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New dominant design and knowledge management; a reversed U curve with long head and tail

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ABSTRACT
After more than 100 years since the emergence of the dominant design of the bicycle, diverse electronic bicycles are emerging in the e-bike industry. We aim to answer two questions: 1) How is the electronic bicycle evolving and what is its dominant design? 2) What is the difference in the evolution and appearance of the dominant design of the electronic bicycles in Daegu (Korea), Naples (Italy), and Nagoya (Japan)? We used the participatory observation and intensive interview methods for this study. Three cities were located at different points on the dominant design curve with long head and tail. Naples is in the business model-based new market creation step, with the fat-tire electronic bicycle as dominant design. Daegu is in the technology-based new market creation step, with the electronic quick board as dominant design. Nagoya is undergoing technology-based existing market expansion with the electronic bicycle design, which is the same as the traditional dominant design.

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Dominant design; knowledge management; electronic bicycle; open innovation; reversed U curve; long tail

1. Introduction and research question

With the Fourth Industrial Revolution, that is, the Second Information Technology Revolution, the open innovation paradigm is spreading as a way to conquer the growth limits of capitalism (Yun, 2015). Hence, open innovation can trigger new emergences, even though it also increases the complexity in the sector. Thus, the speed and emergence of the dominant design in the open innovation paradigm can totally change. One of the examples is that dominant designs lag behind the industry's technical frontier (Anderson & Tushman, 1990; Yun et al., 2016).

Architecturally, bicycles and their components, such as brakes, pedals, cranks, and hubs, have been considerably upgraded through incremental innovation, but the way in which these components operate and link together to form a functional product has changed little since the establishment of a dominant design in the 1890s (Galvin & Morkel, 2001). That is, the bicycle industry had already matured before the twentieth century. However, with the development of the electrical battery and the growing awareness about environmental issues, diverse electronic bicycle designs have appeared in the market. The technology paradigm is shifting, and a new technological trajectory is evolving in the electronic bicycle industry (Dosi, 1982). Even though more than 100 years have passed since the appearance of the dominant design, if more "learning by doing" occurs, associated with more capital-intensive techniques, such as electronic bicycles, the rate of technological change may increase again (Atkinson & Stiglitz, 1969).

Our research questions are:

How is the electronic bicycle in dominant design evolving?

What is the difference in the evolution and appearance of the dominant design of the electronic bicycle between Daegu, Naples, and Nagoya?

The novelty aspects of this paper are that it explores the difference of dominant design evolution in the converted new industries, such as electronic bicycle, electronic car, and so on, compared with emerging new industries, such as intelligent robot, 3D printer, and so on (Yun et al., 2019). And, this study focuses on the dominant design of e-bike as a collection of systems among several levels of dominant designs, such as 1) first-order subsystems including shifter, chain, derailleur, or freewheel; 2) systems including assembler (or frame), brake system, gear shifting system, or non-moving parts; or 3) a collection of system (Park et al., 2018). The difference of dominant design shape and dynamics of e-bike industry as an example of the converted new industry in the Fourth Industrial Revolution will be a milestone of study on dominant design from open innovation and knowledge management.

2. Literature review and research framework

2.1. Literature review

According to the difference in technological regimes, such as creative destruction, that is, "widening with

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horizontal innovations" (e.g., screen size expansion), or creative accumulation, that is, "deepening with vertical innovations such as adding multi-touch screen functions", industries evolve following different Schumpeterian patterns of innovation (Breschi et al., 2000; Cecere et al., 2015).

The dominant design wins the allegiance of the marketplace in which innovators or competitors operate (Utterback, 1994). They are a result of competitions in the product life cycle after a long process of problem-solving (Gawer & Cusumano, 2014). Although they can motivate the process innovation, they can also decrease the radical innovation (Brem et al., 2016). Dominant designs are a milestone of changes that display one or more of the following qualities: 1) technologies that lift the fundamental technical constraints, limiting the prior art while not imposing stringent new constraints; 2) designs that enhance the value of potential innovations in other elements of a product or process; and 3) products that assure expansion into new markets (Abernathy and Utterback 1978). By the way, the dominant design is not a liner process but an evolutionary dynamic and circular process among 1) technological discontinuity, 2) era of ferment, 3) dominant design, and 4) era of incremental change, during which there are selection, retention, and variation with the change of all this process with the pass of time (Herrmann, 2005; Tushman & Rosenkopf, 1992).

A trade-off relation exists between two choices when the dominant design can be imitated, such as 1) a firm enters early to gain first-mover advantages; or 2) the firm waits to minimise the probability of losses associated with choosing a product design that does not emerge as dominant (Tegarden et al., 1999). If a firm enters during the early stage of any industry, it must adapt to the different rules of competition in the subsequent period of incremental change and also switch to the dominant design (Abernathy and Utterback 1978; Teece, 1986). An evolutionary model of technological change has been proposed in which a technological breakthrough, or discontinuity, initiates an era of intense technical variation and selection that culminates in a single dominant design (Anderson & Tushman, 1990).

As shown by the markets for cameras, road vehicles, amplification systems, and personal computers, dominant designs appear through coevolutionary learning with the emergence of market niches (Windrum & Birchenhall, 1998). A dominant design can have two opposite sources, such as the artefact and knowledge dimensions of technology and population of firms and consumers who use it. If central firms, as an information gateway to a network of firms, lead collective actions through density and repeated partnerships and lead to the emergence of a dominant design, it is a kind of technology paradigm-based dominant design (Soh, 2010). Continuous changes are often related to progress along a technological trajectory (today the technological paradigm) and the discontinuity of technology, which is associated with the emergence of a new paradigm that expresses the technology-based dominant design (Dosi, 1982).

The video home system format became the dominant design in the area of video cassette recorders, despite technological weaknesses compared to the Sony Beta format, due to network externalities and appropriability, which may profoundly moderate product commercialisation but appear by and large to be neglected from the marketing perspective (J. R. Lee et al., 1995). That is, non-technological factors, such as users influencing the adoption of a new design, networks of organisations, or historical events, may also dominate the emergence process of the dominant design (Anderson & Tushman, 1990; Arthur, 1989; Tushman & Rosenkopf, 1992). In the automotive industry, several technologies have been proposed to replace the conventional engine. Most notably, the fuel cell vehicle (FCV) received vast support from the automotive industry for a long time. In the end, the hybrid electric vehicle (HEV) has entered the automotive industry as a candidate for the dominant design in favour of the FCV (Hekkert & Van Den Hoed, 2004).

