Innovation Created from Differences in Regulations: A Case Study of the Electric-Assist Bicycle

Manabu Eto
Hitotsubashi University, Institute of Innovation ResearchTokyo, Japan

Abstract--**Electric assist bicycle (e-bike) technology was developed by various companies around the world. Although Swiss company Dolphin E-bikes has started the development of this technology first in the world, Japanese company Yamaha motor was first launched electric-assist bicycle product in the world. In Japan, the targets of this product are women and elder people who have weak physical strength. However, this technology which accomplished in Japan is progressing in the European sports type bicycle. Another Swiss company Biketec entered the European market by using the Japanese unit.**

This is because the Japanese e-bike technology has been developed to pass the regulation in Japan. Japan's Road Traffic Act relates to a bicycle is the most stringent in the world. In order to clear this regulation, Yamaha developed some of the advanced control technologies. China-made electric bicycle which runs by pressing a button can not be sold in Japan.

In Japan, when the regulation of road traffic law has changed, the market of e-bike has expanded for people with weak exercise capacity. Despite the China made electric bicycle is selling in Europa because of lax regulation of e-bike, e-bike technology developed by Japan is expanding in the sport area of Europe.

From this case, I will discuss the importance of companies to management regulations as a technology management.

I. INTRODUCTION

There are numerous examples of technical regulations promoting innovation. Since some innovations themselves have the potential to destabilize society, it is unavoidable that various regulations will be introduced to control them. But there are instances when the introduction of regulations can actually stimulate technological development by clearing away regulatory hurdles, thereby generating new innovation. In this way, the relationship between regulations and innovation is interdependent yet complex.

There are numerous studies on the effects of regulation on innovation but naturally, these studies carried out their research in the same place where the regulations were enforced and where the technological innovation to clear these regulations was created. If the input and output are not in the same place, a cause-and-effect relationship cannot be explained, so naturally these studies select such places for research.

Of course, as was the case with technologies to reduce exhaust emissions, like Honda's CVCC (Compound Vortex Controlled Combustion) engine and various auto manufacturers' catalytic converters, there are examples where technologies developed in order to meet emissions regulations—in this case, in the US—were not implemented in the country in which they were proposed (the US), but in another market instead (in this case, Japan). Ultimately, this was because these regulations were not enforced in the US, whereas in Japan they were. In such cases, it does not necessarily follow that "technologies that are developed in response to regulations spread in the same place where these regulations are enforced."

However, the electric-assist bicycle considered here -hereto referred to as the e-bike -is a case study in which while on the one hand the technology was developed in the same market where the regulations were implemented, on the other, a new market developed in different regions and in a different form to where the regulations were implemented. Specifically, their use spread in the Japanese market as a technology for people with weak exercise capacity, but in Europe their use greatly expanded in the sports cycling market where they are used by young people with a strong exercise capacity.

In this paper, I investigate a case study in detail, using a variety of published information and interviews, and examine the differences in regulations and cultural traits between the two regions. I explain how different markets developed in different regions, and demonstrate that standardization played a major role in these developments.

II. LITERATURE REVIEW

There are many studies on regulations and innovation. As this paper is positioned as a case study that examines the relationship between regulation and innovation, I do not intend this single case to act as a theoretical demonstration in this field. Therefore, I have omitted a systematic arrangement of the various studies on regulation and innovation. However, many prior studies have demonstrated that deregulation brings about innovation; further, innovation is generated not only through technical but also financial and several other forms of regulatory relaxation.

In contrast, studies also show that strengthening regulation brings about innovation and one representative field for this is environmental regulation. The "Porter Hypothesis," [1] authored in 1991, seems to be the cause of the broad debate on the relationship between environmental regulation and policies and innovation. This hypothesis, which was initially a single page article, was later published as a paper in an economics journal in 1995 [2].

Porter argued that strict environmental regulations stimulate technological innovation and as a result, companies in countries where environmental regulations have been introduced acquire competitive advantages over companies in

countries where they have not been introduced. Porter's paper examines a case study involving the abovementioned Muskie Act. The case study details how the State of California attempted to enforce the Muskie Act, which was a regulation on vehicle exhaust emissions in the United States, while Japanese companies developed various technologies to pass these regulations. Honda attempted to qualify by improving the CVCC engine and Mazda by improving the rotary engine; however, other Japanese companies developed catalytic technologies to do the same. In contrast, some companies in the United States tried converting to electric vehicles. Ultimately, U.S. auto manufacturers were unable to develop gasoline engine technologies that satisfied the regulations, and the oil industry, stirred into action by this failure joined forces with the auto industry to have the Muskie Act repealed. This case is the most famous study of the relationship between regulation and innovation; subsequently, many academic papers on this topic were published. This argument can be positively evaluated from case studies of successful developments, such as the previous described CVCC engine to meet emissions regulations in the US, but it has been frequently criticized for its lack of theoretical foundations [3]. Additionally, Porter touched on the fact that U.S. auto manufacturers overestimated the impact of the regulation; however, there is also a paper in which research is conducted through contrasting the Japanese and U.S. automotive industries [4].

The Porter Hypothesis, which attempted to quantitatively analyze the relationship between regulations and innovation, prompted many studies on the relationship between environmental regulations and innovation [5]. Some of them argued that regulations either have a positive or negative effect on innovation [6], while still others argued that no study is able to quantitatively demonstrate the relationship between regulations and innovation [7]. Looking at these various studies, I can see how difficult it is to quantify the effects of regulations on innovation isolated from other environmental and other factors.

