sailing ships, not to mention steamers, were economically beyond the reach of traditional shipping traders.

On the other hand, a few modern shipping companies with relatively large steamers were growing under government protection. One such representative was the Mitsubishi company established by Iwasaki Yatarô—previously a samurai of the Tosa han. However, it bought its ships exclusively from abroad, mainly at the secondhand markets of Shanghai or Hong Kong. All these conditions together resulted in an extremely small domestic market for steamers, and consequently business difficulties for the two modern shipyards.

Ishikawajima built its first steamer (34 GT, paddle propelling) as early as 1877, but no one would buy it. Hirano invited his intimate friend, the president of a shipping company, to this steamer. Hirano himself steered the ship, demonstrating how it moved by steam and mechanical devices, and how it was useful as a ferryboat on rivers or small bays, and he at last successfully persuaded his friend to buy it. In order publicly to demonstrate that steam ferryboats would pay, he established a ferryboat company across the Tokyo bay. It was this company—that is, Hirano's own—which bought the second steamer made by Ishikawajima. In this way, shipbuilders had to struggle to create their customers before building their ships.[9]

The situation slightly favored builders of Western Japan, because the Inland Sea provided ideal conditions for passenger transportation by small steamers. Many feudal lords of Western Japan bought steamships from abroad during the last decade of the Edo period. After the Restoration, they used their ships for the transport of passengers or small cargo, mainly from their previous domain to Osaka. Soon ferryboats became a new business. Already in the early 1880s a keen price war developed between more than fifty ship owners with a hundred small steamers, a considerable part of which were built in Osaka and Kobe. The Kobe Iron Works held the leading position among these wooden steamer builders, and was preparing for the way to building iron steamers.

In 1881 C. E. Kirby grasped a good business chance. Taiko Kisen Company, which had steamer lines across lake Biwa, planned to construct two relatively large steamers with iron hulls (about 500GT). Kirby was successful in securing an order for them because no other builders could construct iron ships. He enlarged the shipyard, imported new equipment, employed six new foreign engineers, and completed two excellent iron ships. However, the enlarged capacity of his shipyard brought him a new burden, namely, that of capacity utilization. No other shipping companies ordered iron ships. He barely secured an order for the warship Yamato (1,500 ton, wooden hull with iron frames, 1,071 Hps double-expansion engine) from the Navy; but in 1883, halfway through construction, the Kobe Iron Works fell into serious financial trouble, and E. C. Kirby committed suicide. The Navy participated in the management of the shipyard in order to finish construction of the Yamato, and later absorbed the Works as the Onohama Naval Shipyard.[10]

This tragedy illustrates the difficulties of modern shipbuilding in a premature market. Whether they were private or state-affiliated, the common weakness of these shipyards was over capacity. In the history of Western engineering, the development of the steam engine preceded that of the steamship, and therefore engine builders preceded steamship builders. As a

result, shipbuilders could save their equipment investment by way of outsourcing marine engines and other mechanical systems from already established machine builders. However, as a latecomer to industrialization, Japanese shipbuilders found no marine engine builders. Inevitably, early Japanese shipyards had to internalize machinery manufacturing capability, including casting, forging and machining in addition to hull building facilities. This resulted in large capital investments which were difficult to recover in a small market for steamers.

As long as Kirby had restricted himself to building small wooden steamers, his business had gone well: in other words, capital cost was balanced with the market size in Western Japan. But once he made a great leap to the iron steamer market, the required capital investment was far larger and the market size far smaller. As a result, his business stumbled on the large gap between capital cost and market size.

How, then, did Ishikawajima cope with this difficulty? The Ishikawajima Shipyard was situated on the mouth of the Sumida river, and was not suited to launching large ships. Instead, it inherited various machines and equipment from the Yokohama Iron Works, and was more suited for engineering work. Further, just around this time manufacturing firms were growing in and near Tokyo. The demand for manufacturing machinery was growing, but imported machines were extremely expensive. Hirano made every effort to secure orders of machinery and iron frame construction. Machinery for mining, civil engineering, silk reeling, and printing as well as iron bridges, boilers, and steam engines for factories were its main items. From 1890 to 1892, for which business records remain, shipbuilding and repair made up only about 20% of the company's shipments; 80% was for engineering work.[11] Perhaps this behavior makes sense given the market conditions in the first half of the Meiji period.

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Though the government shipyards were free from the fear of bankruptcy, they too confronted the problem of small market size. Unfortunately, the new government was financially very weak. After the abolishment of the feudal system, it had to pay a huge amount of money to the samurai who had lost their jobs. In addition, the government was burdened by the expenses of putting down rebellions among discontented samurai. Therefore, except for a few modest ships, the government did not place orders to the three shipyards. Though ship repair was a rather profitable business, it was not sufficiently large to cover the deficits of the shipbuilding department. As a result, shipyards were forced to take orders related to machinery and iron constructions besides ships. Even the Yokosuka Shipyard accepted orders of private or public firms for such

items as boilers, steam engines, and iron bridges, and nearly half of its shipments were to firms other than the Navy.[12]

In addition, programs for technical upgrading did not progress so well. In the Nagasaki Shipbuilding Department, the construction of the Tategami Dockyard—which, on completion was to become the largest dockyard in the Orient—proceeded slowly. Perhaps the most important project of this time was the construction of iron steam vessels using wrought iron produced from the newly constructed Kamaishi Iron Manufacturing Works —a project to which the financially weak government made the largest investment. A British engineer was recruited for the project. However, this Iron Works failed utterly, and closed down before it could produce any wrought iron. Consequently, the British advisor had to return home without constructing any iron ships.[13]

Since 1880, the government had been searching for a new policy of restricting government enterprises to arsenals, and selling off other enterprises to private entrepreneurs. The serious failure of both the Kamaishi Works and the iron vessel project was the final blow that pushed the government to the sale of all its nonmilitary enterprises, including two shipbuilding departments. The Kôbusho was closed down in 1885, and Mitsubishi took over the Nagasaki Shipbuilding Department (since then called the Mitsubishi Nagasaki Shipyard). Kawasaki Shipbuilding took over the Hyôgo Shipbuilding Department (since then Kawasaki Shipyard). Kawasaki was a shipbuilding company that had grown by building Western sailing ships and small wooden steamers. In order to enter into iron steamer building, Kawasaki successfully competed with Ishikawajima to acquire the Hyôgo Department.