Literature on strategic management suggests that opportunities for mature markets and/or industries reside in technological changes (Barney & Arikan, 2001; Bruton et al., 2007). Accordingly, the emergence of a dominant design can be explained as a result of the interplay between technical and market choices because a dominant design is the outcome of a series of technical decisions about a product constrained by prior technical choices and by the evolution of customer preferences (Utterback & Suárez, 1996). The number of firms in an industry – the industry's density – is directly affected by the emergence of a dominant design in a pattern that is common to all industries in that the population density seems to be directly associated with the industry's technological evolution (Suárez & Utterback, 1995). However, in the cases of the typewriter industry, automobiles, TVs, TV tubes, transistors, chip on board (IC), or calculators, the emergence of a dominant design coincided with the peak of the industries (Utterback & Suárez, 1996). This means that the expansion of the industry can also motivate the dominant design.

Innovation, including open innovation in the Fourth Industrial Revolution, is extremely dependent of the availability of knowledge, and therefore the complexity created by the explosion of richness; in other words, open innovation has to be recognised and managed to ensure to arrive at creative evolutionary change by knowledge management (M. Lee et al., 2018; Du Plessis, 2007; Yun et al., 2016). Knowledge management – a term that has now come to be used to describe everything from organisational learning efforts to database management tools, and that includes knowledge creation, knowledge validation, knowledge formatting, knowledge distribution, and knowledge application, is a an approach to adding or creating value by more actively leveraging the know-how, experience, and judgement resident within and in many cases, outside of an organisation (Bhatt, 2001; Ruggles, 1998). The internet of things (IoT), which has aroused much excitement in the last years, is motivating open innovation by building diverse knowledge management systems, and OI is increasing again knowledge management capacity (Santoro et al., 2018). Sustainable innovation means that knowledge management by increasing the absorptive of capacity of firms, motivates open innovation, and open innovation increases knowledge management, so organisational sustainability, knowledge management, and open innovation interplay together and co-evolve (Lopes et al., 2017). By considering knowledge exploration, retention, and exploitation inside and outside organisational boundaries for open innovation, an integrative perspective on dynamically managing a firm's knowledge base should be adopted (Lichtenthaler & Lichtenthaler, 2009). Knowledge creation by cyclical dynamics among externalisation, combination, internalisation, and socialisation with interaction between explicit knowledge, and tacit knowledge, belongs to dynamic view among knowledge management strategies and follows evolutionary paths (Choi & Lee, 2002; I. Nonaka & Konno, 1998; I. Nonaka et al., 2006). Among these, externalisation based on explicit knowledge, and internalisation based on tacit knowledge specially belong to organisational level or inter organisational level, in other words, firm level, or between firms' level (I. J. O. s. Nonaka, 1994). Among knowledge creation theory, the concept of "knowledge conversion" explains how tacit and explicit knowledge interact along a continuum, which is different from open innovation because it focuses on inward or outward transfer of technology (Chesbrough, 2003, p. 43; I. Nonaka & Von Krogh, 2009). As a way of knowledge creation inter-organisation, the role of leader firm is important during knowledge transfer between firms in industrial districts because there are several issues, such as 1) the codification and easily sharing problem, 2) reduction of the number of suppliers, or 3) the speed and reliability between customer and supplier (Albino et al., 1998). By the way, there are four types of knowledge assets in knowledge management, such as 1) Brainware which is knowledge assets related to human resources; 2) Netware which is knowledge assets related to relationships; 3) Hardware which is tangible assets incorporating crucial knowledge; 4) Software which is intangible assets representing crucial knowledge (Schiuma, 2011, p. 174). In the knowledge value chain, knowledge management of four different knowledge assets is linked to value creation through intellectual capital circle; one of the examples will be the managing strategic partnerships with universities in innovation ecosystems (Carlucci et al., 2004; Schiuma & Carlucci, 2018). Another example can be the business model prism which can be used as knowledge management tools to manage and innovate business models of arts and cultural organisations (Schiuma & Lerro, 2017).

According to several literature reviews, technological evolution, which is triggered by inbound open innovation in addition to internalisation and socialisation of tacit knowledge, may motivate the emergence of the dominant design through the maturing of the industry. Hence, we propose Hypothesis 1:

Hypothesis 1. The maturing of the industry, that is, the density of the industry with technological evolution which is triggered by inbound open innovation in addition to internalisation and socialisation of tacit knowledge, may motivate the appearance of the dominant design of the electronic bicycle.

In the HEV case, the environmental factors, including regulations, also affect the appearance of the dominant design of the car engine. The increasing environmental concerns demand deep renewal of the existing technologies and the traditional dominant design in many industries (e.g., several electric vehicle (EV) dominant design candidates) (Midler & Beaume, 2010). A technology that, through change, gains an early lead in adoption may eventually "corner the market" of potential adopters, locking the other technologies out. However, following different insignificant events, such as unexpected successes of prototypes, whims of early developers, or political circumstances, a different technology system can emerge to dominate in unpredictable and potentially inefficient ways (Arthur, 1989). Learning by using with the help of users which is a kind of internalisation or socialisation is another way of evolving the dominant design (Atkinson & Stiglitz, 1969; Rosenberg & Nathan, 1982). Edward Hess received 140 typewriter patents during his lifetime; and when Hess's typewriter achieved the dominant design, he did his best to meet users' requirements, such as reduction in typewriters' production costs (Utterback & Suárez, 1996). A dominant design also embodies the requirements of many classes of users, that is, inbound open innovation with internalisation (Suárez & Utterback, 1995). According to longitudinal studies of cement, glass, and minicomputers, after technological discontinuities, during the era of intense technical variation and selection, several factors including inbound open innovation with internalisation and socialisation affect this selection (Anderson & Tushman, 1990).

Hypothesis 2. The using or consuming environments with market evolution which is triggered by outbound open innovation with externalisation and combination of explicit knowledge may motivate the appearance of the dominant design of the electronic bicycle.

Several studies in the literature highlight some missing points that explain the emergence of the dominant design. Accordingly, we set up Hypothesis 2. During four periods of bike-sharing history, several diverse bikes had been shared according to the location, nation, and economic conditions which mean market evolution with outbound open innovation looking of new bike market, and externalisation or combination meeting the market requirement (DeMaio, 2009; Midgley, 2011). In addition, with the dawning of the Fourth Industrial Revolution, or the spread of information technology (IT) to all industries, the speed of change in market evolution has been accelerated with the increase in demand articulation (Kodama & Shibata, 2015; M. Lee et al., 2018). The using or consuming environments affects the emergence of the dominant design of consumer products such as electronic bicycles.

According to nearly all literature reviews on dominant design curve, most of them had simple reverse U curves shapes. However, hypotheses in this study review that E-bicycle dominant design has a different shape than traditional reverse U curves in the literatures.

