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Sustainable Management Practices of Japanese Companies
in Pre-War Period from the Perspective of SDGs and ESG

8

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No Product, No Invention

April 7, 2020

No. **228**

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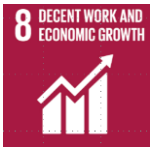





Sakichi Toyoda(1867-1930)

(Source) National Diet Library

Masaatsu Takehara, Naoya Hasegawa

Achievement of Sakichi Toyoda and related SDGs

Economy	 	<ul style="list-style-type: none"> *Automatic loom business *Weaving fabric business *Develop infrastructure for vehicle production
Society	 	<ul style="list-style-type: none"> *Improve productivity through development of power loom *Support for working style reform of workers *Promotion of R & D *Strict quality control
Governance	 	<ul style="list-style-type: none"> Utilization of patent system Creation of intellectual property business Development of global business

1. Early days

It was process innovation through Kaizen -- aiming at improving quality and reducing costs -- that supported Japan's post-war rapid economic growth. On the other hand, Japanese companies have not been very good at product innovation that creates original technology and products.

In order for the Japanese economy to maintain sustained growth, it is necessary for businesses to promote product innovation.

Sakichi Toyoda, who was a founder of the Toyoda Group, invented the automatic loom for the first time in Japan, being inspired by an engineer who supported the industrial revolution in the UK.

In the early Showa period, in elementary school textbook, Toyoda was portrayed as a success story and a hero. In this chapter, we will look back on Toyoda's activities and explore the characteristics of entrepreneurs who succeeded in creating product innovation.

Sakichi Toyoda was born in 1867 in present-day Kosai City, Shizuoka Prefecture, located on the west coast of Lake Hamana (Hamana-ko). The Toyoda family was engaged in agriculture, but their land was not large, and it was difficult for them to make a living from agriculture alone.

For this reason, Sakichi's father, Ikichi, became a carpenter seeking a livelihood other than agriculture. Sakichi's father was a craftsman with a sense of responsibility and ethics. He was a devout believer of Nichiren-shu (a school in Buddhism), a traditional Japanese religion and he believed in Hotoku thought¹ as his life creed. Sakichi Toyoda sincerely worked on technical development throughout his life. It seems the formation of his professional ethics were influenced by his father.

Sakichi Toyoda began helping his father with carpenter work at the age of 13, and he rapidly grew to become the right-hand of his father in just two years. Sakichi received regular education until elementary school. He did not receive regular education after graduating from elementary school, but he was very keen on obtaining new knowledge. Therefore, he held an independent study meeting every night with his comrades aged between eighteen and late twenties and had a lively exchange of opinions.

It is said that Sakichi Toyoda began to work on the development of automatic looms in earnest after he read and was inspired by a translation of Samuel Smiles' "Self Help" (1870) (the book was titled "Saigoku-risshi-hen" in Japanese).² Also, he was encouraged by promulgation of newly established Patent Monopoly Ordinance of 1885.

The S. Smiles' Self Help was translated into Japanese by Masanao Nakamura as "Saigoku-rishi-hen" and became the best-selling book with 1 million copies issued throughout the Meiji period. The book explained the importance of the spirit of self-reliance as symbolized by the words "Heaven helps those who help themselves."

"Saigoku rishi hen" was an enlightenment book that had a great influence on the citizens who were liberated from the feudal status system by the Meiji Restoration.

The book repeatedly stated that people can always succeed if they have ambitions and make continuous efforts. The book explains that the happiness of life comes from diligence and self-learning and maximizing the happiness of the people who make up society, by drawing on the numerous entrepreneurial activities that supported the industrial revolution.

On the other hand, the Patent Monopoly Ordinance of 1885 was promulgated as the first patent law in Japan. In the era when the patent system did not exist, Gaun Tatsumune³, who invented a pure Japanese-style spinning machine, received an award at the first National Trade Fair held in 1877. Ironically however, this resulted in domestic traders copying his spinning machine. Moreover, because these imitators advertised that they invented this spinning machine, Gaun was pressed for daily living expenses.