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Efforts to transfer modern shipbuilding technology after the Restoration were not so successful either. One could say that Japan was not prepared in any way for the introduction of modern shipbuilding technology until around the mid-1880s. Western shipbuilding technology at that time was changing rapidly, from wooden to iron and then to steel hulls, and from single to triple expansion engines. Large cruisers of 5,000–10,000 GT were becoming popular. Market conditions, undeveloped engineering industries, infant higher technical education systems, and poor financial resources, made it difficult for Japan to keep up with this rapid technological change. Even a company managed by a British entrepreneur failed in a venture to make the leap to iron steamers.

A private shipbuilder, i.e., Ishikawajima, survived this difficult situation. At the end of this period the government sold off its two shipyards, and these became the basis for two new private shipbuilding companies, namely, the Mitsubishi Nagasaki Shipyard and the Kawasaki Shipyard. These three were

perhaps the leading private shipbuilders in this period. In the middle of the 1880s, however, their technological position was far behind that of Western shipbuilders. Take, for example, the year when each first completed an iron ship : Ishikawajima completed a gun boat (627 ton) in 1888, Mitsubishi a coal transporting boat (200 ton) in 1887, and Kawasaki a merchant vessel (200 GT) in 1886.[14]

The difficulties of these early years impressed upon the three shipyards an important characteristic : they internalized a general engineering capability that allowed them to cover a wide range of machinery and iron frame constructions. These shipyards were actually companies that manufactured to order all sorts of large machines and machine systems, including iron steamers.

While the technology of advanced countries progressed towards large steel vessels with triple expansion engines, small wooden steamers gradually diffused into the Japanese ship market, mainly as ferryboats for Tokyo Bay, the Inland Sea, Lake Biwa, and some large rivers. In response to this diffusion, smaller shipbuilders sprang up around Yokohama, Osaka and Kobe. These small shipbuilders shared the same character as large shipyards mentioned above, and responded to orders from various machinery, including small steam ships.

It is important to note that workshops of this period, especially the arsenals, large shipyards, and works of foreigners, played the role of technical training centers. As a result of the armament movement of the 1850s, mechanics of the first generation dispersed widely, moving even into regions far away from Tokyo or Osaka. If they felt a need for additional engineering techniques, they went to Tokyo, Yokohama or Osaka to work for a while at, for instance, a Kôbusho factory or a shipyard managed by a foreigner and then returned to their regions. In some cases, skilled mechanics from arsenals or five major shipyards came to the region, and established iron works. In this way, mechanical engineering diffused to local regions far away from Tokyo or Osaka.

According to Suzuki Jun's survey, machinery suppliers to the coal mines of northern Kyûshû in this time were classified hierarchically into three.[15] At the top, the Nagasaki Shipbuilding Department and other Kôbusho enterprises supplied relatively high performance machinery, which were more expensive than imported ones. In the middle, machine builders including small shipbuilders at Kobe and Osaka, provided simpler but efficient machinery at reasonable prices. And at the bottom, the cheapest but inferior performance machines were supplied by mechanics of the first generation in local regions. This hierarchical structure characterized the social distribution of mechanical skills which supported the economic growth of the following decades.

Part 2 : The rise of the modern shipbuilding industry.

Changes in the ship market with the economic growth

Economists regard 1886 as the starting point of Japan's modern economic growth. A sustained economic growth started from this year. The growth was supported by a mixture of different categories of industrial development : a) the development of the modern cotton spinning and half-modernized silk reeling industries, which became the pillar of Japan's exports until the mid-1930s ; b) weaving and other traditional consumer goods industries, which mainly drew on traditional handicraft techniques ; c) export-oriented soap, matches, rugs, mats, and other manufactures which were exported to the Asian and American markets ; d) copper and coal mines in which Japan was naturally rich ; e) railways, the aggregate length of which stretched 123 km in 1880, 2,251 in 1890, 6,480 in 1900 and 9,980 in 1910, the share of private railways being about 80%.

This economic growth radically changed the environment for shipbuilding. Japan's international trade developed remarkably, and business opportunities of shipping and ship repair increased in parallel. People became gradually aware of a large gap between the abundance of business opportunities, and the country's weakness in shipping and shipbuilding.[16]

In 1884, fifty-five small shipping traders in the Inland Sea in association with the leadership of the Sumitomo family—a large copper mine owner in West Japan—formed the O. S. K. Lines, Ltd.. This move was a defensive measure to avert serious price competition in the midst of a long and steep recession; but it actually worked to prepare the modernization of Inland Sea shipping, and to create a large shipping company. In the next year, the largest shipping company, Mitsubishi, merged with its competitor Kyôdô Shipping Co., to form the Nippon Mail Ship Co.. This move, too, was a defensive effort to escape from the price competition between the two, but it also paved the way for the subsequent rapid growth of Japan's international trade. The birth of these influential customers of large merchant vessels had important consequences for later developments.

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Perhaps it was the Mitsubishi company which profited most from this market change. When it merged with Kyôdô Shipping, the company was already a large conglomerate operating many coal, gold, silver, and copper mines, a large shipyard (borrowed from the government), a bank, and a few agricultural farms ; it also had at the same time the largest shipping department. After separating the shipping department for the new company—Nippon Mail Ship—it reorganized the remaining part as a limited partnership, and started anew in 1886. In 1887 Mitsubishi officially bought the Nagasaki Shipyard from the government and launched into an ambitious project to develop it into a large

modernized shipyard which could compete with its British counterpart.

The company already owned Mitsubishi Iron Works since 1875, which was actually a ship repair shop that had accumulated experience in ship repair under the guidance of British technical and managerial advisors. The equipment from the Works, along with four foreign advisors, a few Japanese staff and skilled mechanics were transferred to Nagasaki. While most of the engineering staff of the Kôbusho Shipbuilding Department had left the Shipyard, two of them remained.[17] In addition, an experienced British engineer was recruited as the manager in charge of the engineering works. Notwithstanding these efforts, the overall workforce of the new shipyard lacked shipbuilding experience. The company history states:

> When the Mitsubishi company assumed the shipyard there was a remarkable lack of staff experienced in shipbuilding. This was the reason why we were so enthusiastic to recruit young engineering personnel.[18]

The department of shipbuilding of the Kôbu Daigakkô (Imperial Engineering College) had been producing young engineers every year since 1880. After the abolishment of the Kôbusho, it became the shipbuilding department of the Engineering School of the Imperial University and continued to produce shipbuilding engineers. From 1890 to 1897, Mitsubishi Nagasaki recruited two graduates from the Imperial Engineering College, five from the Imperial University, one from Glasgow University, and twelve from the Tokyo Technical College and other technical colleges. This reflects their intensive recruitment of engineers. These engineers actually supported technically the development of the Shipyard since 1896.[19]

These young hires also lacked experience in actual shipbuilding. It was O. S. K. Lines which gave them their first experience of building a steel vessel with a triple expansion engine. When O. S. K. started in 1884, it ordered four iron steamers with double expansion engines from the government shipyards. The first ship was constructed at the Onohama Naval Shipyard (previously Kobe Iron Works). The construction of the second, third, and fourth was carried on at Hyôgo Shipbuilding Department of the Kobusho, which was taken over by the Kawasaki Shipbuilding Company halfway. Consequently, the Kawasaki Shipyard completed these three iron ships. Perhaps their good performance convinced O. S. K. that private shipbuilders were competent to build a steel merchant vessel of 500 GT class.