First, E-bicycle can have long head in the reverse U curve because activated inbound open innovation and internalisation or socialisation of tacit knowledge will let traditional bicycle dominant design be maintained longer time than others before the explosion of diverse dominant design of e-bicycle.

Second, E-bicycle can have long tail in the reverse U curve because activated outbound open innovation and externalisation or combination of explicit knowledge will let E-bicycle dominant design be maintained longer time than others until developing diverse new business models which can use the dominant design E-bicycle.

2.2. Research framework

Dynamic Knowledge creation with open innovation will be the context of the appearing of dominant design of electronic bicycle (Figure 1). Tacit knowledge socialisation and explicit knowledge externalisation will be core engine of outbound open innovation in that tacit knowledge outbound open innovation has the characteristics of socialisation, and explicit Knowledge outbound open innovation such as technology licencing has the characteristics of externalisation. And inbound open innovation will motivate explicit knowledge combination, and tacit knowledge internalisation together.

Technology and the market influence the maturing of the industry and the consuming environment (Figure 1). Following Hypothesis 1, the maturing of the industry affects the appearance of the dominant design (Figure 1). Furthermore, Hypothesis 2 states that the consuming environments or consumer requirements affect the emergence of the dominant design of electronic bicycles (Figure 1).

The details of Hypothesis 1 in this research framework are shown in Figure 2. As the electronic bicycle

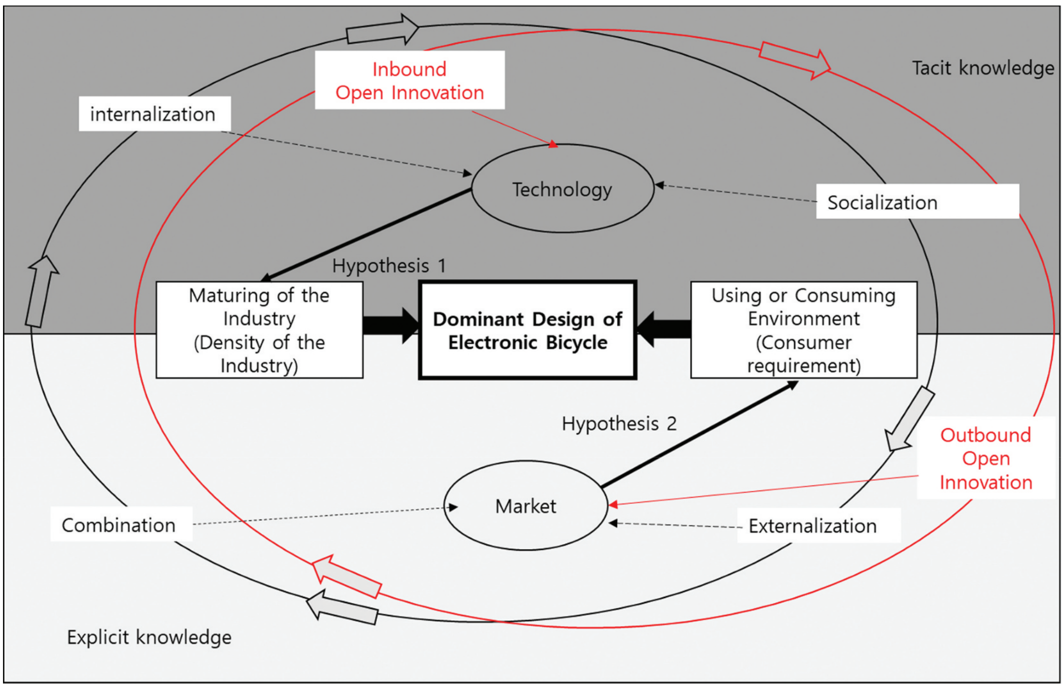

Figure 1. Research framework for the analysis of the dominant design of the electronic bicycle.

industry matures, first, the number of electronic bicycle designs does not increase much for the time being in a society in which bicycles are extensively used. Second, the number of electronic bicycle designs increases with the increase of the percentage of electronic bicycle, and designs decrease again until the ratio of electronic bicycle arrive at top and sustain. Third, the number of electronic bicycle designs is maintained at a small number with dominant design until a new destructive innovation occurs in the industry.

We correlated the growth of diversity of e-bicycle design with percentage of electronic bicycle/all bicycle at Figure 2. E-bicycle industry has global Supply Chains even though it has factories mainly in Asia. And, global top e-bicycle companies consist of just not Asian firms but firms of Germany, Italy, and others. We analyse E-bicycle dominant design not from producer markets but from diverse consumer markets base because electronic bicycle industry is a kind of traditional consuming product.

As the existing bicycle industry is transforming into an electronic bicycle industry, for the time being, the electronic bicycle designs will not be so diverse in addition though the percentage of electronic bicycles is high, which has long head from inbound open innovation with internalisation and socialisation of tacit knowledge, which means high technological level in E-bicycle like hypothesis 1 parts in Figure 2. The electronic bicycle industry of Japan, which was observed at Meijo University, may represent this case.

In the case of the emergence of electronic bicycles without the popularity of the traditional bicycle industry, the growth of the electronic bicycle industry rises from B and decreases again to a low level of diversity (Figure 2). Daegu may be located at nearly top of the reverse U curve because electronic bicycles in Daegu started without the dominance of the traditional bicycle industry, and the diversity of electronic bicycles has been increasing recently.

After the mature of E-bicycle, the dominant design of e-bicycle will have long tail line like hypothesis 2 parts in Figure 2 because the activated outbound open innovation with combination and externalisation of explicit knowledge from the Fourth Industrial Revolution will produce new market and new business model (Chesbrough, 2003, p. 44; Lasi et al., 2014). In the case of Naples, Italy, the situation of electronic bicycles may be near here because Italy has a higher ratio of electronic bicycles than Korea and the number of product designs of electronic bicycles is decreasing.

According to the research on new emerging industries, such as the typewriter industry, automobiles, TVs, TV tubes, transistors, IC, and calculators, the relation between the growth of the industry and the number of product designs was just the reverse U curve except any expansion time like between A and B in Figure 2 (Suárez & Utterback, 1995; Utterback & Suárez, 1996). Like the Japanese electronic bicycle industry that converted from traditional bicycle industry, if any industry appears as converted from traditional industry, the expanded starting period of simple designs will exist like between A and B.