"Saigoku rishi hen" stated that the patent system protected the rights of inventors and this became the driving force of the industrial revolution. Toyoda earnestly read the book and fully understood the significance of the Patent Monopoly Ordinance.

A biography about Toyoda stated the following story:

Sakichi happened to visit a primary school to help his father's work and heard a class discussing the "Saigoku rishi hen". He borrowed the book from a primary school teacher. Also, he learned about the Patent Monopoly Ordinance from the teacher and was very inspired. These experiences drove him to a series of innovative inventions.

The biography says that Toyoda was especially influenced by James Hargreaves⁴, who developed a multi-spinning machine (spinning jenny) and patented it. Hargreaves was also from a poor carpenter family. This story was introduced in Japanese elementary school language textbooks in the early Showa era, and has been handed down to this day as an episode that inspired Sakichi to invent innovative products.

However, according to Hirakawa (2006), it became clear that the episode that has been told in

Toyoda's biography is fiction. The episode first appeared in 1931 in a book, "The Loom Tycoon Toyoda", written by Matsusaburo Yora. Since then many Toyoda biographies followed its description so it was taken as a fact.

Even if the episode about Toyoda's encounter with "Saigoku rishi hen" was fiction, it is highly likely that Toyoda read the book. "My record of Invention" which Toyoda authored, described that in 1884, Toyoda tried to join the Enshu Futamata Spinning Company, which was established as a spinning mill by the Meiji government for the purpose of promoting industrial development, but he failed. The Enshu Futamata Spinning Company was founded by Ryoichiro Okada, President of Dainippon Hotokusha based in Kakegawa City, Shizuoka Prefecture. It was one of ten spinning companies established throughout the country. Okada explained the significance of entrepreneurial activities by citing the cases of James Watt⁵ and Richard Arkwright⁶ who were introduced in "Saigoku rishi hen".

As Sakichi Toyoda was an enthusiastic follower of Hotoku thought, it is possible that he came to know about the "Saigoku risshi hen" through Okada's writings and lectures. Okada developed the philosophy of Hotoku thought originally promoted by Sontoku Ninomiya and emphasized the significance of integrating economy and morality and advocating the idea that the pursuit of economic rationality led to the moral completion of entrepreneurs.

Okada aimed for economic independence in the Enshu region through the cultivation of the spinning and cotton fabric industries. As a result of this influence, many automatic loom manufacturers were established in the Enshu region such as Toyoda Loom Industries established by Sakichi Toyoda (predecessor of Toyoda Motor Corporation) and Suzuki Loom industries established by Michio Suzuki (predecessor of Suzuki Motor Corporation).

Toyoda Sakichi began to develop a power loom while receiving direct and indirect influences from Hotoku Thought and "Nishi-National Zhen". However, as Toyoda was still an amateur at this time, he couldn't develop a power loom overnight. Therefore, for the time being, he focused on improving manual looms to enhance productivity. Thus, Toyoda's more than 40 years research and development activities began.

2. Development of the power loom

In 1890, the 3rd National Industry Fair was held in Tokyo. At the first exposition, the above-

mentioned Gala spinning machine invented by Tatsumune Gaun attracted attention and spread nationwide. Toyoda has an anecdote that he visited the exposition hall every day and was suspected by guards. It is considered that Toyoda lacked mechanical engineering expertise and was unable to understand by just looking at the exhibited machines.

After returning home, Toyoda made the first wooden human-powered loom as his first invention. This loom was an improvement over the traditional hand-woven loom, called the “Battan loom” and it gained a reputation for its efficiency that was 40 to 50% higher than the previous loom. In 1891 Toyoda acquired the first patent for this invention.