When it planned the modernization of its coastal lines by introducing steel merchant vessels of 500–600 GT, O. S. K. provided three companies an equal

opportunity to build them—Kawasaki, Mitsubishi Nagasaki, and Osaka Iron Works. The last one was a shipbuilding company established in 1881 by E. H. Hunter, who had previously been an employee of the Kirby Trading House. Technically, it was ranked next to the Kobe Iron Works among shipyards run by foreigners. Though its location in Osaka was not appropriate for the construction of large vessels, O. S. K. Lines gave it priority with regard to relatively small vessels, since all O. S. K. lines started from Osaka.

On this occasion Mitsubishi Nagasaki built three steel vessels of 600 GT class. For the young engineers who had been recruited, this was not only their first experience of actual shipbuilding, but also the first step in their attempt to master the latest shipbuilding technology. In order to supplement their lack of experience in making iron or steel hulls, a foreman was recruited from the Onohama Naval Shipyard. He brought with him some mechanics skilled in iron hull building, and the abundant knowhow that he had gained when the Kobe Iron Works constructed two iron steamers in 1881.[20] In other words, he was responsible for transferring the iron hull technology of the Kobe Iron Works to Mitsubishi Nagasaki.

The guidance of foreign advisors was even more important. Around this time the shipyards recruited three technical advisors from Glasgow, who were made responsible for drawing, mechanical engineering, and casting respectively.[21] This suggests a situation in which the shipyards still very much required the guidance of foreign advisors for the assimilation of latest technology. However, the earlier advisors from Mitsubishi Iron Works were up to this task.

Meanwhile, growing international trade provided shipbuilders with increasing opportunities to repair large steel ships. The repair and maintenance of large steel ships had two implications for the rise of the modern shipbuilding industry. First, young engineers were trained and prepared for the construction of larger ships through this experience. Second, ship repairing was a good business for shipyards. For the first time since the Restoration, major shipyards enjoyed good business, and accumulated enough capital to modernize their yards. Here, Mitsubishi Nagasaki had an advantage, because of its strong connections with Nippon Mail Ship, the largest owner of large vessels in Japan; at the same time, it owned the largest dockyard in Japan, the Tategami Dock.

Helped by these conditions, Mitsubishi Nagasaki succeeded in constructing a larger steel vessel Suma-maru (1,592 GT) in 1895. Young Japanese engineers took the initiative to implement this project and carry it out. This was an important experience which gave them the self-confidence to proceed to more advanced challenges.[22]

The challenge of Mitsubishi Nagasaki Shipyard

The Sino-Japanese War of 1894-95 made the government aware of the country's weakness in transoceanic shipping. During the war the government had had urgently to import many large steel vessels, and this taught it that Japan lacked shipbuilding capability too. In 1896, it implemented two maritime laws to promote shipping and shipbuilding. The former provided subsidies to shipping companies which set up lines across the ocean, and the latter to shipbuilders who built steel or iron ships larger than 700 GT.

Both Nippon Mail Ship and Mitsubishi Nagasaki Shipyard reacted promptly to these laws. The former planned to buy 12 new vessels of 6,100-6,300 GT with the subsidies that the law provided, and the latter made every effort to secure a few of the orders. Eventually Nippon Mail Ship decided to order two vessels[23] from Mitsubishi. It was a true venture for both sides. It was widely believed that Mitsubishi would fail to respond successfully to this order. However Mitsubishi succeeded in launching two large vessels which showed excellent performance in serving Nippon Mail Ship's line to Europe.

Witnessing this success, O. S. K. Lines began to order relatively large vessels from Kawasaki and Osaka Iron Works to take advantage of the shipping law. A few developing shipping companies followed.

During the first decade of the century, 89 vessels were launched with the subsidies provided by the shipbuilding law. 21 were vessels over 5,000 GT, of which 16 were built at Mitsubishi, and 5 at Kawasaki. All these large vessels were ordered by Nippon Mail Ship, O. S. K. Lines, and a newly emerging shipping company Tôyô Steamers (Tôyô Kisen). Ishikawajima built only two relatively small ships (1,600 GT and 917 GT) mainly because it did not have close relations with either Nippon Mail Ship or O. S. K. Lines, and consequently could not secure their orders. We can say that the Japanese modern shipbuilding industry stood on its own feet at last towards the end of the third phase. However at the same time a clearly ranked order was established among early shipbuilders, as shown in Table 1. Mitsubishi's leading position is striking.

Let us analyze the above process from the viewpoint of engineering

Table 1 Ships built between 1898 and 1912 with subsidization by the Shipbuilding Law

Gross Tonnage of Ships	over 10,000	3,000 – 9,999	1,000 – 2,999	700 – 999
Mitsubishi	3	20	19	1
Kawasaki		10	16	5
Osaka IronWorks			10	20
Ishikawajima			1	1
Uraga Dock			2	
Ono Ironwork				2

capability building.

Two main targets of technical efforts in this process were : i) the building of even larger steel hulls, and ii) the construction of even larger triple expansion marine engines. The latter target appears to have been achieved with relatively less difficulty by all four shipyards, including Ishikawajima. Boilers and steam engines were the most important items for their business during the hard period when they were forced to do various engineering work other than shipbuilding. Since the beginning of the Meiji period, they had had much experience in constructing boilers and engines for mines, factories, power stations, and ships, and thus had developed the capability to produce boilers that could generate high pressure steam and power triple expansion engines. This suggests the importance of experience in the building of engineering capability. In fact the experience of manufacturing an engine is the best learning process for acquiring engine technology and, at the same time, the most secure step for manufacturing a larger engine. This was, of course, the same for the first target, namely, even larger steel hulls. Here the difficulty that Japanese shipyards faced was the shipowners' preference for buying their ships from abroad. They did not have confidence in local shipyards because they lacked experience in constructing large ships. And yet, local shipyards could never gain experience in building large steel hulls unless they received orders for large ships—a vicious cycle intrinsic to the manufacturing industry of latecomers.

