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A Study on creativity of the manufacturing industry according to types of industry

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Abstract

The environment surrounding companies is changing rapidly, such as entering an advanced information society, intensifying competition between companies on a daily basis, and creating new management forms such as fabless companies. Innovation is important for sustainable management of companies, and much research has been done. Individual creativity is important for creating innovation within an organization. Therefore, in this study, we focused on the individuals who belong to the company, and summarized the characteristics of creation by industry in the manufacturing industry based on the creation that is carried out every day.

1 Introduction

In the advanced information society, information analysis such as big data is becoming more and more popular, and the speed of management using these data has increased. In addition, fabless companies, which do not have their own factories, have emerged as a new management method, and the environment surrounding companies is changing rapidly. In this context, the development of supply chains has heated up international competition, including the movement of production bases out of the country. However, last year's outbreak of covid-19 highlighted the impact on Japan's manufacturing industry when the supply chain did not operate properly. Under these circumstances, Japanese small- and medium-sized manufacturing companies are not only required to achieve a higher level of QCD, but also to expand new sales channels by developing their own products. Therefore, corporate creation is important and research on creation is being conducted.

In recent years, research has been conducted on corporate creativity, mainly on creativity within organizations. For example, Inamizu conducted a study on the interaction between individual and workplace characteristics on creativity, not just organizational or occupational characteristics. As a result, he used a shortened version of Gough's Creative Personality Scale (CPS) to show that there is a correlation between workplace characteristics that promote creativity and the CPS. The results of this study indicate that CPS is lower in workplaces where routine tasks are the norm, due to lower workplace characteristics that encourage creativity. Thus, research has been conducted on creativity in companies

with regard to the work environment and motivation. However, it is important to clarify what creativity in a company means in terms of what individuals in the organization are creating in their daily work.

In Japan's manufacturing industry, the number of young workers aged 34 and under has been declining since 2002, while the number of older workers aged 65 and above has been on an upward trend since 2012. This means that it is important and urgent for companies to pass on skills and convert knowledge into data as the generation of skilled workers retires. Each company is using various methods to discover and solve problems, and is trying to improve work efficiency and establish technology while utilizing the creativity of individuals. In order to facilitate the improvement of work efficiency and the establishment of technology, it is important to organize and summarize the improvements and other creations that are made on a daily basis in the company. Therefore, when it comes to the creation of a company, it is important to focus on and understand the creation of individuals who belong to the organization.

The study of creativity has been conducted mainly on individual creators in fields such as art and music. Later, Gilford quantified the results, and the research spread to various fields. Most of the research on creation has been on the concept of creation and its forms. Among other things, the definition of creation has varied depending on the subject matter. In this study, creation is defined as "the production of new information. Based on this definition of creation, the authors have conducted case studies in various fields such as business, science and technology. Also, based on the idea that new information is produced by combining known information, the following equation was used.

Known information A * Known information B = New information N (1).

This equation (1) is called the equation of creation, and we have confirmed that equation (1) is valid in the case studies listed above. In the process of decomposing the above creation case into the information elements of the equation for creation, it was found that “trigger K,” which is the trigger for creation, is an important element. Therefore, the flow from trigger K to the equation of creation was summarized as the creation process. In this study, we will use the process of creation to summarize the characteristics and differences in the tendency of creation within companies in different manufacturing industries.

2 Purpose of study

The purpose of this study is to summarize the characteristics and differences based on each information element of the creation process using the equation of creation for the daily creation that takes place in each manufacturing industry.

3 Research Methods

Five manufacturing companies located in the industrial park of Narashino City, Chiba Prefecture, were interviewed, focusing on factory leaders, sub-leaders, and internal managers. Decompose the obtained examples of daily Kaizen into each information element of the creative process using the equation of creation, and clarify the characteristics based on the relationship between each information element. The classification of the manufacturing industry was based on the medium classification of the Japan Standard Industrial Classification issued by the Ministry of Internal Affairs and Communications (Table 1).