Toyoda established a weaving factory in Tokyo to manufacture this wooden human powered loom. He had to secure funds to develop the power loom. However, the development of the power loom did not proceed as expected, and the management of the weaving factory was stalled. In 1893, Toyoda returned to his hometown. The following year, his eldest son Kiichiro was born. Even after returning to his hometown, Toyoda continued his research in the room all day long, but the development of the power loom was slow. His wife, Tami, was tired of living with research-centric Toyoda and left him, leaving the little Kiichiro.

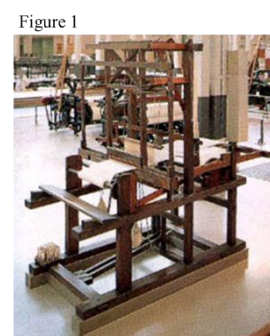


Figure 1
Wooden human power loom
Source: Toyota Motor Corporation website

Despite this situation, in 1895, Toyoda succeeded in developing a yarn knitting machine (reeling machine), his second invention. The yarn knitting machine was a necessity for farmers who made woven fabric as their side business, but conventional products were operated by hand and were difficult to handle. Toyoda made a foot-operated (pedaling) yarn knitting machine and succeeded in improving the efficiency by 2 to 3 times. This yarn knitting machine was very well received and achieved great business results.

As Toyoda was able to rebuild his financial base with the success of the yarn knitting machine, he went to Nagoya and began selling this product in earnest. Utilizing the funds he obtained, Toyoda resumed his research on power looms. Toyoda succeeded in developing the wooden power loom in 1897, two years later. The invention of the yarn knitting machine became a turning point in the development process of the power loom.

Becoming financially stable with the success of the yarn knitting machine, Toyoda conducted a field survey of the looms used in regions from Enshu to Aichi Prefecture. Toyoda studied the actual

situation of small and medium sized farmers using looms, listened to their requests, and addressed them in the development of power looms.

After repeated weaving experiments using prototypes, the first Toyoda-style wooden power loom was completed around the summer of 1897 in Japan. Toyoda obtained a patent for this product the following year.⁷ Toyoda succeeded in producing a power loom as a modern machine seven years after he developed the wooden manpower loom.

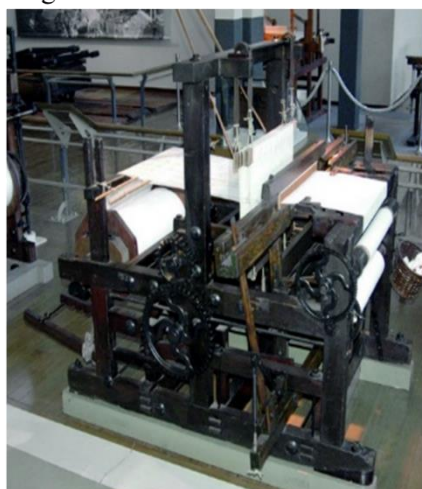
Although a power loom was developed by Toyoda, the production of hand looms was the mainstream in the weaving industry at that time, and there was much demand for inexpensive wooden man-made looms. Although some large-scale weaving factories were planned, the prospect of its realization was not feasible. And Toyoda himself did not have enough funds to start commercial production of power looms, so he did not have an opportunity to stimulate demand for power looms.

Amid this situation, Tohachi Ishikawa, a middle merchant in Aichi Prefecture, who was a yarn knitting machine customer suggested that Toyoda establish a weaving company using a Toyoda wooden power loom. Ishikawa carried out a business of bringing yarns to the farmers and having them weave and buy the fabric. Toyoda agreed with Ishikawa's proposal under the condition that Ishikawa pay for the construction cost of the weaving factory and Toyoda provide 60 power looms he developed. Thus, the Otsukawa Cotton Cloth joint-stock company was established in 1897,

Because the cotton fabric produced by the Otsukawa Cotton Fabric was uniform in quality, it attracted the attention of Mitsui & Co., Ltd., the purchaser of the cotton fabric. It was common that the quality of fabric conventional human-powered looms made was not uniform, but the fabric made by Otsukawa Cotton Fabric did not have such unevenness. Mitsui dispatched their staff to Otsukawa Cotton Fabric, and they found out that the secret was the power loom developed by Toyoda.