In Figure 2, we measure the diversity of product design of electronic bicycles as a percentage as follows:

Diversity of product design = {100-(top e-bike design/all e-bikes) *100}

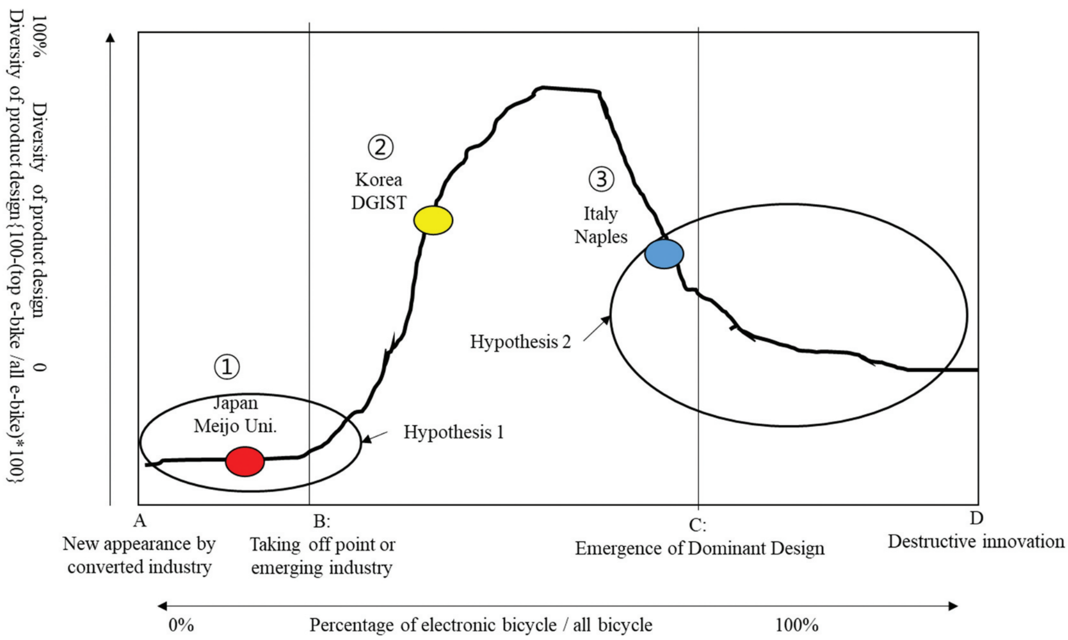

Figure 2. Expanded reverse U curve of the appearance of the dominant design of the electronic bicycle.

The calculated diversity is based on the percentage of the top number design among all e-bikes at the three markets, such as Daegu Korea, Nagoya Japan, and Naples Italy. We measure the percentage of the dominant design of electronic bicycle at the consumer market because electronical bicycle is a kind of consumer product. Thus, the diversity of product design will be between 0% and 100%; 100% means that there are very diverse e-bike designs. That is, there is no dominant design.

The details of Hypothesis 2 are as follows (Figure 3):

The consuming environment of electronic bicycles is dependent on several factors, such as the road situation, the condition of connected public transportation, the main consumer condition, or an additional consuming environment (Figure 3). Outbound open innovation from moto-bike or cars will meet the main consumer condition, connected public transportation condition, or road situation, match the consuming environment of electronic bicycle, and construct new dominant design in e-bike. And externalisation of explicit knowledge from car or moto-bike will meet road situation and motivate the outbound open innovation. In addition, the combination of explicit knowledge from traditional bicycle, moto-bike, or car industry will meet connected public transportation condition and motivate the appearance of new dominant design of e-bicycle. In the end, the dominant design of electronical bicycle can be evolved differently according to the consuming environment. However, the participant observation method can be a very powerful technique in this study because it poses several challenges, such as accurately assessing the effect of investigator and managing the analysis and reporting of the findings (Becker, 1958).

3. Research methods, and scope

3.1. Participant observation

Research based on participant observation is useful to investigate the meanings of human existences as they are constructed and enacted by people in everyday life and the number of human beings themselves (Jorgensen, 2015). Researcher enters into conversation with some or all of the participants in these situations and discovers their interpretations of the events he or she has observed (Reinharz, 2017). Therefore, we used participant observation and semi-structured questionnaire in the same case study.

First, to investigate electronic bicycles, we stayed for 3 days for 3 h (8–11 a.m.) on August 1–3 2018 at three places in the Korea DGIST campus: the front of the DGIST main gate roundabout, the DGIST dormitory inside the campus tunnel front, and the door besides the main building of DGIST. During this observation period, we counted all the conventional bicycles, the electronic bicycles, and the dominant design electronic bicycles and compared them with other electronic bicycles and non-electronic bicycles. In addition, we took photos of all the bicycles (Appendix 1 and 2). We additionally examined the pass-way condition for bicycles around the DGIST campus.

Second, we stayed at three places in Naples city centre, Via S. Caterina, Via Chiaia, and Via Toselo, for 4 days for 3 h (2–5 p.m.) on October 22–25 2018. During these times, we counted all the conventional bicycles, the electronic bicycles, and the dominant electronic bicycles and compared them with other electronic bicycles and non-electronic bicycles. We also took photos of all the bicycles possible (Appendix 3). We additionally examined the pass-way conditions for bicycles around Naples city centre.

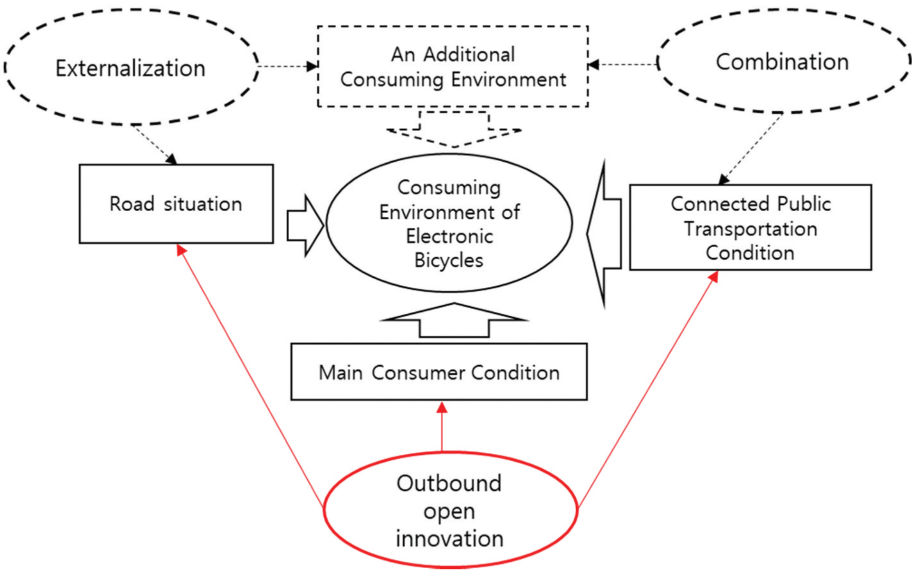

Figure 3. The sub-structures of the consuming environment of electronic bicycles.