Industry Type	Company	Number of Employees (man)	Number of Surveyed Persons (man)
Manufacture of Plastic Products, Except otherw	A	25	4
Manufacture of Fabricated Metal Products	B	25	8
Manufacture of Production Machinery	C	104	76
	D	22	2
Manufacture of Transportation Equipment	E	41	5

Table 1 : Basic Data of Industry

4 The equation of creation

In this study, creation is defined as "the production of new information". Based on the idea that new information is produced by combining known information, the equation of creation is expressed by the following equation.

Known information A * Known information B = New information N (1)

The flow from trigger K to the equation of creation is summarized as the creation process. The definition of each information element is shown in Table 2.

	Definition
K	It means awareness of problems such as problems and purposes that you want to solve. Information that is a direct opportunity to define the A * B
A	Information obtained from events and things that are subject to K
B	Information to combine with A
N	New information that contributes to K

Table 2 : The Definition of Each Information Element

The relationship between each information element obtained using the creative process was summarized as K-type classification for the relationship between trigger K and other information elements. In addition, the relationship between known information A and known information B was systematized as a sense of distance and AB combination type classification based on about 900 creation cases obtained from business, science and technology fields.

5 K-Type classification

In the process of analyzing creative cases using the equation of creation, it was found that "trigger K," information that serves as a cue for creation, is important in the creative process. For this reason, the relationship between the four elements of the information, the trigger K, the known information A and B obtained from the equation of creation, and the new information N was systematically classified into three types: K=A type, K=N type, and K≠A, N type. The above three types are collectively called K-type classification.

(1) K=A type

In this model, the known information A in the equation of creation is identified from the trigger K, which is the cue for creation, and the known information B is explored and combined to produce the new information N.

(2) K=N type

This is the type of case where the concept of new information N is formulated from the trigger K, which is the cue for creation, and many combinations of known information A and known information B are accumulated to realize the new information N.

(3) K≠A, N type

This is a case where neither known information A nor new information N is identified from the trigger K, which is the clue for creation, and new information N is created from a result different from the initial prediction by what is called serendipity in science, i.e., a product of chance.

From the equation of creation, creation occurs when known information A is identified, followed by the search for and identification of known information B, resulting in new information N. Therefore, in K-type classification, K=A type is the basic form of creation. Next, we summarized the relationship between the two known pieces of information A and B in the creation equation. In considering the relationship between the two, it is important to note that after known information A is identified, known information B is searched for and multiplied. Therefore, in putting together the two relationships between known information A and known information B, it is important that known information A is identified. As a result, the relationship between the two information elements was summarized for the K=A type case of K-type classification. That is the sense of distance and AB combination type classification.

6 SD: Sense of Distance and AB combination type classification

SD is defined as the ease of searching for known information B after known information A is identified. The creative act takes place in the mind of the individual. Therefore, we thought that SD could be classified according to the creator's own method of searching for known information B and the ease with which it is done. As a result, the classification method is summarized in the following three levels (Table 3).

How to search	SD	Areas by SD
Inside information	Extremely Near	Awareness Area
Reference	Near	Selection Area
Learning	Far	Inspiration Area

Table 3 : SD and SD Area

First of all, the SD where the known information B is identified only by the internal information (knowledge) in the mind of the individual was defined as “Extremely Near” and designated as the Awareness area. Next, the SD that corresponds to the “reference” of Marchionini was set to “Near” and set to Selection area. Finally, the SD that correspond to exploratory searches such as “learning” and “survey” were summarized as “Far” in the Inspiration area. However, that evaluation sometimes requires a lapse in time.

The word “profit” is often added to the definition of corporate creation. This is because when people talk about whether a creation is good or not, they often use monetary valuation to evaluate its value. This is a case where the result is considered the creative level. Therefore, in considering the creative level, the sense of distance perspective can be one of the evaluations.

7 AB combination type classification

From the equation of creation, in order to perform the act of creation, it is important to identify the known information A, and then search for, identify, and combine the known information B. In other words, AB combination type classification is a systematic way to search for known information B after identifying known information A.