In these circumstances, it is appropriate to carry out case-study research that focuses on specific regulations. The Porter Hypothesis focused specifically on environmental regulations, which gave rise to various other studies that built on this work. For this reason, a large body of research has been accumulated on environmental regulations [8].

However, there are only a few studies that consider other regulations. This is clearly because many regulations impede innovation as they attempt to reduce the social unease that might be caused by a new innovation. The Road Traffic Law that is considered in this paper was enacted to minimize loss of life and property through traffic accidents, and therefore the objective of creating traffic rules, such as setting speed limits, was to increase safety. As mentioned, this sort of deregulation creates multiple innovations, while it is obvious that enacting regulations inhibits innovation in its initial stages.

Yet, paradoxically, in the case of the e-bike, Road Traffic Law regulations that should have impeded innovation have actually accelerated it in another region. Of course, this innovation might still have occurred even without these regulations, but it is indisputable that their existence accelerated advances. It seems that up until now, there has been absolutely no research conducted on a case study such as this.

I use a variety of published information to analyze the historical development of the electric-assist bicycle and its regulatory background. In addition, I conducted interviews with the electric-assist bicycle development team of Yamaha Motor Company and the electric assist unit development teams of Switzerland's Biketec AG and Sunstar, and by supplementing each company's business strategy, I examine the differences in the development of the electric-assist bicycle in Europe and Japan as well as their relationship with regulation.

III. THE DEVELOPMENT HISTORY

Since the distant past there have been attempts to motorize the bicycle. From the second half of the 19th century, various types of electric bicycle were developed. In 1975, Matsushita Electric launched an electric bicycle in Japan called the E-bike. However, these were treated as motor-assisted bicycles, and practically all of them disappeared from the market without ever becoming popular.

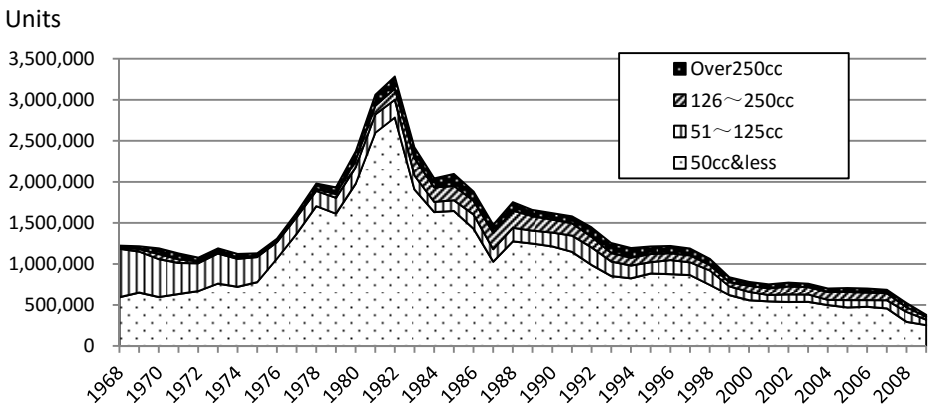
The evolution of the e-bike that is popular in the current market was developed in parallel by Yamaha Motors of Japan and Swiss companies (Dolphin and Biketec), although they targeted different markets. First, I will review the histories of both company developments.

A. The development of the electric-assist bicycle by Yamaha Motors

1) The unique features of the two-wheeled vehicle market in Japan

Yamaha Motors is one of the leading manufacturers of motorcycles in Japan, and after Honda, which holds a 50 percent share of the global market, it holds an approximate 30 percent share of the global bicycle and motorcycle market.

In Japan, there is a special category in this two-wheeled vehicle market; the class 1 50cc motorized bicycle (moped). This category appeared following the 1954 amendment to the Road Traffic Regulations Enforcement Ordinance, but then in conjunction with the enactment of the 1960 Road Traffic Law, it became necessary to acquire a driver's license to ride vehicles in this category. However, since it was possible to acquire a license solely by written test without having to take a practical driving test, their use spread rapidly as an auxiliary means of transportation among physically frailer groups, such as women and the elderly.



Source: Honda Motor Co., Ltd.

Fig. 1 Motorcycle sales in Japan

During this period the moped accounted for around half of all units produced in the two-wheeled vehicle market, and as mopeds were in principle not for export, it is said that domestically, mopeds accounted for approximately 80 percent of this market (see fig.1) [9]. In particular, the number of moped users rapidly increased in 1978, when it became a legal requirement to wear a helmet when riding a two-wheeled vehicle above 50cc.

However, moped sales sharply declined after 1986, when moped drivers also became legally required to wear a helmet and. In response to this, the Yamaha Motor Company developed "an electric bicycle for which a license and a helmet are not required." In other words, Yamaha developed a new market for a product positioned between the bicycle and motorcycle, which while having motorcycle-like functions, was able to capture replacement demand from bicycle users [10].

2) Yamaha Motor Company approach

The 1986 introduction of the new legal requirement to wear a helmet was to strengthen the regulations following a rise in the number of accidents that had occurred in conjunction with the increase in moped users. Given this context, lobbying for a relaxation of the helmet-wearing regulations (deregulation) was not an option. Consequently, Yamaha's response was to develop a motorized vehicle that would still be recognized as a bicycle by the Road Traffic Law. The company actively held meetings with the police and other relevant parties to clarify the definition of "bicycle" in the Road Traffic Law.

From this, it was clarified that a vehicle was recognized as a bicycle by the law if the feeling of riding it was the same as riding a conventional bicycle, even if some type of auxiliary power was added to it.