Third, we counted the number of bicycles at the bicycle parking lot of Meijo University from 2 to 3 p.m. on November 29 2018; December 3 2018; and December 10 2018, and calculated the average of all conventional bicycles, electronic bicycles, and dominant design electronic bicycles. We took photos of nearly all of electronic bicycles (Appendix 4).

3.2. Semi-structured questionnaire-based interview or qualitative research with research scope

Semi-structured interviews (SSIs) are used extensively in research even though enough knowledge on its underlying assumptions, construction, and broad applications to qualitative and mixed-method research was not accumulated (McIntosh & Morse, 2015). Semi-structured questionnaire-based interview method is better than structured interview in finding new knowledge and adding the participatory observation (Brugha et al., 1999; Glaser & Strauss, 2017).

We chose three cities: Italy Naples as the representative city of long history of capitalist economy with a tradition of high using of moto bike, Japan Meijo as the representative city of matured capitalist economy with a tradition of high using of traditional bicycle, and South Korea, Daegu as the representative city of late-capitalist economy with no high tradition of moto-bike or traditional bicycle.

First, we distributed the questionnaire in Appendix 1 to all the bicycle users identified in the DGIST field research and received answers from 51 bicycle users. We called some of them and asked further questions to find out additional factors of the consuming environment.

Second, we interviewed bike users of Naples with the same questionnaire. We distributed it to nearly 50% of the bicycle users in Naples city centre and received answers in a few cases. We additionally discussed the usage pattern of electronic bicycles with Naples citizens and research team from Naples.

Third, we asked the same questionnaire to students of Meijo University to examine the qualitative conditions of the consuming environment of electronic bicycles in Nagoya, Japan. In addition, we asked this to Nagoya research team.

4. Evolution of electronic bicycles and shaping of the dominant design

4.1. DGIST Campus of Daegu Korea

A total of 141 bicycles were counted during our field research at the DGIST. Among them, there were 61 electronic bicycles, accounting for 43.26% of the total number of bicycles. The electronic bicycles consisted of 41 electronic quick boards, 2 large-tier electronic bicycles, 5 Segways, and 13 small-tire electronic bicycles, as shown in Appendix 2. The ratio of electronic quick boards among the electronic bicycles was 67.21%. Thus, the diversity of the product design was 32.79%.

We can highlight the rising location of the product design in the DGIST case because the electronic quick board itself is increasing in designs, as shown in Figure 4. The design diversity of electronic quick boards attracted additional customers. According to our qualitative research, plain road conditions and the well-developed public transportation system motivated the usage of electronic quick boards. In addition, the lack of bicycle parking lots in the DGIST campus increased the use of electronic quick boards, which can be carried anywhere by the rider. Furthermore, the number of bicycles is not particularly high at the DGIST. This means that the electronic bicycles at the DGIST are starting from B, the emerging industry in Figure 2. That is, the electronic bicycle industry in Daegu, Korea, is growing as a new emerging industry without converting from non-electronic bicycles.

4.2. Naples city centre in Italy

We counted 349 bicycles in Naples city centre, Italy, during our research. Of these, 177 bicycles (50.72%) were electronic bicycles, as shown in Appendix 3. Even though there were diverse electronic bicycles, the most common was the fat-tire electronic bicycle (48.02%; 85 bicycles). Hence, the diversity of product design in Naples city centre was 51.92%, as Figure 4 shows. The peak can be left and right of "Naples" just if Naples is located right than Daegu. But, we pointed "Naples" the right of the peak because this city had similar usage amounts of electronic bicycle compared to moto-bike. From this, we predicted the transformation of usage from moto-bike to electronic bicycle is occurring with the appearing of dominant design of electronic bicycle because the appearance of dominant design appears right of the peak.

In this city, answer of most fat-tire electronic bicycle riders to the question regarding the reason of riding the fat-tire bicycle was the turbulent pavement condition because of the lack of plain stone bricks on the bicycle road. In addition, Naples city centre does not have enough car parks. Many businessmen or workers who work their own fat-tire electronic bicycles instead of cars. In addition, electronic bicycles gained popularity early here because most places in Naples city centre have substantial slopes. In addition, the poor condition of the public transportation motivated the usage of fat-tire electronic bicycles. Moreover, according to additional interview with Naples research team, the desire of environment protection by Naples citizens also motivated the usage of electronic bicycles early.

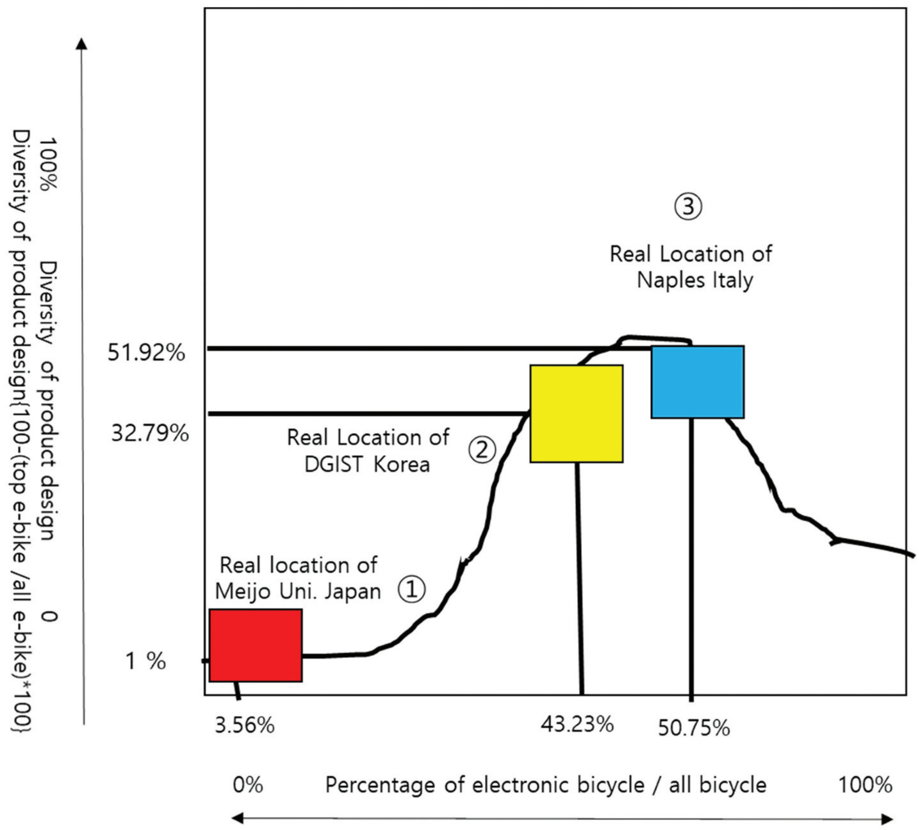

Figure 4. Real locations of e-bikes from three places on the dominant design curve.