In order to systematize the AB combination type classification, we focused on the creation case of K=A type and paid attention to the contents of known information A and known information B. Some cases of creation obtained in the process of analysis were found to fall under multiple AB combination types. In such cases, they were classified as types that fall into both categories. In order to summarize the search methods, I referred to Altshuller’s 40 Principles of Invention, which created TRIZ, and Tsukamoto’s search methods for creation, and summarized them into three groups of 18 categories.

The first group was designated as “Introduction type” because of the image of introducing external information into the search process. The second group was called “Hybrid type” because of the image of changing internal information such as changing the size. The third group is called “Extension type” because of the image of expanding to the outside world.

Using the above K-type classification, SD and AB combination type classification, we will summarize the examples of creation for each industry in the manufacturing sector.

8 Results and Discussion

As a result of the interview survey on creative cases conducted for each industry, 19 cases were obtained from the manufacture of plastic products, except otherwise classified, 32 cases from the manufacture of fabricated metal products, 166 cases from the manufacture of production machinery, and 71 cases from the manufacture of transportation equipment (Table 4).

Industry Type	Company	Number of Creative Cases
Manufacture of Plastic Products, Except otherwise classified	A	19
Manufacture of Fabricated Metal Products	B	32
Manufacture of Production Machinery	C	153
	D	13
Manufacture of Transportation Equipment	E	71

Table 4 : K-type classification of Industry

The obtained cases were decomposed into each information element of the creative process using the equation of creation, and K-type classification was performed to show the relationship between the trigger K and other information elements（Table 5）.

	K=A type	K=N type	K≠A,N type
Manufacture of Plastic Products, Except otherwise classified	16	3	0
Manufacture of Fabricated Metal Products	29	3	0
Manufacture of Production Machinery	158	8	0
Manufacture of Transportation Equipment	70	1	0

Table 5 : K-type classification of Industry

The results of the K-type classification show that the K=A type, in which known information A is derived from the trigger K, is often performed in all industries. In other words, in many cases, from the impetus for creation, the object of creation is specifically identified and the search for known information B to be multiplied is conducted. The next most common case was the K=N type. In this case, the concept of new information N was developed from the trigger K, and various creative activities were carried out in response to it. In this study, it was found that the concept of improving work efficiency, improving organizational management, and sales strategies for the company's products were mainly presented by managers and factory leaders to other members. The K=A type case study also confirms the creative act to carry out this. Finally, in this study, we were not able to identify any K≠ A, N type cases.

Next, for the case of K = A type, the relationship between known information A and known information B was analyzed by SD and AB combination type classification.

The results of the SD analysis of the domains showed that there was a lot of creation in the "Awareness area" and "Selection area" in all industries (Table 6).

	Awareness Area	Selection Area	Inspiration Area
Manufacture of Plastic Products, Except otherwise classified	8	8	0
Manufacture of Fabricated Metal Products	16	12	1
Manufacture of Production Machinery	73	68	17
Manufacture of Transportation Equipment	38	30	2

Table 6 : SD Area of Industry

The awareness area is the creation of cases in which known information B is relatively easily explored by the knowledge possessed by the individual creator. In this study, we were able to confirm many examples in this area, such as the improvement of familiar work efficiency such as the improvement of the worktable during work. The next selection area is the case of getting advice from someone close to you in searching for known information B. In this study, we were able to confirm many of these areas in cases of work efficiency and work improvement in response to customer complaints. It was the knowledge possessed by the skilled workers that would help them with advice and other assistance. It was confirmed that many workers utilize the experience and knowledge possessed by skilled workers in performing creative acts in this area. Finally, the inspiration area is a case of "learning" or "survey" and searching for known information B in performing the creative act. In this study, there were cases of investigating the bottleneck process to shorten the working time and investigating the properties of blade to make improvements to the grinding of blade used in the work.