Yamaha developed the technology in order to satisfy this requirement. Specifically, as shown in the figure 2-1 & 2-2 , the auxiliary power was to be applied only when the rider turned the pedals to assist the force applied by the rider. If this mechanism could be realized, the rider would not feel the auxiliary power and would be able to ride the bicycle simply by using less effort to pedal. While the assist power is kept equal to the power applied by the rider, once the speed reaches 15km, the assist power is weakened, and when it reaches 24km, it is reduced to zero. By incorporating a control system in this way, it acknowledges the fact that the speed limit for a bicycle is 30km and that in practical terms, the speed up to which it is safe to ride a bicycle is 25km.

This sort of mechanism requires advanced feedback technology and precision auxiliary power controls. Initially, Yamaha considered realizing this mechanism using a gasoline engine, but after determining this to be unfeasible, it instead achieved this effect by equipping the bicycle with an electric motor.

Based on the development of this advanced technology by Yamaha, the authorities revised the enforcement regulations of the Road Traffic Law, and officially classified the electric-assist bicycle within the category of bicycle, as "a bicycle with an auxiliary motor." Following this, in 1993 Yamaha began sales of its e-bike in certain regions only, and then launched nationwide sales in 1994.

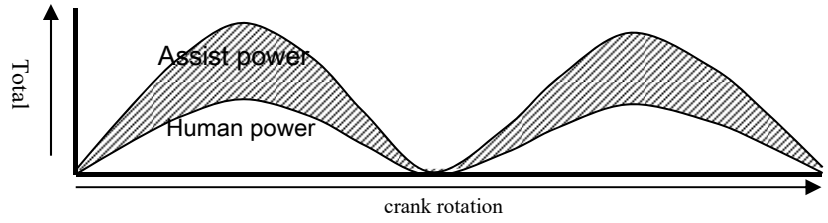


Fig. 2-1 Image of the response of the motor force / waveform similarity

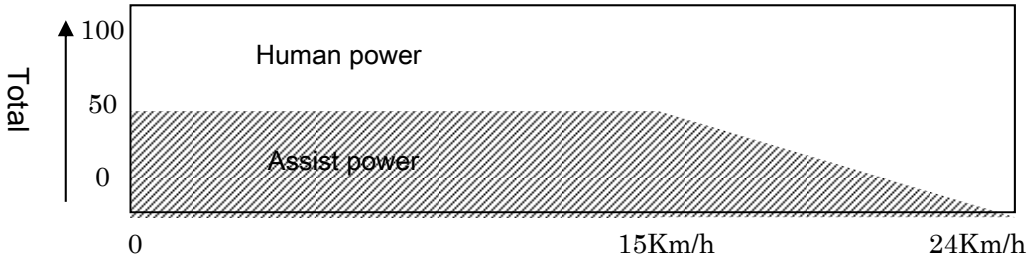


Fig. 2-2 Balance of speed and assist power

3) The spread of the e-bike

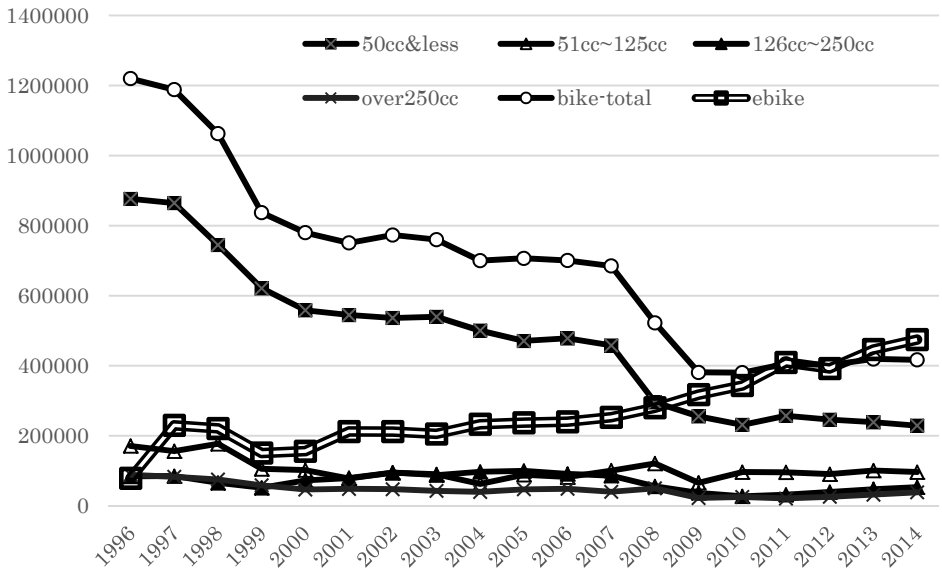
Amid the challenge of differentiating products due to the mature state of the bicycle market in Japan and the high levels of product standardization within it, the e-bike had great value as a new product innovation, which was comparable to the change from magnetic tape to optical disc for the recording medium.

Demand for the e-bike grew for several years after its launch, before it plateaued and remained stagnant for a while. Subsequently, however, demand grew again and the number of e-bikes shipped domestically in 2010 exceeded 380,000 units, and for the first time its annual shipments exceeded those of bikes overall, excluding those of foreign manufacturers. The demand that followed their initial launch was from purchases by elderly men, but subsequently it seems demand was driven by young women as a substitute for bicycles, whose sales had fallen by around 10 percent compared to their peak, helping Yamaha to rapidly realize its sales promise of "no helmet required."

Further, the total number of bicycles produced in Japan gradually dropped and by 2013 finally fell below the 1 million-units level. In 2014, the number of e-bikes produced exceeded 50 percent of all bicycles and constituted 76.3 percent of the total monetary amount (Fig. 3) [11] [12].