As Mitsui promoted power looms, Toyoda quickly became known to the public as an inventor of power loom. Demand for power looms from small and medium sized craftsmen increased day by day, and the Otsukawa Cotton Fabric Joint Stock Company developed steadily. Toyoda decided to

Figure 2



Wood-iron hybrid automatic loom
Source: Toyota Motor Corporation website

give his shares of interests to Ishikawa and concentrate on manufacturing looms and research and development.

In Japan at that time, the main power source of power looms was hydropower. The industrial revolution in the United Kingdom was powered by a steam engine using coal as an energy source. In Japan in the early Meiji period, as coal was expensive, hydropower using a turbine was the main energy source. However, hydropower had a fatal flaw as a power source in that it was difficult to secure stable power. The failure of the Enshu Futamata spinning company, which Toyoda once tried to join, was due to its inability to effectively use the hydropower of the Tenryu River.

Then Toyoda newly developed an oil engine driven loom to solve the power source problems, which prevented the spread of power looms. The development of this oil engine driven loom became a factor that accelerated the spread of power looms in the Enshu region.

As mentioned earlier, Mitsui & Co. was first interested in Toyoda's power looms. Let's look back on the background of Mitsui's interest in power looms.

At that time, the Meiji government was worried about the processing of , “Gun-pyo”, a military note issued in Manchuria during the Sino-Japanese War. Gun-pyo was a bill issued by the Japanese military in the battlefield or occupied area to finance the military budget. The bill had a condition that it could be exchanged for Japanese currency if it was brought into a Japanese government agency. However, if all Gun-pyo funds were to be exchanged for Japanese currency, the government would have to be forced to issue a huge amount of currency, resulting in possible negative effects such as inflation.

The Meiji government planned a policy to export large quantities of cotton fabric to Manchuria as a way to collect military bills without exchanging them for Japanese currencies. However, Japan did not have a capacity to mass-produce cotton as it only had man-made looms at that time.

Mitsui & Co. showed their will to cooperate with the policies of the Meiji government, but did not have a specific way to mass produce cotton. Thus, Mitsui came to know the power loom developed by Toyoda. Toyoda had been working on his invention with the purpose of contributing to the nation and society. The power loom he invented contributed to saving the nation from a financial crisis.

3. Establishment and failure of the Toyoda Loom

In 1899, Mitsui & Co., Ltd. established a joint company, Igeta Shokai, for mass production of power looms, and Toyoda became the chief engineer. During this period, Toyoda made an important technological breakthrough for the development of automatic looms. He successfully developed a device that could supply weft yarns while the loom was in operation. It was an important technical element indispensable for the automation of the loom.

However, it is clear that no matter how much technically important an invention is, if the invention does not lead to commercialization and monetization, it has no meaning for a company. Faced with the difficulty of balancing R&D and corporate earnings, Toyoda left Igeta Shokai (Company) and started a weaving business again at Toyoda Shokai.

The business of the Toyoda Company was very smooth, so Toyoda left the management to his second wife Asako and his younger brother Sasuke, and he focused on research and development of automatic loom by investing much of company's earnings.

"Thirty-eight year model" and "Thirty-ninth year model" Toyoda developed during 1905-06 were mixed wood and steel power looms. These new looms improved so that thick fabrics could be woven, enhancing durability, versatility and efficiency. Even with these improvements, the price was kept low, so a flood of orders poured into the Toyoda company.

In 1905, there was an event that had a major impact on the development of automatic looms.

A performance comparison test of looms from Japan, the United States, and the United Kingdom (2 companies) was conducted at the Hyogo Factory of Kanegafuchi Spinning. As a result, the normal loom of Platt, UK, showed the best results.⁸ The loom developed by Toyoda was not able to deliver satisfactory performance. The reason why Pratt's loom achieved a good result was that it delivered stable performance even when poor quality cotton yarns were used. This provided an important suggestion for Toyoda's product development.