Next, while SD indicates the ease of searching for known information B after identifying known information A, AB combination type classification summarizes in what information domain known information B was searched after identifying known information A. In this study, there were relatively many cases of creation by Introduction type in all industries (Table 7, Figure1). The Introduction type is a case where external information is searched against known information A to identify known information B. There are 8 categories in the introduction type. In this study, there were many examples of "the knowledge and experience type" in all industries. Next, "the imitation type" cases were relatively common in all industries. This case is about mimicking what others are doing and dealing

with the problem. What is important here is not to directly imitate what others have done, but to use it as a reference and adapt it to our own environment as an original.

Next, as a place to search for known information B, the creation of “Experiment type” was more common in all industries in Hybrid type, an image that changes internal information. In the Manufacture of production machinery, there were cases of “Concentration type” and “Functional combination type” from the perspective of adding value to products.

Finally, there are 4 categories in extension types, which are subcategories that push existing objects outward as search locations. Among them, there were many “exchange type”. In this study, it was observed that with the development of PCs and other devices, there were cases where analog management methods such as handwriting were replaced by digital management. In addition, there was a substitution type between manufacture of production machinery and manufacture of transportation equipment. This is a case where a different material is substituted in response to a customer's request or complaint.

		Manufacture of Plastic Products, Except otherwise classified	Manufacture of Fabricated Metal Products	Manufacture of Production Machinery	Manufacture of Transportation Equipment
Introduction type		13	21	124	58
	Imitation type	1	4	16	9
	Knowledge and Experience type	7	11	78	27
	Custom type	2	3	10	10
	Functional addition type	3	2	11	8
	Association type	0	0	3	3
	Functional application type	0	0	3	0
	Correlation type	0	1	1	1
	Analogy type	0	0	2	0
Hybrid type		2	2	23	9
	Experiment type	2	2	11	6
	Size-change type	0	0	0	1
	Concentration type	0	0	6	0
	Functional combination type	0	0	2	0
	Anti-commonsense type	0	0	0	0
	Unification type	0	0	4	2
Extension type		1	6	11	3
	Use-development type	1	0	1	0
	Exchange type	0	6	9	2
	Substitution type	0	0	1	1
	Sensitivity type	0	0	0	0
Total		16	29	158	70

Table 7 : AB Combination Type Classification of Industry

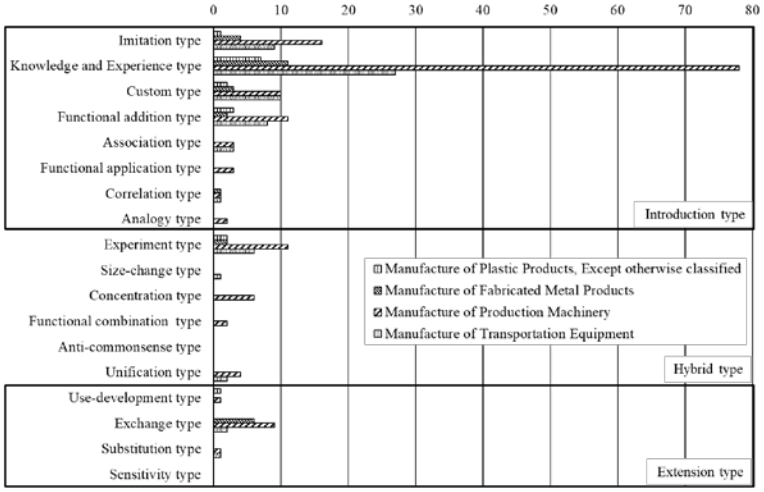

Figure 1 : AB Combination Type Classification of Industry

Next, we performed AB combination type classification of SD area. In the Awareness Area, there was a lot of Introduction type creation across all industries (Table 8, Figure 2). Hybrid type and Extension type were not widely used in the results of this interview survey, and were not found for Manufacture of Plastic Products, Except otherwise classified. Next, in the Selection Area, we found that Introduction type, Hybrid type, and Extension type were created in all industries (Table 9, Figure 3). Finally, in the Inspiration Area, the Introduction type was being used except for Manufacture of Plastic Products, Except otherwise classified (Table 10, Figure 4). It was also found that Hybrid type and Extension type are carried out in two industries, Manufacture of Production Machinery and Manufacture of Transportation Equipment.