B. The spread of Chinese-made electric bicycles

Following the launch of the e-bike market in Japan, the market for electric bicycles also developed in newly emerging countries. In China, companies entering the e-bike market soon appeared, and they began manufacturing electric bicycles that did not satisfy Japanese regulations—the motor was activated simply by pressing a button and there were no controls for the assist power. It did not require advanced controls technology like Japan's and could be manufactured simply by installing a motor and a battery onto the bicycle, making the barriers to market entry very low. As a result, in 2010 the annual number of e-bikes manufactured in China reached 10 million units, and many were exported to various countries throughout the world.



Source:Japan Automobile Manufacturers Association, Inc.
Japan Bicycle Promotion Institute

Fig. 3 Motorcycle and e-bike sales

In Japan, however, due to the Road Traffic Law in place, the majority of Chinese-made e-bikes could not be used on public roads. By contrast, in Europe, even though there was a speed limit set for bicycles, there were no regulations on the motor-assist ratio—which meant that as long as the vehicle's motor produced less than a certain defined output, it would be classified as a bicycle. Consequently, sales of Chinese-made bicycles skyrocketed in Europe. Further, as button-operated types are allowed in the US and Canada, there remains plenty of scope for e-bike growth (see Table 1). In this context, due to the inconsistency of regulations across various countries, practically no Japanese-made e-bikes were exported overseas, while Chinese-made versions spread throughout the global market [13]. Yet the fact that there were global sales of e-bikes without advanced controls might be seen as indicating that the development of an advanced-assisted bicycle was being delayed in China.

TABLE 1. DIFFERENCES OF REGULATIONS IN EACH COUNTRY

	Maximum Assist Speed	Maximum Motor Power
Japan	24km/h	none
EU	25km/h	250W
Canada	20mph(32km/h)	500W
U.S.	20mph(33km/h)	750W
China	none	none

Chinese electric bicycle technology is easy to manufacture; therefore, Yamaha stood no chance of winning in competitive pricing. Therefore, Yamaha's appeals to its customers are based on the safety of its own advanced electric-assist technology and promote the international standardization of the electric-assist bicycle. However, they were unable to prevent Chinese-made electric bicycles eating away at their market share.

What brought about a change to this sequence of events was the pedal-assist bicycle market in Europe.

C. The development of the pedal-assist bicycle in Europe

1) The history of the development of pedal-assist bicycle in Europe

First proposed in Germany in 1982, a prototype of the pedal electric bicycle, more commonly known as the "pedelec," was developed by Michael Kutter in 1992. Swiss company Velocity GmbH (subsequently, Dolphin E-bikes GmbH) began selling the-bike in 1995, but ultimately it went bankrupt. However, another Swiss company, Biketec AG, was able to turn the pedelec into a successful business.

Despite the absence of regulations like the Road Traffic Law in Japan, the development of the pedelec in Europe was initially carried out for bicycles that would assist with pedaling, since the target market there was bicycles for cycling.

Biketec AG was established in 1995 and the first model was co-developed jointly with various institutions, including ETH Zurich (Swiss Federal Institute of Technology in Zurich). It chose the brand name Flyer for the e-bike when it was launched, and in Europe this name has since become synonymous with e-bikes.

But at the time it was initially launched, the value of a bicycle with a motor had not sufficiently penetrated the European market due to insufficient assist performance, and following sluggish sales, this company also temporarily went bankrupt. Subsequently the management was changed and it gave up on in-house development, but in 2002, the business was revived by importing and using the electric-assist units of Panasonic Cycle Technology Co., Ltd. (at that time, National Jitensha Kogyo Co., Ltd.)

In 2010, this company was producing 50,000 pedal-assist bicycles a year, and was exporting and selling them not only in Switzerland, but also in Germany and Austria. Swiss domestic pedal-assist bicycles market is also rapidly expanding (fig. 4) [14].

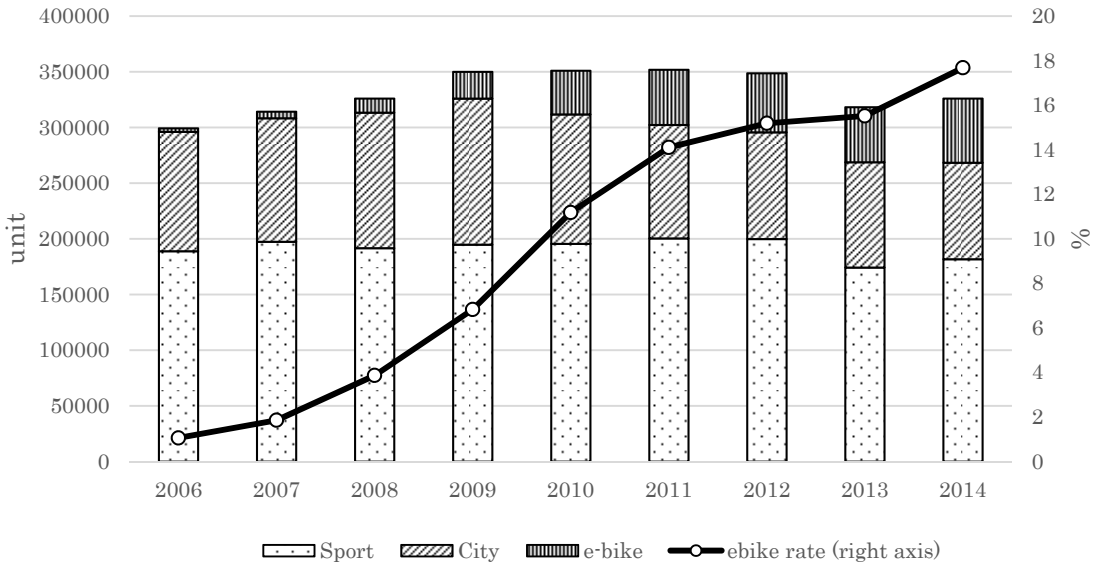
2) The special features of the European market

In Japan, for an e-bike to qualify as "a bicycle," the Road Traffic Law requires extremely advanced controls but in Switzerland and Germany, legally, as long as the pedelec only has a motor installed and runs at less than 25km/h, it is categorized as a bicycle without requiring the advanced controls seen in Japan.