It was Mitsui & Co., once again, who was the first to set its eyes on the rapid growth of Toyoda Company. In the past, Toyoda was forced to leave the Igeta company that both Toyoda and Mitsui established because of a conflict between the management team from Mitsui and him. Mitsui & Co. proposed to reorganize Toyoda Shokai as a stock company. Toyoda agonized over whether to accept the Mitsui's proposal for about six months because of the bitter experience at the Idate Shokai. He finally accepted the proposal.

In 1906, Toyoda Loom Co., Ltd. (capitalized at 1 million yen) was established as the first full-scale loom manufacturer in Japan. Toyoda became the chief engineer.

The new company's business was sluggish from its establishment. Toyoda was held responsible for the poor business performance, so the president Taniguchi forced him to resign. Toyoda focused on pre-sales trials aimed at improving product quality, but his plan was opposed by the management team who wanted to sell products as soon as possible to secure profits. Eventually, Toyoda was forced to resign, losing the financial base and the place for research and development he accumulated since his time at Toyoda Shokai.

4. Completion of the G type automatic loom

Toyoda, who was forced to leave the Toyoda Loom Company, visited the United States and the United Kingdom. In the United States, he researched Northrop type automatic looms that was well-known in Japan, but Toyoda had an impression that its technical level was not necessarily high compared to the automatic looms he produced.

The automatic loom has a function that can automatically replenish the weft. For the weft replenishment method, there are two methods; a method that replaces a wooden pipe wound with yarns and a method of replacing shuttle. Around 1894, J. Northrop in the United States completed the former method, and in 1926 Toyoda completed the latter method.

During his visit to the United States, Toyoda visited Jokichi Takamine, who discovered Takadiastase and adrenaline. Takamine was well-informed about Toyoda's invention and his personality so he was pleased with Toyoda's visit. Sakichi Toyoda Biography Compilation Committee (1933) introduced the following Takamine's comment:

"Many inventions are often buried unsuccessfully. It is not only a crime of society but also the responsibility of the inventor. (Omitted) The inventor should not leave the invention until it is expected that it will be safe to use in society. But until the prospect of being able to fly enough in the sky, the inventor is responsible for taking care of it. I think this may be the reason for the completion of the invention. "

Takamine's remark was in line with Toyoda's belief that the true value of a new invention cannot be launched into the market unless it goes through complete sales testing. The words of Takamine, who established a solid record as a manager of a bio-venture in the United States, helped broken-

hearted Toyoda regain himself and his courage. Toyoda, who had been fighting alone, is reported to have visited Takamine several times since then as if he enjoyed the encounter with a person who, for the first time, understood his feelings as an inventor.

In 1912, Toyoda returned to Japan with a new determination and established the Toyoda Auto Textile Factory in Nagoya to obtain R & D funds. In 1914, he established a new factory and entered the spinning industry. At that time, the quality of the cotton yarn was poor and hindered the testing of the automatic loom, so Toyoda ran both a woven fabric business and spinning business to secure high-quality cotton yarn. The management risk associated with entering the spinning industry was high, but the spinning industry was growing rapidly on the wave of the economic boom of the First World War.

In 1918, Toyoda Boshoku Factory was converted to a stock company and Toyoda Boshoku Corporation was newly established. Later, Toyoda Boshoku produced Toyota Boshoku, and the Toyota Boshoku became the Toyota Motor Corporation.

The cessation of imports of British cotton products in China due to the effects of World War I accelerated Japanese textile companies' entry into China. In 1921, Toyoda established Toyoda Boshoku Sho (a kind of subsidiary) in Shanghai and moved to China. Toyoda instructed Kiichiro, his eldest son who just graduated from a university, to continue research and development on the automatic loom.