The slope or the pavement situation disturbed the maintenance of non-electronic bicycles in Naples, Italy. Instead, in Naples, there are many auto-bikes, which have an engine and a big tire, similar to the fat tire of electronic bicycles. That is, the fat-tire electronic bicycle in Naples city centre is a good alternative to an auto-bike as it is cheaper, has no sound, requires no fuel, and is clean.

4.3. Meijo University in Nagoya, Japan

We counted the number of bicycles at the bicycle parking lot of Meijo University on three occasions from 2.30 to 3 p.m. on November 29 2018, December 3 2018, and December 10 2018. The average total number of bicycles was 403 = (429 + 343 + 437)/3, and the average number of electronic bicycles was 14.3 = (19 + 9 + 15)/3. Consequently, the ratio of electronic bicycles was 3.56%, and the diversity of electronic bicycles was simple, nearly one type, as shown in Appendix 4.

In Nagoya, non-electronic bicycles are very popular because there are well-equipped bicycle parking lots near the subway station, at the entrance of the shopping mall, and in the small hospital parking lot. The well-developed traditional bicycle industry has arrived at one to two near-dominant designs of bicycles, which is same as the only design of electronic bicycles, as shown in Appendix 4; the location is shown in Figure 4.

Currently, the customers of electronic bicycles are new customers, such as older people who need engines to ride a bicycle or women who transport babies or shopping in the basket of the electronic bicycle. Thus, the customers of electronic bicycles in Nagoya have been consumers of the traditional dominant design of non-electronic bicycles until now.

The main producer of electronic bicycles is Panasonic, which was the number one electronic battery producer in the world in January 2019. In addition, the electronic bicycles of Nagoya produce electricity and consume it simultaneously. This indicates that the technological advancement of the electronic bicycles in Japan is highly different from that of others even though the design of electronic bicycle is simple at the converted step industry A-B in Figure 2.

5. Discussion

5.1. The difference in driving power on the dominant design curve

According to our research on electronic bicycles in three global cities, there are four different steps of driving power on the dominant design curve, as shown in Figure 5. We developed these four steps from the deep case studies of three different electronic bicycle markets. First step was inferred from Nagoya case. Second step was inferred from Daegu case. And, third step was inferred from Naples. Fourth step is our prediction which should be proven from next research. First, there is the technology-based existing

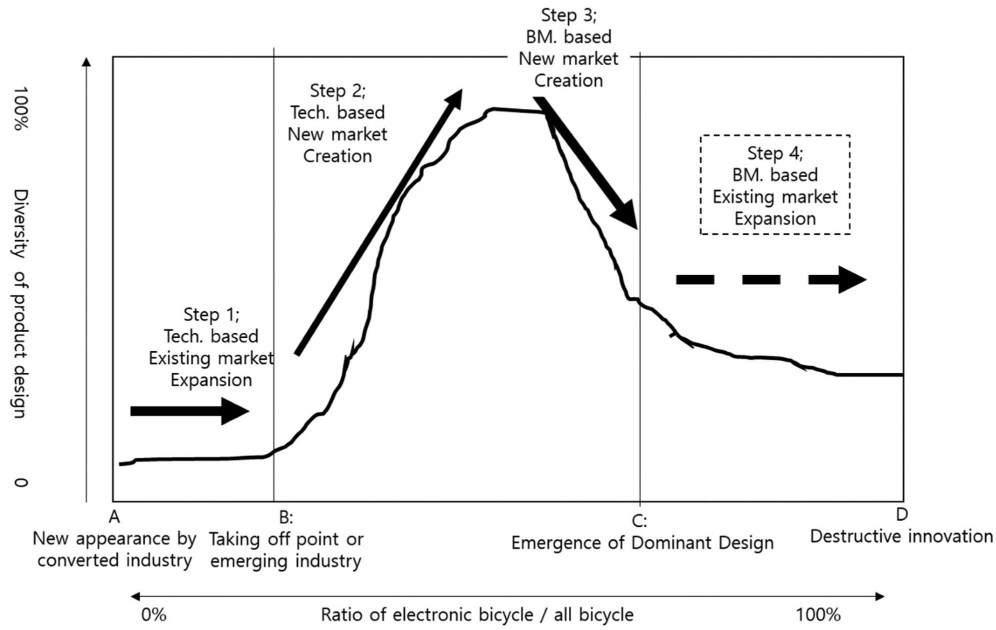

Figure 5. Four steps of driving power on the dominant design curve.

market expansion step. An example of this is the electronic bicycles in Nagoya. In Nagoya, non-electronic bicycles are popular with all generations except for people aged over 60 and women in their 20s–40s who take care of babies and visit the market for shopping nearly every week. The older generation and women with babies cannot ride traditional bicycles because they take too much energy to ride. However, as shown in Appendix 4, they can use electronic bicycles with a baby seat or shopping baskets and electronic engines. Electronic bicycles have nearly the same design as traditional bicycles, which they have ridden before. As the example of Nagoya shows, with the new appearance of the converted industry, the existing market can be expanded with new technology (Yun et al., 2019). Maybe, the converted industry will need new business models to grow in competing with existing traditional bicycle.

Second, there is a technology-based new market creation step. The concrete case of this step is the electronic bicycles of the DGIST in Daegu, Korea. In Daegu, traditional bicycles are not popular because Daegu is not well equipped with bicycle roads and it lacks bicycle culture. In addition, the well-developed public transportation system eliminates the need of riding bicycles. However, with the introduction of several technologies for electronic bicycles, such as Segways, electronic bicycle batteries, smart locking systems for electronic bicycles, connecting technology between smartphones and electronic bicycles, and several types of smart quick boards, a new market for electronic bicycles has appeared and has been growing at the DGIST in Daegu, Korea. At the DGIST, several electronic bicycle designs are competing, including several designs of electronic quick boards. According to the interviews, the key selection factors among diverse electronic bicycles, or diverse electronic quick boards, at the DGIST are the excellence of technology, such as the power of electronic engines, the maintenance time of the battery, and the connectivity of electronic bicycles with smartphones, among others.

Third, there is a business model-based new market creation step. The fat-tire electronic bicycles in Naples city centre are an example of this. Citizens of Naples use the fat-tire electronic bicycles, instead of taxis or cars, basically to travel to work and return home. The intensive use of electronic bicycles highlights a cultural change because Naples, like majority of the cities in the south of Italy, is the land of scooters and Vespa (Fort, 2009; Mazzanti, 2005).