Therefore, many of the previously described "electric bicycles in which the motor is switched-on upon pedaling" are sold in this market. As of 2010 in Switzerland, there were 92 e-bike-related companies (the majority of which, import and sell products from China, although some import components from China and sell the products that they themselves assemble).

In spite of high prices ranging from 300,000 to 800,000 yen, the reason why pedal-assist bicycles that incorporate the high-performance controls of Japan's e-bikes remained competitive, despite the availability of inexpensive Chinese-made versions, was because they were for different target markets.

The target market for Japan's electric-assist bicycle were groups such as women and the elderly who lack physical strength, and sales were centered on these target groups who needed help from a motor to use a bicycle on a daily basis. However, this group of users' needs are still met if they can propel a motorized bicycle forward by only applying a weak force (pedaling), even if the bicycle does not possess advanced-controls technologies. If the intention behind the purchase was daily use by women or the elderly, the sales price was important, because as long as the product meets the requirement of making bike-riding more enjoyable, then low-priced products tend to capture market demand.



Source: velosuisse

Fig. 4 Bicycle sales in Swiss

But in contrast, the main market of Biketec's pedal-assist bicycle, the Flyer, is young people who enjoy long-distance cycling for pleasure and sport during their downtime. What this company was aiming for in its development of a pedal-assist bicycle was not simply "making bicycle riding more enjoyable," but also "making a bicycle that is enjoyable to ride." It was for precisely this reason that it selected the model name of Flyer, to give the impression of flying through the air on a bicycle. For consumers in this purchasing group "enjoying a hobby," price is less important than the product's appeal. In fact, Biketec has launched a high-powered assist bicycle that is capable of running at speeds of more 25km/h. Aimed at consumers who seek more of an adrenalin rush than what a mere "bicycle" can provide, this target group are invited to obtain a license and ride an "electric bicycle" that runs faster and has higher performance.

So why has this target market not also been created in Japan? It would seem that this was due to differences in respective national characteristics. In Japan, people consider cycling using an electric-assist bicycle to be "lazy," as it is thought if you are cycling, you should ride solely through your own power. But by contrast in Europe, where cycling is pursued for its enjoyment, a need arose in this region for an assist bicycle that makes pedaling easier.

3) Biketec's sales strategy

Biketec carries out various activities for its sales promotion efforts for Flyer [15]. To give some typical examples, first is the establishment and maintenance of cycling roads with charging stations installed at rest points on them to enable users to easily set out on long-distance-bike rides of over 100km. The company cooperates with local governments and cycling-related groups to support this endeavor.

Further, bicycle rental systems have been established in main cities. There are 600 rental stations in Switzerland and 100 in Germany and it is possible to rent a Flyer for a month for a rental fee in the region of 20,000 yen. This makes it possible for potential users to fully experience the-bike's performance before purchasing one. After a while the rental bikes are returned to the company's head office for cleaning and repairs, and are then sold. It replicates the same business model constructed by auto manufacturers and rental car companies.

Moreover, even if potential customers do not rent a bike, they are able to test ride a bicycle at any time at the company's head office in central Switzerland. The company offers test rides every day, including on weekends, and every week around 70 test ride groups from across Switzerland visit the head office and take a test ride in order to help them make a decision on a purchase. This sort of appealing evangelism can be said to be essential for sales of high-priced products.

One more feature of the company's Flyer is that it is packed with functions that will appeal to enthusiasts. Dura-Ace and Ultegra, which are Shimano's electric gearshift systems, are installed on the derailleur, and the Shimano logo glows on the handle bars. The speedometer displays a range of information, including distance travelled and average speed, and the-bike is full of features to make cycling more enjoyable. In terms of safety, it has disc brakes installed on both the front and rear wheels, making cycling possible in hilly, mountainous terrain.

4) Differences between the assist bicycles in Europe and Japan

In this way, even though Japanese-made assist units with advanced feedback controls have an excellent reputation in Europe, the controls that make it feel like there is absolutely no motor assist are not required by law. However, in reality, many of Europe's electric-assist bicycles are equipped with a motor that makes the rider feel they are being assisted by a motor. The role of the motor in the electric-assist bicycle in Europe is not simply to make it easier to pedal, but also to make it more enjoyable for two people to ride a bicycle with a motor. Thus, in terms of having these sorts of advanced assist controls, there is greater value in having Japan's electric-assist unit technology, which is manufactured to such a high level that the rider does not feel they are being assisted by a motor. This sort of technology has only been produced in Japan, where it is legally required.

IV. CHANGES IN THE DIRECTION OF DEVELOPMENTS DUE TO DIFFERENT REGULATIONS

The subsequent expansion of the e-bike markets in Japan and Europe also proceeded in different directions. In Japan, where products were developed with the objective of meeting the regulations, the market expanded by supporting physical frailer people, but in Europe, e-bike manufacturers utilized standardization to grow in the sports market.