Kiichiro developed a loom equipped with a newly developed automatic shuttle changing device on a Toyoda's ordinary loom, and conducted a test operation with these 200 new automatic looms at the Kariya test plant newly established in 1924. This new automatic loom was named the "G-type automatic loom," and the first machine was completed in November 1925.

Kiichiro was instructed by his father, Sakichi Toyoda, to mass-produce the "G-type automatic loom" and planned to build a new factory. In constructing the new factory, a new company for automatic loom manufacturing named Toyoda Automatic Loom Manufacturing was established in Kariya in November 1926. The method adopted by Kiichiro in the development of the "G-type automatic loom", which was gradually increasing production capacity while mastering

Figure 3



G-type automatic loom
Source: The Toyota memorial Museum of Industry and Technology

production technology, was also utilized in their automobile business.

With conventional ordinary looms, the number of looms that one worker could operate was 4 to 5, but the "G-type automatic loom" enabled one worker to operate 50 looms. In 1929, late-night work of women and young people was banned based on a resolution of the International Labor Conference, so the demand for automatic looms in order to secure productivity increased sharply. It can be said that the innovation Sachi and Kiichiro realized was a solution to social issues at the time. In addition to the Japanese market, Toyoda-type automatic looms were exported to countries including China, India, the United States, Canada, and Mexico

Pratt, a leading loom manufacturer in the U.K., highly praised the performance of the Toyoda-type automatic loom. Platt applied for the transfer of the patent right of the "G-type automatic loom", and in December 1929, the Toyota-Platt agreement was signed. The patent transfer agreement between Pratt and Toyoda was for a patent on a shuttle-type automatic loom developed by Toyoda.

Under this agreement, Pratt paid Toyoda £ 100,000. This money was used to fund Kiichiro's research into the automobile business and laid the foundation for today's Toyota Motor Corporation.

After the completion of the automatic loom, Toyoda was based in Shanghai and worked on the research of the circular loom⁹ that he had tried before. He was also interested in social contribution activities and made a donation of 1,000,000 yen to the Imperial Invention Association to encourage the invention of a storage battery. The qualifications for applying for this research grant were limited to Japanese. This reflects Sakichi's desire to improve the Japanese capabilities of technical development.

After 1927, he suffered a cerebral hemorrhage and was unable to research as he wished. He died of an illness in October 1930 without seeing the completion of the circular loom he was working on. The spirit of Sakichi Toyoda was handed over to his son, Kiichiro's, automobile business.

Table 1 Major Innovations by Sakichi Toyoda and Kiichiro Toyoda

Name	Year	Description
Toyota wooden human-powered loom	1890	First loom Sakichi invented. The previous loom required both hands to weave, but the model Sakichi improved enabled one hand operation with the shuttle running to either side. This improved productivity by 40-50%.
Yarn knitting machine (Reeling machine)	1894	The conventional hand-operated loom was improved to a foot-operated type. Work productivity increased by a factor of two to three. This success enabled Toyoda to cover the cost to develop the power loom.
Wood-iron mixed power loom	1896	The first power loom in Japan developed by Sakichi Toyoda. A single person could operate three to four units. Productivity increased 20-fold. The quality of the fabric was very high and the loom became very popular.
38 year loom	1905	The 38 year loom was equipped with a device that would stop the operation when weft or warp was cut, preventing problems such as weaving of damaged fabric.
Circular loom	1906	An ideal loom which contained a revolving shuttle. Sakichi worked hard for its commercial application, but died without seeing the finished products of the circular loom.
L-shaped iron-powered loom	1909	In order to create a robust and efficient loom that would address the large-scale industrialization of the weaving industry, Toyoda transformed a wood-steel-mixed power loom into a complete steel-made power loom.
N-type wide powered loom	1914	To address a growing demand for cotton fabric from overseas, the N-type wide powered loom was created by improving a conventional wide loom with adding new functionalities such as a warp cutting stop device. This loom became the basis for the G-type automatic loom.

(Source) Created by the author based on various materials.