And so an important question here is : who dared to provide Mitsubishi Nagasaki with the opportunity to construct larger hulls ?

The first opportunity to construct 500–600 GT hulls was given by O. S. K. to three shipyards. O. S. K. required high performance ships of this class in order to get ahead of competitors in the Inland Sea. However it was very difficult to find such ships in the secondhand market in Shanghai or Hong Kong; the ships that plied the waters between Europe and East Asia were considerably larger. Thus O. S. K. had to order these ships from competent local shipbuilders. Next, Mitsubishi Nagasaki took the lead over the other two by constructing a hull of 1,592 GT. This was a gamble for the Mitsubishi company. At first Mitsubishi planned to sell the ship to O. S. K., but the latter was reluctant to buy it. Construction began without an order from an outside customer. The Mitsubishi company was supposed to use it for the transportation of coal from its mines if the completed ship could find no customer. The ship was completed in 1895 in the midst of Sino–Japanese War. The army hired it immediately for the transportation of munitions. After the war it was bought by O. S. K. .[24] The inner market provided by the Mitsubishi conglomerate served to reduce the risks in this venture.

Mitsubishi Nagasaki then extended its lead over the other two by constructing two 6,000 GT hulls. This opportunity was provided by Nippon Mail Ship, a shipping company which originated from Mitsubishi. Though it was a risky venture to order such large ships from a local shipyard, upgrading the ship building and repair capabilities of Mitsubishi Nagasaki was to the advantage of Nippon Mail Ship, which was developing rapidly. It dared to run a risk in order to gain this advantage.

This last situation was the same with O. S. K. Lines. As the second largest shipping company, it also found it advantageous to develop close ties with some adequate shipyards. It chose Osaka Iron Works as a candidate, but unfortunately its location was not appropriate to the building of large vessels. After the Sino-Japanese War, O. S. K. began to develop lines between East Asia and Japan, and ordered larger vessels from Kawasaki, leaving the smaller vessels for the Inland Sea lines to Osaka Iron Works. However, O. S. K. had no need of large vessels over 5,000 GT until 1910, when it opened a line across the Pacific Ocean to North and South America. This deprived Kawasaki of the opportunity to construct a larger steel hull, and was the cause for its technical lag behind Mitsubishi Nagasaki. In this way a hierarchy developed among Mitsubishi, Kawasaki, and Osaka Iron Works.

The situation was much harder for the shipyards in Tokyo and Yokohama, including the Ishikawajima Shipyard. They lacked the close relations with the two shipping companies, and the two for their part were not so large as to place orders over the capacities of Mitsubishi Nagasaki, Kawasaki, and Osaka Iron Works. Other ship owners were still largely inclined to buy secondhand vessels from abroad. When the two maritime laws were enacted, a few shipbuilders including Ishikawajima constructed large new shipyards expecting an increased demand for shipbuilding and repairing, but on the contrary they fell into the worst price competition possible in a narrow market. Ishikawajima had to sell its new shipyard to its competitor, Uraga Dockyard. Nevertheless, it survived this hard situation by shifting its business activities toward general engineering work.

Among the three successful shipbuilders, Osaka Iron Works developed into a builder that mostly specialized into ships, while Mitsubishi and Kawasaki took advantage of their success and developed into general engineering companies. Ishikawajima survived as the third important company oriented to general engineering.

* * *

The period we are concerned in this section was characterized by the start of modern economic growth—a growth which was necessarily accompanied by

surging demand for various capital goods. Who supplied these capital goods? The answer to this question will clarify the structure of the engineering capability that Japan had accumulated until this time. As we noted earlier, modern economic growth was sustained by roughly five different trends in industrial development.

The first trend: the development of the modern cotton spinning industry depended exclusively on equipment imported from the West, mostly from Britain; by contrast, the silk reeling industry grew depending almost solely on locally manufactured equipment—a phenomenon which I have previously termed "hybrid technology".[25] Traditional carpenters, craftsmen and mechanics who had come from earlier shipyards and other factories collaborated in its manufacture. Some firms, after having developed into larger companies, began to buy more sophisticated boilers and reeling equipment from local engineering firms such as Ishikawajima.

The second trend: the growth of textile and other traditional consumer goods sector started soon after the opening of ports and accelerated with the abolishment of the feudal system. Capital goods were naturally traditional ones, manufactured by traditional craftsmen, but they were gradually influenced by imported machinery; various mechanisms borrowed from abroad were adapted to traditional tools. For instance, in the 1890s, some carpenters adapted the power drive mechanism to the traditional treadle loom, and developed a wooden power loom for kimono cloths. This was an important innovation which contributed greatly to the development of the weaving industries.

The third trend: products supporting this trend can be divided into two categories, namely, products of Western origin, such as soap and matches, and traditional Japanese products, such as rugs and mats. The former products were exported to the Asian market as cheap, but inferior goods, and the latter to the American market as oriental curiosities. The latter were manufactured mainly by handwork, and necessarily required no meaningful capital goods. The former also were produced in a labor-intensive way using very primitive tools. For instance, in the early stage of soap manufacture, the saponification process was carried out in a large iron pot heated on a traditional Japanese cooking stove. It was in the first decade of the century that a simple chemical reactor began to prevail in this process. The reactor constituted of an iron tank, a stirrer, and a steam pipe heater, and could be produced by a small iron works run by a mechanic trained in small shipbuilders or factories.[26]

The fourth trend: the development of mining industries was specifically important to latecomer Japan. Mines were good customers of local engineering firms in the earlier phases. Large boilers, steam engines, and machines such as

crushers and winches were appropriate items for early large shipbuilders and engineering firms. Smaller and simpler items such as pumps, trucks, and small boilers were appropriate for small shipbuilders or small iron works run by local mechanics. However, along with economic growth major mines began to rationalize their mining process, and adopted the latest Western technology, for instance, high pressure steam engines, electric motors and machinery, and power stations. All such machinery and plants were imported.

The fifth trend : the development of railways depended largely on the import of both rolling stock and rails. Import substitution of carriages and freight cars began relatively early, but the local manufacture of locomotives was rare until the end of the Meiji period. We might as well include the development of the shipping industry in this trend. Here the early growth of large shipping companies depended exclusively on imported vessels. In contrast, well-developed coastal shipping continued to rely solely on traditional Japanese sailing ships. With the start of modern economic growth a new type of shipping company emerged. O. S. K. Lines, for instance, started with relatively small iron and steel vessels built by local shipyards, and in the following decade the three shipbuilders established their business foundations through the process described above. In spite of this, a majority of ship owners continued to believe that it was most profitable for them to buy secondhand vessels from abroad. This situation did not change radically until World War I.