In addition, several Naples city tour companies rent fat-tire electronic bicycles for tourists to travel around Naples city centre and not just stay near Naples harbour, considering the poor conditions and steep slope of the roads for small-tire bicycles. According to interview with Naples research team and citizens, the new business activities of bicycle including e-bike rental were born to tempt both tourists and citizens in using bicycles. In this process, some roads have been restructured to be connected with pedestrian areas, while the others remain in poor conditions. Another reason of expansion of new business models by e-bike is that the topic of environmental sustainability in the city of Naples became central.

This means that fat-tire electronic bicycles are already creating new business models in Naples. In addition, some riders use fat-tire bicycles for deliveries in the city centre. New business models are appearing for fat-tire electronic bicycles. Indeed, in Naples, the existence of small business activities in some fields (i.e., street food and groceries) has led to the use of electronic bicycles to do deliveries in the neighbourhoods.

Fourth, there is a business model-based market expansion step. We did not find a direct example of this step in our research. However, with the references to topics such as auto-bikes or automotive ventures that are continuously expanding the market, such as car-sharing and bike-touring communities, we can imagine the expansion of business models of electronic bicycles after the maturing of the electronic bicycle industry. Thus, in the future, the competitive advantage of electronic bicycles will move from the technology to the creativity of their business models.

6. Conclusion

6.1. Main findings

Most of all, E-bicycle has the reverse U-shaped dominant design curve with long head and long tail according to our research. However, individual dominant designs and related situations of electronic bicycles differ among Naples city centre, Italy; Meijo University, Nagoya, Japan; and DGIST, Daegu, Korea. The most common electronic bicycle designs of Naples, Nagoya, and Daegu are, respectively, fat-tire electronic bicycles, electronic bicycles with the same design as traditional bicycles, and electronic quick boards, which have several versions. According to the participatory observation and the interviews with customers, the locations of the three cities on the dominant design curve were completely different from each other, as shown in Figure 4.

And, three cities in different countries are located in different situations in knowledge circle. Japan Nagoya case is located in the externalisation and new combination of electronic bike technology to the traditional market like Table 1. So, to say, just hypothesis 1 only is accepted in Nagoya. Korea Daegue case is located in the externalisation, combination, and internalisation of electronical technology like Table 1. So, hypothesis 2 and partial of hypothesis 1 are accepted in Daegu Korea. Italy Naples case is located in the full circle of the knowledge circle of electronical technology from externalisation, combination to internalisation and socialisation. In other words, hypotheses 1 and 2 together are fully accepted in Naples Italy.

The same dominant design curve (DDC), which has long head and tail together, is valid for all the three cities. In fact, electronic bicycle sectors of several cities can have several sub-level dominant designs. However, they can be expressed in one dominant design curve if the design curve includes diverse cities or local markets in addition to diverse sectors of electronic bicycle. But one dominant design curve of electronic bicycle does not mean that there is only one international electronic bicycle market. The only one dominant design curve is expressing several local dominant designs, or several sub-sectors dominant designs according to the location of the curve.

Table 1. Summary of findings.

Hypothesis	Knowledge circle	Italy Naples	South Korea Daegu	Japan Nagoya
Hypothesis 1	Internalisation	O	O	
	Socialisation	O		
Hypothesis 2	Combination	O	O	O
	Externalisation	O	O	O

6.2. Theoretical implication

According to this study, the motivation of knowledge circle dynamics will trigger the appearance of dominant design. The evolution of electronic bicycle design is not liner but system dynamics, with several meaning loops under the knowledge circle dynamics. This study gives the chance to understand the evolution of electronic bicycle industry as system dynamics as <Appendix 5>.

The converted new industry like electronic bicycle with existing user base, which is different from emerging new industry like intelligent robot of which user base should be started from zero, increases "diffusion of new product and service (user base)". Moreover, "emerging new industry with disruptive new technology" motivates technology innovation. Diffusion of new product and service with user base also motivates technology innovation with a little time delay. In addition, diffusion of new product and service with user base increases market adaption, so to say, business model and consuming environment adaptation with longer time delay.

Technology innovation positively impacts the diversity of product and service design. However, market adaptation, that is, business model and consuming environment adaptation, negatively impacts diversity of product and service design. However, diversity of design augments satisfaction of customer's diverse needs. Moreover, the emergence of dominant design consists economy of scale and learning efficiency. Last, the satisfaction of customer's diverse needs and economy of scale and learning efficiency motivate the diffusion of new product and service.

6.3. Practical implication

Most of all, the major finding of this study is that electronic bicycle industry has as its dominant design curve, the reversed U curve with two side long tails. This means that competition strategies of firms in converted new industries should be different firms, which have simple reverse U dominant design curve.

According to our research, in addition to the difference in the growth of the electronic bicycle market, which was measured by the percentage of electronic bicycles to total bicycles, the consumption conditions that were discussed as the motivation power of market growth, such as technology or the business model, affected the appearance of the dominant design.

6.4. Limits and additional research goal

First, additional research is needed on the time series of the electronic bicycle industry to analyse the dynamic change in the dominant design, technology, and market in each city.

Second, follow-up research should undertake a comparative analysis of electronic bicycles between Naples, Nagoya, and Daegu to fully understand and finish the dominant design curve of electronic bicycles.

Third, it is necessary to conduct research on electronic bicycle designers, producers, and repairers to establish the final dominant design curve of electronic bicycles. This expresses the necessity of an overlapping perspective between the demand side and an offer side. Indeed, the viewpoints of both producers and repairers can reveal something that is fundamental and important to better delineate the state-of-art of dominant design curve of electronic bicycle.

Fourth, several new business models for electronic bicycle should be developed to expand this industry and understand fully the technology and market of electronic bicycles. The development of new business models for electronic bicycles should be undertaken in collaboration with current customers, potential customers, and future customers together.

Fifth, this topic can be analysed in more detail in the light of environmental sustainability and whether and to what extent this issue can differ in the geographical contexts or component contexts. We included quick boards, classic bikes, segways, etc., in electronic bicycles because these are moved by electronic power, and human power and leg power together. But, if any researcher wants to analyse dominant design of each sub-categories, such as quick board, seaways, and so on, it will also be possible. In addition, studies on dominant designs of each components of electronical bicycles such as the type of battery, the type of the electric motors and the power transmission, or the location of motor will also be possible.