A. Development of the electric-assist bicycle in Japan

1) A market that actively wants deregulation

As was previously explained, in Japan the assist power provided by the motor to assist the rider had to be the same as the power applied by the rider (a 1-to-1 ratio). But alongside the spreading use of electric-assist bicycles, demand also increased for a stronger assist power. The calls for this were particularly loud from the taxi business that utilizes electric-assisted bicycles.

The pioneer of the bicycle taxi industry is Velotaxi of Germany, which provides taxi services using a unique type of bicycle-based vehicle. As they are not powered by fossil fuels, their use is increasing in regions that are particularly sensitive to environmental problems. Their use in Japan started in 2002 in Kyoto City and they were subsequently introduced mainly at tourist destinations.

From when they were first developed, the Velotaxis incorporated electric-assist technology, but in Japan it was not possible to strengthen the auxiliary power of the motor, as they were subject to the same strict regulations in the Road Traffic Law as electric-assist bicycles.

However, from around 2005, this industry began cooperating with Yamaha to lobby the government to ease the regulations (deregulation). By that stage, 10 years had passed since electric-assist bicycles first appeared in the market, and there had been almost no accidents specific to electric-assist bicycle as had been initially feared, confirming that the same regulations as for conventional bicycles were a sufficient response to them. But after that, another three years were needed before deregulation. In December 2008, the e-bike's motor assist power was finally permitted to be increased by up to two times the power that had been allowed up to that time.

Inevitably, this deregulation increased the use of electric-assist bicycles in the human-powered taxi industry, but on looking at the scale of the market, I see that it was still extremely small. However, it led to further deregulation that resulted in the creation of a separate and large market.

2) A new market created by two deregulations

Another regulatory development that expanded the electric-assist bicycle market also occurred in 2008, the same as the previously described deregulation. But initially this was not a development for deregulation, but to strengthen regulations for the three-person bicycle (Table 2.).

TABLE 2 HISTORY OF
THE ELECTRIC BICYCLE-RELATED REGULATIONS IN JAPAN

Year	Events
1986	Moped drivers became legally required to wear a helmet
1993	Yamaha began sales of its e-bike
2002	Velotaxi started in Japan
2006	Change parking violation regulations
2008	Assist power has doubled
2009	Allowed for a total of three riders
2015	Assist power has tripled only for delivery busines

Originally under Japan's Road Traffic Law, a bicycle was to be ridden by one person only and it was prohibited for two people to ride it. However, limited to when the driver was16 years or over with an infant seat installed on the handlebars, the metropolitan Tokyo and prefectural road traffic regulations (Public Safety Commission regulations) permitted a child aged under 6 years to ride in the infant seat. (One local government allowed for a total of three riders, with another infant seat installed on the rear of the-bike.)

The use of the infant seat spread among mothers taking their children to nursery school or other destinations, but when they had two children, many mothers could be seen dropping-off or picking-up their children on a three-person bicycle, with a child in an infant seat at the front and rear of the bicycle. Without question, this was in violation of the Road Traffic Law, but in the past the police overlooked these transgressions, meaning that three-person bicycles were tacitly allowed.

However, following an increase in the number of accidents arising from riders using a mobile phone or listening to headphones whilst cycling, a movement to clamp down on dangerous cycling by strengthening the regulations developed momentum. In July 2007, a revised Road Traffic Law was approved by the Diet and soon after regulations were strengthened from 2008, information leaked out that the regulations for three-rider bicycles were also to be strengthened.

This provoked a strong reaction from mothers who

dropped-off and picked-up their children at nursery schools. In fact, it became clear that once these regulations were enforced, many mothers with two children would no longer be able to use the same nursery and would be forced to find a new one.

Faced with this challenge, the police changed direction on policy and supported the development by the industry of a bicycle that could be ridden by three people. As a result of this, a groundswell of support grew for officially permitting three people to ride a bicycle, and in the summer of 2009, the standard for the three-person bicycle was completed. This standard's requirements included a strengthened bike frame, increased safety to prevent the-bike toppling over, and reinforced brakes, while at the same time it regulated on the stability needed to start and ride the bicycle. Specifically, due to the tendency to run jerkily when running in lower gears, meeting the standard was determined by whether the-bike was equipped with a drivetrain system with a low gear ratio of 1 revolution per 4.3 meters or below or whether it was an electric-assist bicycle. Through this development process, a de-facto standardized installation for an electric-assist bicycle was created for a three-person bicycle.

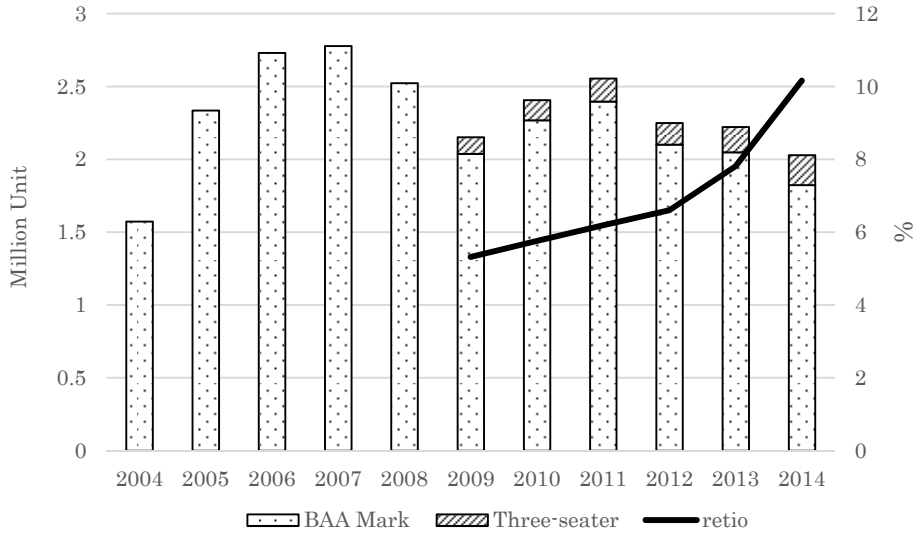
As a result, electric-assist bicycles in Japan steadily spread due to their use as a three-person bicycle. As shown in the figure, the number of bicycles authenticated by the BAA (Bicycle Association Approved) mark system as a Japanese-made high-performance bicycle, peaked in 2011 and then gradually declined. But despite this, the number of BAA marks for the three-person bicycle has continued to increase since 2009 when the system was launched. Currently, around 200,000 bicycles have been sold with the BAA mark, which is more than 10 percent of the total BAA marks, and many of them are considered to be electric-assist bicycles (Fig. 5) [12].