* * *

The above survey can be schematically summarized (Fig. 1). Japanese historians have long insisted that Japan's Industrial Revolution took place around the 1890s, and that it was a development in which no capital goods were made in Japan. In other words, the development depended exclusively on imported capital goods. However, Fig. 1 gives us a very different picture. It is true that the relatively narrow top section represented by the development of large companies in the spinning, mining, shipping, railways and other industries depended largely on imported capital goods. However, even in this level, large capital goods produced by local engineering firms, including shipbuilders, had started partly to substitute for imported capital goods.

The firms in the middle section of the hierarchy depended mainly on locally manufactured capital goods. And various developments at the bottom section depended on traditional capital goods and simple machines. Of course, all these were manufactured locally.

It may be useful for later analyses to consider the economic nature of this hierarchy. In general, capital is a scarce resource in a developing country, and foreign currency is usually scarce. Therefore, a capital-intensive course of

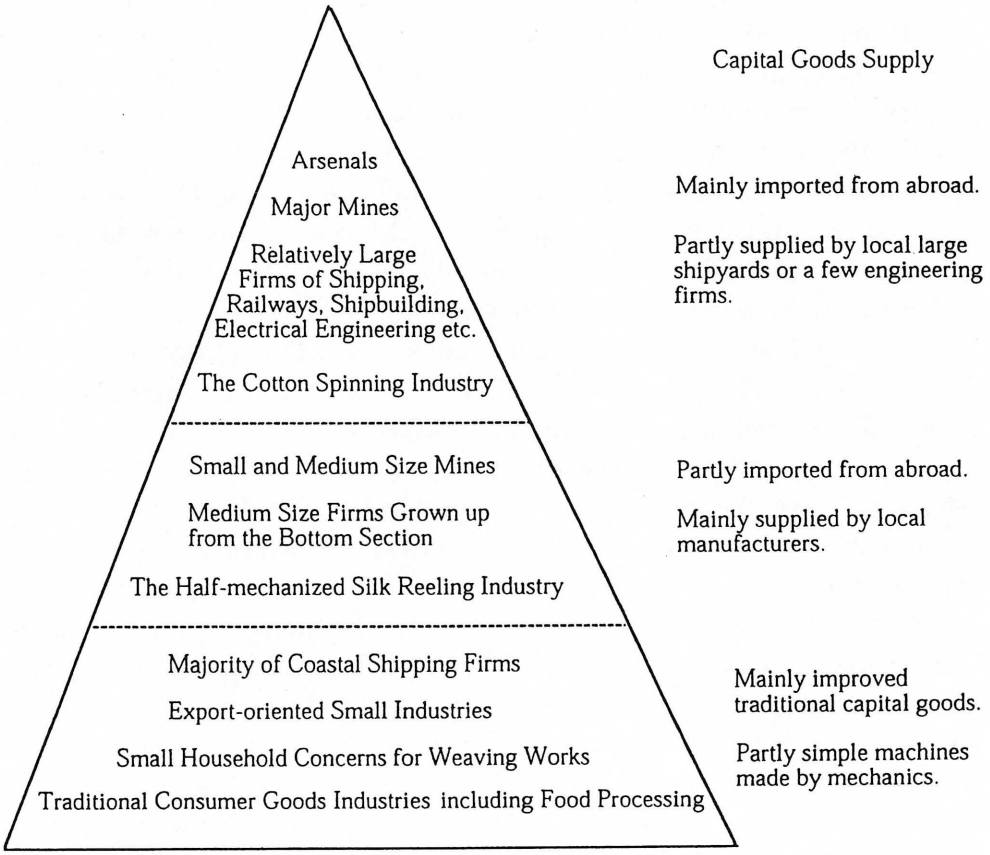

Fig. 1 The hierarchical structure of Japanese industry and suppliers of capital goods to it. (Around the turn of the century)

industrialization based upon imported equipment is in principle impossible to follow. This held true for Japan in the Meiji period. A closer look at these developments reveals that an adequate combination of capital-intensive and labor-intensive development—or of a development depending intensively on imported machinery and one depending solely on locally manufactured ones—represented the secret of rapid industrial development of this time.

Take the cotton industry as an example. The spinning sector of the industry developed depending exclusively on full lines of the latest plants imported from Britain. As a result, spinning frames occupied the top share in Japan's import of machinery for a while. Many large and modern enterprises grew in this sector. In contrast, the weaving sector of the industry developed largely around small household works, which were organized by the "putting out system". Expansion of the domestic market and the improvement of the wooden loom and other traditional weaving techniques were what pulled development of this sector.

There is thus an impressive contrast between the large-scale and mechanized production of the spinning sector and small-scale and handicraft-like production of the weaving sector. Some authors characterize the latter as a remnant of the feudal production system and a symbol of Japan's backwardness.[27] However, the cotton industry as a whole, which combined the two sectors, worked as an economic textile production system that was relatively capital saving. It partly adopted advanced technology, partly took advantage of the abundant labor that was mechanically unskilled; this was a combination which was eminently appropriate to latecomer Japan.

The combination of the silk reeling industry and the railways offers another similar example. The development of railways depended heavily on the import of locomotives, rolling stocks, and rails, and consequently was accompanied by an increase in imports. However, railways promoted the growth of the silk reeling industry, the most important export industry in Meiji Japan. The first successful private railway, the Nippon Railway, connected Tokyo and Aomori through northeast Japan where sericulture had developed. The construction of the Nippon Railway remarkably decreased the transportation costs of silk yarn from regions along the line to the port of Yokohama, and contributed enormously to the development of the silk reeling industry—exclusively dependent on locally manufactured capital goods—in these regions. And the intensive import of capital goods by the railways was paid for by foreign currency which the silk reeling industry earned through the export of silk. Technologically, then, Japanese industry at that time was not homogeneous. Heterogeneous sectors or heterogeneous industries complemented each other and constituted a relatively efficient overall economic system.

* * *

We find this economic structure reflected in the engineering industry of the time. It was a heterogeneous mixture of works ranging from large firms, with modern engineering, to craftsmen's ateliers not so different from that of the Edo period. Table 2 shows the distribution of firms in the Japanese machinery sector in 1911. The concentration of major firms in the shipbuilding subsector is remarkable. Five firms were listed with more than a thousand employees. They were Mitsubishi Nagasaki, Kawasaki, Uraga Dockyard, Osaka Iron Works, and Mitsubishi Kobe. However, even more impressive is the concentration of small firms in every subsector. These firms had different origins, and consequently were of a different nature than the major firms. Comparing Table 2 with Fig. 1, we can discern a hierarchical structure divided into three sections.