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Appendices

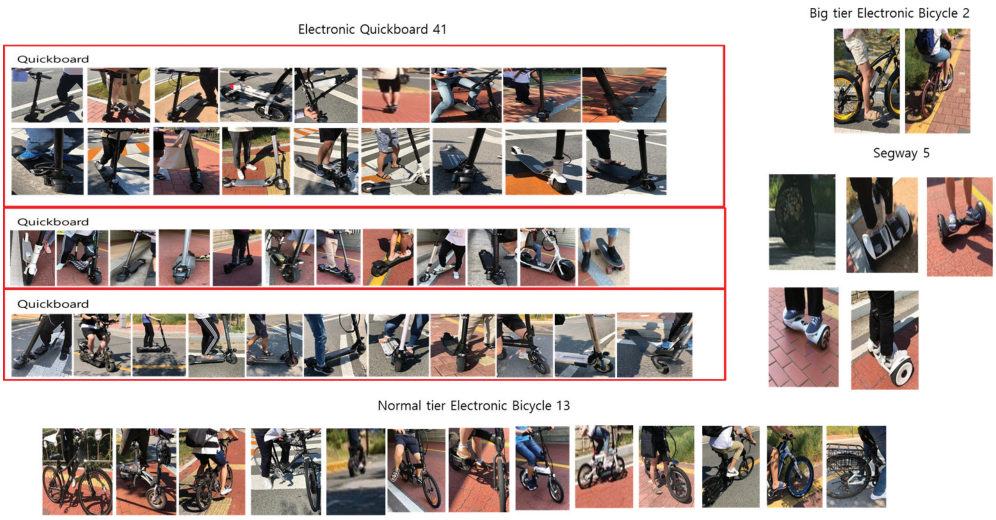
Appendix 1

Half-Structured Research Questionnaire:
The Evolution and Shaping of the Dominant Design of Electronic Bicycles

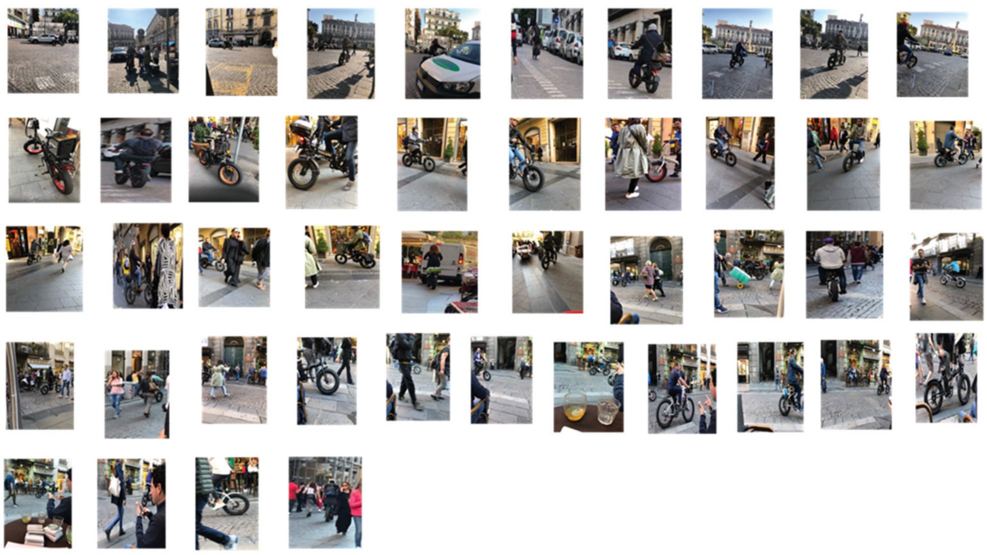
(1) How long have you been riding your current bike? () Year(s) () month(s)
(2) How many days a week do you ride your current bike?
(3) What motivated you to ride your current bike?
(4) Before your current bike, did you have any other bike for riding?
- Yes/no
- If you did, what kind of bike was it?
  Bicycle, ordinary-wheel electric bicycle, big-wheel electric bicycle, quick board, others ()

(5) Would you like to paste a picture of your bike?

Appendix 2. Diversity among electronic bicycles on the DGIST campus

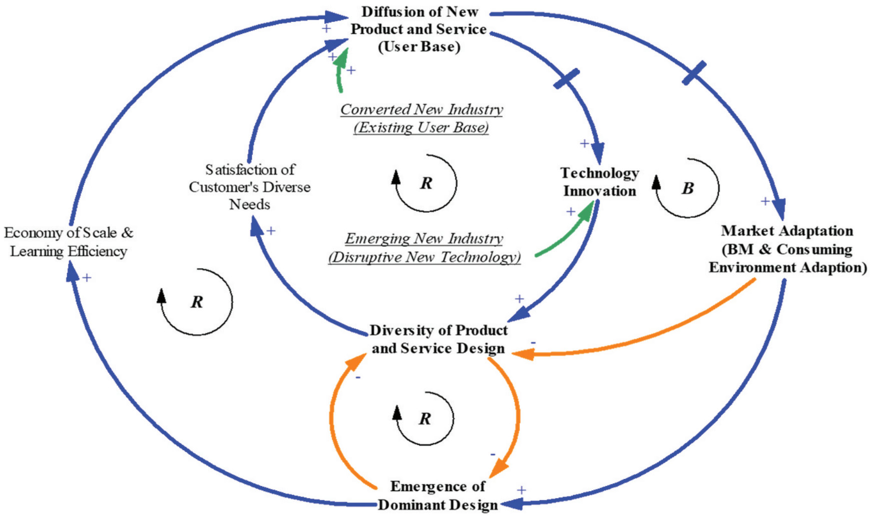


Appendix 3 Fat-tire electronic bicycles in Naples city centre



Appendix 4. Electronic bicycles at Meijo University (similar designs for non-electronic and electronic bicycles)

Appendix 5. Causal loop model of e-bike design evolution



(Reinforcing loop 1) Diffusion of New Product and Service ↑ → (with Time delay) Technology Innovation ↑ → Diversity of Product and Service Design ↑ → Satisfaction of Customer's Diverse Needs ↑ → Diffusion of New Product and Service ↑

(Reinforcing loop 2) Diffusion of New Product and Service ↑ → (with Longer Time delay) Market Adaptation ↑ → Emergence of Dominant Design ↑ → Economy of Scale & Learning Efficiency ↑ → Diffusion of New Product and Service ↑

(Reinforcing loop 3) Diversity of Product and Service Design ↓ → Emergence of Dominant Design ↑ → Diversity of Product and Service Design ↓

(Balancing loop) Diffusion of New Product and Service ↑ → (with Longer Time delay) Market Adaptation ↑ → Diversity of Product and Service Design ↓ → Satisfaction of Customer's Diverse Needs ↓ → Diffusion of New Product and Service ↓