5. Conclusion

Sakichi Toyoda acquired his knowledge and skills in mechanical engineering on his own and succeeded in creating and commercializing epoch-making innovations that were recognized by advanced countries in the machine industry such as Europe and the United States. He is highly regarded as the pioneer of R & D type venture entrepreneurship in Japan.

Importantly, Sakichi Toyoda was a good engineer before becoming an entrepreneur. What is most important for R & D venture companies is a core innovative technology for their business. No matter how good their entrepreneurial qualities are, it is difficult to create a research-and-development type

venture company unless they grasp the core innovative technology by themselves.

Needless to say, R & D investment creates innovation and this contributes to increasing corporate value. As the external environment surrounding companies changes, companies are required to accurately grasp the potential needs of society and return to society as innovation.

In order to revitalize the economy, it is important to commercialize the seeds acquired through R & D, but R & D in Japanese companies has not been necessarily linked to commercialization and therefore has become a major bottleneck in the Japanese economy. From this point of view, it can be said that there are many points that modern companies need to learn from Toyoda's way of life as an entrepreneur.

Also, one of Toyoda's unique characteristics as an entrepreneur was his high awareness of patent rights (knowledge). In light of the promulgation of the Patent Ordinance, Toyoda actively acquired patents for the results of his technological innovation.

Toyoda's active use of patents was not to gain huge wealth by commercializing the acquired patents, but to secure sufficient funds for his next R & D projects.

Today, for some venture entrepreneurs, their purpose is to make money, but for Toyoda making money was not a purpose, but just a means of research and development. Toyoda did not own the patents he acquired, but instead had his company own them. From such attitudes, we can guess his philosophy as an entrepreneur.

Succession of the Business of a R & D type venture company is very difficult. This is because entrepreneurs themselves must have excellent R & D capabilities. In the case of Toyoda, he was blessed with Kiichiro, a successor who was a better engineer than his father. Kiichiro acquired his own technological seeds through his efforts on the development of an automobile that his father Sakichi never worked on and made the cornerstone of today's Toyota Group. Human resources that have the skills of both researchers/technologists and entrepreneurs are extremely rare, and that is why Sakichi Toyoda is regarded as the ideal and desired figure for R & D type venture entrepreneurs to date.

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¹ Hotoku thought is a philosophy that Sontoku Ninomiya advocated and propagated. Ninomiya appealed for the integration of economy and morals, and argued that if one contributed to society, rather than seeking private interests, the return would eventually return to him. Ninomiya especially emphasized "Suijo (concession)", "Kinben (hard work)", "Shisei (sincerity)", "Bundo (computational general equilibrium)".

² Samuel Smiles (1812-1904) was a Scottish doctor and writer. Self-Help, which was published in Japan as "Saigoku rishi hen" had a significant impact on the formation of the philosophy of young people during the Meiji era.

³ Gaun Tatsumune (1842-1900) was an inventor who invented the Gaun type spinning machine in the early Meiji era. He won the first prize at the 1st National Industrial Expo held in 1877 in Japan. However, as his invention was released before the patent protection ordinance was enacted, his products were driven out by imitations.

⁴ James Hargreaves (1720-1778) was a British carpenter and inventor. In 1764, he invented a Jenny spinning machine by dramatically increasing the yarn production efficiency.

⁵ James Watt (1736-1819) was a mechanical engineer from Scotland. The industrial revolution in the U.K. advanced with his steam engine improvements.

⁶ Richard Arclight (1732-1792) was a British inventor. He developed a hydraulic spinning machine powered by a water in 1771.

⁷ Patent No. 3173 (August 1898).

⁸ The automatic-loom operates continuously, replenishing weft unless the warp is broken. A loom without this function is called a normal loom.

⁹ Toyoda invented the "circular loom" in 1906 and obtained a patent the following year. Since the circular loom inserts the weft yarn by the circular motion of the shuttle, it reduced energy loss and noise generation.



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