At the upper section, major shipbuilders and a few relatively large engineering firms were manufacturing machinery that could barely compete

Table 2 Japanese Engineering Sector in 1911

Firm Size (by number of workers)	Prime Mover & Parts	Textile machinery	Agricultural & Mining machinery	Electrial machinery	General machinery	Ship	Rolling Stock	Cart bicycle & Others	Total
5 – 9	67	70	27	14	176	50	4	92	500
10 – 29	76	36	26	11	96	32	6	12	295
30 – 49	23	6	6	6	10	8	1	1	61
50 – 99	11	2	4	3	13	9	5	2	49
100 – 199	1	4	3	1	2	1	4	1	17
200 – 499	4		1	3	1	7	5		21
500 – 999				1		3			4
1,000 – 1,999						3			3
2,000 – 4,999						1			1
5,000 –						1			1
Total	182	118	67	39	298	115	25	108	952

Source : *Meiji 44-nen Kōjō tsūran* (*List of factories in* 1911)
The table was cited from the author's *The learning process and the market : the Japanese capital goods sector in the early twentieth century* STICERD, London School of Economics and Political Science, 1994.

with imported ones either in quality or in price. The following list summarizes the engineering work of Ishikawajima in 1910s. It gives us a sense of the engineering capability of firms in the upper section.[28]

- Electrical machinery : generators, boiler and steam engines for generators, switchboards *mainly for small power stations.*
- Cranes : *for shipyards, iron works, steel makers and civil engineering work.*
- Rolling stocks : freight cars, steam or electric locomotives for narrow gauges, signal mechanisms, *for mines and private railways.*
- Iron frame constructions : bridges and buildings *for national as well as private railways, stations, and factories.*
- Miscellaneous : silk reeling equipment, gas tanks, iron pipes for water supply, various sorts of pumps.

From these items we can see how a wide range of demand for local engineering work was generated by growing industries and the related development of infrastructure, and the degree to which the engineering capability of the top firms was able to meet them.

In the middle section of the hierarchy were many medium-size firms with employees ranging from 50–300, which manufactured a wide range of industrial machinery in response to the increasing demand for capital goods from smaller mines, textile industries, small manufacturers, and local railways. While mechanization was beginning to spread into every area of the development in this period, machines or machine systems made by major firms, and of course those imported from abroad, were beyond the reach of most manufacturers and entrepreneurs. Consequently, there emerged a great demand for locally

manufactured and cheaper machines. Demand for such machinery as oil and gas engines for small firms and fishing boats, mining machines for small mines, rolling stock for local railways, and narrow width power looms for kimono weavers, was especially strong. Medium-size engineering firms more or less specialized in building one of these items. They had different origins. For instance, the machine shop of a large mine or a railway company separated from the parent company to become a specialized builder of mining machines or rolling stock; mechanics from a machine shop of the early years grew into an oil engine manufacturer; the workshop of a hybrid machine inventor grew into a loom works. Toyoda Loom Works, established by an inventor of narrow-width power looms, and which later became Toyota Motor, is an example of the last case.[29]

At the bottom, a large number of small firms manufactured various machines or various components of machinery. As official statistics of this time

Table 3 Classified list of products by small firms and number of firms producing them

Prime mover and related machinery :	205	Oil and gas engines	92
		Steam boilers	59
		Steam engines	48
		Electric motors and generators	6
Transport equipment :	213	Small ships and repair	101
		Various carts	75
		Bicycles and repair	37
Machinery related to urban lives :	153	Pumps	47
		Metal products for building	18
		Printing and related machinery	26
		Electricity, gas and water supply related	32
		Food processing machinery	30
Machinery invented locally :	108	Narrow looms and others	48
		Rickshaws	13
		Noodle manufacturing machines	7
		Rice milling equipment	45
Machinery for the primary sector :	56	Mining machinery	22
		Sawmill machinery	10
		Cotton beating machines	11
		Agricultural machinery	13
Textile machinery :	55	Machinery related to cotton spinning	22
		Devices for silk reeling	14
		Devices for weaving	8
		Sewing machine and repair	7
		Machinery related to dyeing	4
Machinery for export-oriented labor-intensive industries (match, knitwear, braid, etc.) :	15		
Machine-tool :	18		
Various machines :	130		
Repair to machines :	61		
Machinery parts :	26		

Source : *Meiji* 44 *-nen Kōjō Tsūran.*

omitted firms with less than five employees, we may suppose that far more smaller firms existed than are listed. Table 3 shows a rough picture of the items that they manufactured.

Part 3 : Towards the age of automobiles

The impact of World War I

The outbreak of the World War I cut off imports from the West, and thus dealt a serious blow to Japanese industry. Construction work on all large power stations and high voltage transmission lines stopped because imported equipment became unavailable. The growing shipbuilding industry suffered from a shortage of steel plates, and a large increase in prices. Many other industries suffered similar shortages of chemicals, machine tools, and other imported materials and machinery.

However, this chaotic situation provided capable engineering firms with a marvelous opportunity for import substituting production. Top–rank firms could thus construct high voltage electrical equipment, middle–rank firms could supply machine tools, and innovative entrepreneurs could make steel with open hearths.

Moreover, some countries belonging to the allied force required the help of Japanese manufacturers to produce munitions. Russia ordered a large amount of machinery from a few middle–rank firms to make shells and light arms. Facing a shortage of cargo building capacity, the United States arrived at an agreement with the Japanese shipbuilders that the U. S. government would provide steel plates to the builders who sold them cargo at a favorable rate on its tonnage. The agreement profited not only the three already established builders, but also others which previously had been excluded from the large vessel market. Ishikawajima took advantage of this situation to make its entry into large vessel building.

Thus World War I provided Japanese engineering firms with a great chance to improve their business position.

Towards a conglomerate of engineering industries

Of course, the situation offered the greatest opportunities to the top two firms, namely Mitsubishi and Kawasaki. Already in the decade preceding the war they were preparing to make an entry into machine building fields other than ships. Mitsubishi started research on steam turbines and internal combustion engines including diesel engines. Though Mitsubishi succeeded in constructing its first merchant vessel over 10,000 GT propelled by a steam turbine, its final target was perhaps the application of turbines to electric

generators; that is, Mitsubishi targetted the capital goods sector of the newly emerging electric power distribution industry. Similarly the goal of the internal combustion engine division was to apply this technology to all sorts of new transportation machinery such as submarines, aircraft, and automobiles. Mitsubishi invested much into the internal combustion engine and electrical machinery divisions of its Kobe Shipyard. These two divisions were soon separated from Kobe Shipyard to become the Mitsubishi Internal Combustion Engine Co. (1920) and the Mitsubishi Electrical Engineering Co. (1921).