3) A new market created from the strengthening of car parking regulations

Further, more recently in Japan, an expansion in the use of electric-assist bicycles was observed due to the strengthening of the regulations in the Road Traffic Law; specifically, strengthened regulations on street parking.

The Road Traffic Law was revised in 2006, following which the supervision of prohibited street parking, which up to that time had been directly carried out by the police, was outsourced to private-sector companies. Further, the penalty for unpaid fines were made more stringent and if a driver had not paid a fine, they were required to also pay an "unpaid fine charge" equal to the initial fine. If the driver still did not pay, they were forbidden from driving or forced to undergo a vehicle inspection. Therefore, a need particularly arose among convenience stores and the home-delivery industry responsible for delivering small parcels in urban areas for measures in response to this situation, including having two drivers and additional agreements with companies providing paid-for car parks.

Emerging from these strengthened regulations was a home delivery business using a cart pulled by a bicycle. As the car parking fine regulations do not apply to a bicycle and cart, many home delivery operators, particularly in cities, have introduced this system. However, using this mode of transport, bicycle drivers must pull the many parcels they are to deliver, which places an onerous physical burden particularly on women drivers.



Source: Japan Bicycle Promotion Institute

Fig. 5 Three-seater ratio of BAA label

For this reason, home delivery operators lobbied the police for the deregulation of legislation for electric-assist bicycles used to pull a cart. Then in April 2015, the Act on Special Measures to Enhance Industrial Competitiveness came into force, which enables e-bikes with a cart attached and with a motor power to manpower ratio of three to one to be utilized for delivery purposes only. Following this, companies such as Yamaha have been developing electric-assist bicycles specifically to be used to pull a cart.

In this way in Japan, the development of electric-assist bicycles with the objective of providing extra power to persons who are typically physically weaker has progressed and the relevant regulations changed.

B. The development of the electric-assist bicycle in Europe

1) Increase in electric-assist bicycle entrants into the sports cycling market

As was previously mentioned, the spread of electric-assist technology in Europe was from its introduction into, and increased use in, sports cycling. This technology spread in the form of imports of electric-assist units from Japan.

As the high-level standardization of bicycles took place at the same time as the difficulties experienced in developing advanced assist-control technology, Europe constituted a large market for the assist units developed in Japan that could be used unchanged for the bicycles in this region.

Viewed globally, the most detailed and precisely defined bicycle product standard is Japan's JIS (Japanese Industrial Standards). Europe has a bicycle standard too, but it is primarily a performance standard for aspects such as safety, and it is no exaggeration to say that Japan's JIS is always used throughout the world bicycle industry as the standard for product specifications. As the standard for Chinese- and Taiwanese-made bicycles is the same as for Japanese bicycles, it is a well-known fact that Chinese- and Taiwanese-made bicycles have eaten into the Japanese bicycle market [10].

However, in the current expansion of the electric-assist bicycle market, Europe's bicycle product standard was consistent with the JIS, which was a major advantage for Japanese manufacturers of e-bikes. For European bicycle manufacturers too, it was easier for them to import an electric-assist unit from Japan and install it unchanged onto their own companies' bicycles, rather than developing a unit in-house from scratch. Moreover, if this unit was an advanced product protected by many patents, it seems likely that there was little incentive for them to change course toward developing the components in-house.

In fact in Europe, there are only a few examples of bicycle manufacturers developing an electric-assist bicycle unit. Among them is Bosch, well known as a manufacturer of automotive parts and machine tools. In September 2010, Robert Bosch (France) SAS, which is the French subsidiary of Bosch, exhibited an electric-assist unit at Eurobike, Europe's largest bicycle exhibition, and announced that it would start mass production from 2011.

Bosch was not originally a bicycle-parts manufacturer, but decided to tap its technological strength for its mass production of an electronic-assist system from the variety of other products it produces each year, including 80 million motors, more than 100 million computers, and in excess of 200 million sensors. It has also adopted lithium-ion batteries, such as for its machine tools. Consequently, Bosch developed a product that matched the preferences of Europe's bicycle users, and after entering it, Europe's electric-assist market was seen to rapidly expand even more.

2) The electric-assist unit sales business of Sunstar Engineering Inc.

This company utilized the global unification of the bicycle standard and started a business in Europe that could not be realized in Japan, selling retrofitted electric-assist units [16].