In a similar manner, in the first decade of the century Kawasaki began to manufacture locomotives and other rolling stocks. After the Russo-Japanese war, the government requisitioned main private railways and, together with the governmental lines, created the National Railways network, which covered the main islands of Japan. Then it launched on the project of the localization of its standard locomotives. Kawasaki played an important role in this project as the leading manufacturer, and became the largest locomotive maker. During the war, it established a steelmaking division to cope with the shortage of steel, as well as a shipping company in order to provide an inner market for its shipbuilding department. Thus Kawasaki followed the path of a conglomerate, though it was smaller in scale than Mitsubishi.

Towards automobile manufacturing

At this time, perhaps one of the most important targets for the two was the automobile industry. And in fact Mitsubishi started trial manufacture of passenger cars as early as 1917 in the internal combustion engine division of Kobe Shipyard. Nevertheless, neither Mitsubishi nor Kawasaki proceeded to the large-scale production of automobiles. Why they didn't is an interesting problem of prewar Japan's industrial development.

The start of the trial manufacture of automobile was directed by the main office of Mitsubishi company.[30] This fact testifies to the fact that automobile manufacture was actually one of strategic targets of Mitsubishi in this period. A passenger car imported from Fiat was broken up and every part was sketched and investigated in detail. Afterwards the manufacture of a dead copy was tried out. The innumerable difficulties that were recorded give us the impression that the tools and mechanical engineering techniques used in shipbuilding were too large and rough for manufacturing passenger cars.[31] In the event, Mitsubishi completed five test cars and began to plan a third shipyard having the capacity to manufacture several submarines, 300 cars, 360 aircraft engines, and a few stationary diesel engines.

Meanwhile, the Army implemented a law to subsidize military vehicles, and

invited many competent firms, including Mitsubishi Kobe, Kawasaki, Osaka Iron Works and Ishikawajima, to enter into the production of military trucks. Ishikawajima accepted the Army's offer. It had been preparing since 1916 to manufacture automobiles and signed a contract in 1918 with a British car manufacturer Wolseley, to purchase the design of two passenger cars and and a truck with technical aid. However, the sale of Wolseley cars in the domestic market was not very successful, so Ishikawajima decided to enter into the production of military trucks, which were subsidized by the Army.[32] Other shipyards did not accept the Army's offer; neither did Mitsubishi, notwithstanding its careful preparations for automobile manufacture.

It is supposed that Mitsubishi had carried out comparative production tests between aircraft and automobiles, and decided to focus on aircraft production for the navy. Since the beginning of the century, Mitsubishi had been developing close relations with the navy by gradually increasing the share of warships in ships built in Nagasaki Shipyard. When the plan of the Nagoya Shipyard was realized, it was actually an aircraft manufacturing plant for the Navy, and the equipment from the supposed automobile shop was transferred to its small works at Tokyo, which subsequently developed into a tank manufacturing plant in the 1930s.

Mitsubishi's course represented the fate of major engineering firms in the interwar period. They involved themselves deeper and deeper in the production of munitions. The Kawasaki group also gradually increased the weight of warships, aircraft and tanks.[33] Ishikawajima continued the production of military trucks, and soon separated its automobile division as Ishikawajima Automobile Co., which merged with other two manufacturers to form Tokyo Automobile Manufacturing. This company continued to produce heavy military trucks and later tanks under the protection of the army. Meanwhile the Japanese car market was dominated by Ford and GM.

Concluding remarks

We have surveyed the development of Japan's engineering capability since the mid-19th century to the interwar period.

The development of Japan's social capability for engineering was closely related to that of the shipbuilding industry. As early as the 1850s the Bakufu started its effort to transfer Western shipbuilding technology into Japan. The Meiji government followed up on the Bakufu's effort and tried to modernize the local shipping industry by making steamers as soon as possible. But as a latecomer to industrialization, Japan found this impossible to achieve.

The difficulties faced by early modern shipyards can be summarized as

follows. Imported machinery was very expensive. Furthermore, because no engineering industries actually existed in Japan, they had to incorporate the capacity to manufacture machines which their Western counterparts could easily obtain by outsourcing. At the same time, the Japanese shipping industry needed few steamers. Sailors did not know how to steer these, nor did ship owners know how to apply these to their business. They preferred traditional sailing ships to steamers. As a result, all these shipyards suffered from a large gap between the relatively large capacities of their expensive plants and the small market for their products.

While the Japanese shipbuilding struggled with these difficulties, Western shipbuilding technology rapidly changed towards large cruisers with steel hulls and triple expansion marine engines. Notwithstanding the former's intensive efforts, the technological gap between Japan and the West was widening.

However, from 1890 to 1911, Japanese shipbuilders made a great technical leap and almost caught up with their Western counterparts. Mitsubishi Nagasaki Shipyards led this process. In this respect Mitsubishi's case deserves closer consideration.

The tragedy of Kobe Iron Works shows eloquently that this type of technical leap in the early difficult conditions was quite risky. On the one hand, such a leap required a huge investment in equipment and engineering staff, and on the other it was difficult to find customers for a newly manufactured products. This is when the gap between production capacity and market demand was greatest. The two maritime laws provided a new political measure to alleviate this risk. The shipping law aimed at the development of the domestic large ship market through the promotion of long distance shipping. The aim of the shipbuilding law was to cover the financial burden of builders by subsidization. In spite of this double protection most entrepreneurs still feared the risks.

Mitsubishi proceeded very cautiously. It designed its technological advance not as a single leap, but as a series of small jumps. It constructed the first steel vessel of 610 GT with a 483 Hps triple expansion engine in 1890. A small jump to the vessel of 1,592 GT (853 Hps) was achieved in 1895, and the second jump to 6,172 GT (3,847 Hps) in 1898. The third jump to a vessel of 13,454 GT with 20,608 Hps 3 Parsons D. C. Turbine was carried out in 1908, after the company had experienced the construction of 9 vessels of the 6,000 GT class. It was a carefully prepared, long series of small jumps. Furthermore, these small jumps were accompanied by risk-hedging devices as exemplified by coal transportation in the first jump, and close ties with Nippon Mail Ship in the second jump.

Throughout the process the key factor working to Mitsubishi's advantage was the fact that it was a conglomerate. First of all, this factor was favorable to large investment. Next, demands for various machines raised by many of its branches constituted a sort of inner market. Mitsubishi took advantage of this inner market to hedge the risks of the first jump. Should the jump have ended in a failure, the resulting financial damage would have been dispersed to all the related branches and finally assumed by the Mitsubishi, and not solely by the Nagasaki Shipyard. If the jump was successful, then the upgraded engineering capability of the Nagasaki Shipyard would be to the advantage of every branch of the Mitsubishi conglomerate. The same argument can be applied to the relation between Nagasaki Shipyard and Nippon Mail Ship in the second jump. Here the role of Nippon Mail Ship functioned almost like a shipping branch of the Mitsubishi conglomerate.

Thus Mitsubishi demonstrated that a conglomerate under adequate government protection represented an appropriate form for a private firm of a latecomer country safely to venture into a risky business requiring the latest engineering techniques.

Changes following from World War I initiated a new era for Japanese business, in which engineering firms enjoyed abundant opportunities. In this situation, Kawasaki and to a lesser degree Ishikawajima drew upon their long accumulated engineering capability to follow the trail blazed by Mitsubishi, that is, the path of a conglomerate under government protection. Already established zaibatsu such as Sumitomo, Mitsui, and Furukawa adopted the same strategy, taking advantage of the engineering capability accumulated in their large machine shops for mines and metal refining plants.

Throughout the interwar period however, government protection was gradually shifting towards the munition industries. As a result, major engineering firms gradually developed a close relation with the army or the navy, leaving the unprotected and very risky engineering fields to medium-size firms in the middle section of the hierarchy. One such field was the mass production of passenger cars, where Ford and GM were dominant presences. While the army had a strong interest in the automobile, this interest was restricted to heavy vehicles for military use. It regarded passenger cars as a luxury consumer good that was in no way related to its military operations.

In the interwar period, many entrepreneurs and engineers who were personally enchanted by the motor car tried to enter into passenger car production. As with the efforts of Kobe Iron Works to break into iron steamer building however, the result was always a failure. But during that time two engineering firms in the middle of the hierarchy were advancing steadily

approach towards the mass production system of passenger cars. One was Toyoda Automatic Loom Works, which had begun as a manufacturer of improved traditional looms at the bottom of the engineering hierarchy. The other was Tobata Casting, which had started by manufacturing malleable iron castings and internal combustion engines for fishing boats. Toyota Motor separated off from the former in 1937, and Nissan Motor from the latter in 1934. In 1935 Nissan began to produce a very small car called Datsun on a new line at the Yokohama Plant with a capacity of 10,000 cars per year.

However, just around this time the army and the government agreed to involve the two companies in the production of military trucks. Thus the establishment of a Japanese version of the mass production system for cars was postponed until after World War II. How they achieved this feat and overcame the big gap that existed between the large capacities of expensive, integrated plants and an extremely small market for their products is another story —one which in some ways resembles and in other way differs decisively from what has been described in this paper.

Notes

1. A brief description on this movement is given in T. Nakaoka, "The European industrial economy and the endogenous development in Asia" in Yamada Keiji, ed., *The transfer of science and technology between Europe and Asia, 1780–1880*, (Kyôto : International Research Center for Japanese Studies/IRCJS, 1993), 15–38.
2. Nakanishi You (1982) and Kusumoto Juichi (1992) are good references for Nagasaki Iron Works. A detailed description of the study of schooner building is found in the chapter 1 of Yamamoto Kiyoshi (1994).
3. Suzuki Jun, *Meiji no Kikaikôgyô* (*Engineering industry in the Meiji period*), (Kyôto, 1996). Chapter 1 is an excellent study on this process.
4. Nagasaki Iron Works changed its name four times after the Restoration : that is, Nagasaki Shipyards, Nagasaki Manufacture, Nagasaki Engineering Branch and Nagasaki Shipbuilding Dept.. This fact reflects the fluctuation in its orientation between general engineering works and shipbuilding. Here we adopt its last name. It is same for Hyôgo Shipbuilding Dept.
5. Teratani Takeaki (1979) 38–50.
6. Suzuki Jun (1996), 50–52.
7. An excellent survey of Westerners' shipyards in East Asia in the second half of the 19th century is found in Frank Broeze, "The transfer of technology and science to Asia 1780–1880 : Shipping and Shipbuilding" in Yamada Keiji (1993), 117–139.
8. Ishii Kenji (1995), 114–118.
9. Teratani Takeaki (1979), 51–53.
10. Suzuki Jun (1996), 62–64. Descriptions on Kirby and Kobe Iron Works in this paper owe to

Suzuki's book.

11. Ishikawajima Heavy Industries (1961), 278.
12. Muroyama Yoshimasa (1981), 90–92.
13. Kôbusho (1896), 314.
14. Zôsen Kyokai (1911), 593 ; Ishikawajima Heavy Industries (1961), 236.
15. Suzuki Jun (1996), Chapter 5.
16. Inoue Yôichirô (1990) is a good reference with regard to the development of shipping and shipbuilding in the Meiji period.
17. Suzuki Jun (1996), 68–69.
18. Mitsubishi Shipbuilding Co. Nagasaki Shipyard (1928), 35.
19. *Ibid.*, 38–42.
20. Shiota Taisuke (1938), 105–6.
21. Suzuki Jun (1996), 70.
22. Shiota Taisuke (1938), 119–122.
23. Hitachi-maru (6,172 GT) and Awa-maru (6,309 GT). Technical aspects of the construction process of the former are analyzed in Nakaoka Tetsurô (1987).
24. Shiota Taisuke (1938), 119–122.
25. Nakaoka Tetsuro (1987).
26. Yamamoto Kiyoshi (1994), 377.
27. A representative of such analysis is Yamada Moritarô (1934).
28. Ishikawajima Heavy Industries (1961), 305–12.
29. Toyoda Loom Works did not directly develop into Toyota Motor. Though Toyoda Sakichi was the founder, he left his Works because his R & D policy was rejected by the executive board. In 1926 he established with his son Toyoda Kiichiro Toyoda Automatic Loom Works. This is the parent company of Toyota Motor.
30. Mitsubishi Automobile Manufacturing Co. (1993), 33.
31. *Ibid.*, 32–35
32. Isuzu Motors Ltd. (1988), 3–13.
33. Kawasaki manufactured two test vehicles of military truck in 1919. The next year the automobile section of the Kawasaki Shipyard was established. As early as 1921 its name was changed to the aircraft section. Japan Automobile Manufacturers' Association Inc. (1967), 327–8.

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