Sunstar is known for oral care products such as toothpaste, but originally it started selling bicycle parts and developed as a company by manufacturing and selling rubber cements for bicycles. Following a decision by the company founder to sell toothpaste inserted into the same metal tubes it had been using for its rubber cements, the company was reborn, founded on "Sunstar toothpaste." However, it continued to sell bicycle parts, gradually coming to focus on gear and crank parts, and this subsequently led to it manufacturing sprocket disc brakes for motorcycles. Even today, in the market for motorcycle disk brakes, Sunstar is a leading company that ships its products to all the main motorcycle manufacturers throughout the world.

It was also involved in the development of the electric-assist bicycle unit from the very start of the market in Japan, completing an electric-assist unit in 2002 and launching sales of it in 2003. However, it found it difficult to launch an electric unit Original Equipment Manufacturer (OEM) business within Japan, and initially it sold electric-assist bicycles on a small scale after procuring the bicycles themselves from external suppliers. The company's assist unit was the crystallization of its own technologies; for example, it collaborated with Fujitsu General and introduced a noise-free motor technology that was used for air conditioners, developed a brushless thin motor, and succeeded in making the unit lighter through sensor techniques. But for various reasons, the company withdrew from the business of finished product electric-assist bicycles. However, initially it had envisaged selling the assist unit only to be subsequently retrofitted onto the bicycle, and based on this idea, embarked on this new sales direction.

As has already been stated, many bicycle parts are standardized throughout the world according to the JIS, and as there are common standards for a variety of components, particularly for the frame, it is relatively easy to commercialize the manufacture and sale of accessories that are externally attached. Therefore, entry into the bicycle industry can be realized solely by manufacturing some components, which is one of the reasons why many companies have entered into this industry. On seeing this, Sunstar decided to sell its electric-assist unit in the retrofitted

components market. Users would purchase Sunstar's electric-assist unit and install this unit onto their own favorite bicycle, thereby creating an electric-assist bicycle. As previously explained, the company's unit utilizes a light motor that it developed in-house, so even after the unit was retrofitted, the weight of the bicycle does not increase by much. Moreover, leveraging the retrofitting concept, users can select a battery size best suited to how they will use the bicycle. For example, if they will use it within the city, they can select a light battery for short distances, but if they intend to use it for leisure cycling, they can select a large battery for longer periods. Thus, one of the features of this retrofitting product is providing benefits that existing products cannot provide.

However, in order to conduct this business in Japan, it is essential to individually acquire type certification as an electric-assist bicycle to comply with the strict control-related standard stipulated in the Road Traffic Law. Therefore, sales of retrofitted units in Japan were not feasible but in Europe, as long as the speed limit (up to 25 km/h) and the upper limit on motor output (up to 250 watts) are observed, even if the electric-assist unit was retrofitted, it is not necessary to acquire type certification or other such certification.

Bicycles in Europe are not merely a means of traveling short distances; they are also used as sports and fashion products, and many users build and use the bicycle they want by assembling it from the components that they like. The unit price per bicycle is high and correspondingly the unit's life cycle is also long. Sunstar's retrofitted unit enables this type of user to design an electric-assist bicycle according to their preferences. It can be said that this business is possible precisely because of Europe's regulatory environment.

V. CONCLUSION

As was described above, the developments of electric-assist technology took completely different paths in Japan, which has strict regulations, and in Europe, which does not have such regulations. The technology used for these developments was originally developed in Japan, where there are these regulations.

However, as can be seen from the many studies on environmental regulations, had there been the same regulatory environment in Europe, it is likely that many companies in Europe would have also developed an electric-assist unit and innovation would have been achieved by companies in that region.

In the case study presented here, the technology developed under Japan's strict regulations, as it was essential for it to be sold in Japan, but this created separate value in a different market where this technology was not essential, but adopted as a product-differentiating factor. The results of technology development incentive by regulations, produce value in areas that are not regulated.

As a result, the subsequent development of this technology took different directions in Japan and Europe. In Japan, it was important that the electric-assist bicycle was light and could be handled easily as they were to be ridden by the physically weaker. Therefore, in the development process, the focus was placed on making the drive unit small and the battery light. In addition, the requirement that costs be kept down was also stronger than in Europe.

By contrast in Europe, greater emphasis was placed on comfortable cycling and therefore various changes, such as to the position of the battery and the power transmission system, were made. What was most important for the development of the unit in Europe was its design. A beautiful design was essential for a deluxe bicycle intended for pleasure cycling. Therefore, for example, Sunstar recruited an Italian designer for the unit's design. Recently, new developments in technology have rendered the assistance invisible by concealing the assist unit.

However, within this context of developments taking different directions, innovation synergies also occurred. Originally in Japan, the electric-assist bicycle was controlled from the sensing of two variables, the size of the torque and the speed. However, to provide assistance for the enjoyment of two riders, as described above, it was essential to install a sensor for the number of crank rotations in order to reduce the feeling of unevenness from the assist power. Yamaha developed technologies in order to enter the European unit market, but in addition it invested in these technologies for electric-assist bicycles in Japan and succeeded in improving the feeling of comfort when riding an e-bike in this country too. Innovation generated by user needs in a market without regulations was able to contribute to product differentiation in a market environment with regulations.

As I have seen above in this case study, innovation developed differently depending on whether or not there were regulations, and from this I conclude that the component technology developed was not only innovation in those respective markets, but also has had significant value in markets with regulations and without regulations. It was also confirmed that product standardization played a major role in the spread of this innovation.

This research considers only one case study on the relationship between regulation and innovation; therefore, it is not possible to draw generalized conclusions from it. However, examining this case study in isolation, it does offer an alternative perspective to studies that deal with market development by global companies that are have no choice but to comply with various regulations in different countries.

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