Areas by SD	A*B Combination type		Manufacture of Plastic Products, Except otherwise classified	Manufacture of Fabricated Metal Products	Manufacture of Production Machinery	Manufacture of Transportation Equipment
Awareness Area	Introduction type		8	15	68	37
		Imitation type	1	3	9	8
		Knowledge and Experience type	3	9	53	17
		Custom type	2	3	6	8
		Functional addition type	2	0	0	4
		Association type	0	0	0	0
		Functional application type	0	0	0	0
		Correlation type	0	0	0	0
		Analogy type	0	0	0	0
	Hybrid type		0	0	2	1
		Experiment type	0	0	2	0
		Size-change type	0	0	0	0
		Concentration type	0	0	0	0
		Functional combination type	0	0	0	0
		Anti-commonsense type	0	0	0	0
		Unification type	0	0	0	1
	Extension type		0	1	3	0
		Use-development type	0	0	0	0
		Exchange type	0	1	3	0
		Substitution type	0	0	0	0
		Sensitivity type	0	0	0	0

Table 8 : Awareness area and AB Combination Type Classification of Industry

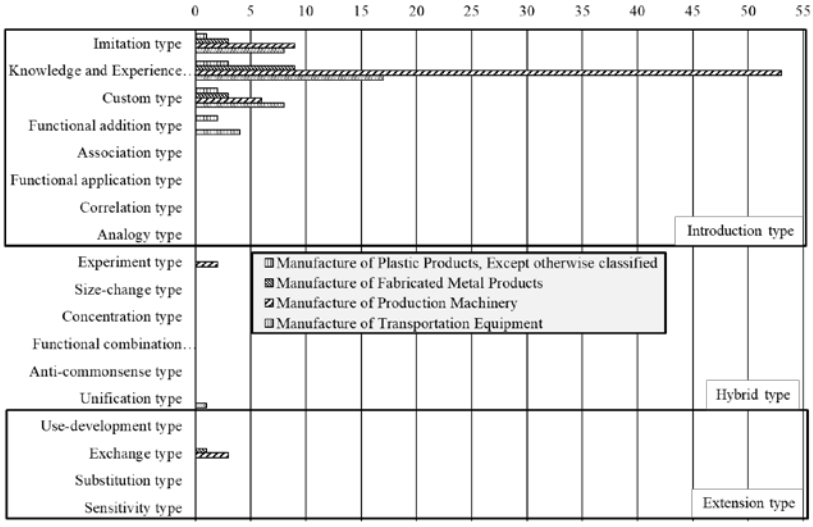

Figure 2 : Awareness area and AB Combination Type Classification of Industry

Areas by SD	A*B Combination type		Manufacture of Plastic Products, Except otherwise classified	Manufacture of Fabricated Metal Products	Manufacture of Production Machinery	Manufacture of Transportation Equipment
Selection Area	Introduction type		5	5	46	19
		Imitation type	0	1	7	1
		Knowledge and Experience type	4	2	22	10
		Custom type	0	0	4	2
		Functional addition type	1	2	11	4
		Association type	0	0	0	2
		Functional application type	0	0	2	0
		Correlation type	0	0	0	0
		Analogy type	0	0	0	0
	Hybrid type		2	2	16	8
		Experiment type	2	2	9	6
		Size-change type	0	0	0	1
		Concentration type	0	0	6	0
		Functional combination type	0	0	0	0
		Anti-commonsense type	0	0	0	0
		Unification type	0	0	1	1
	Extension type		1	5	6	3
		Use-development type	1	0	0	0
		Exchange type	0	5	6	2
		Substitution type	0	0	0	1
		Sensitivity type	0	0	0	0

Table 9 : Selection area and AB Combination Type Classification of Industry

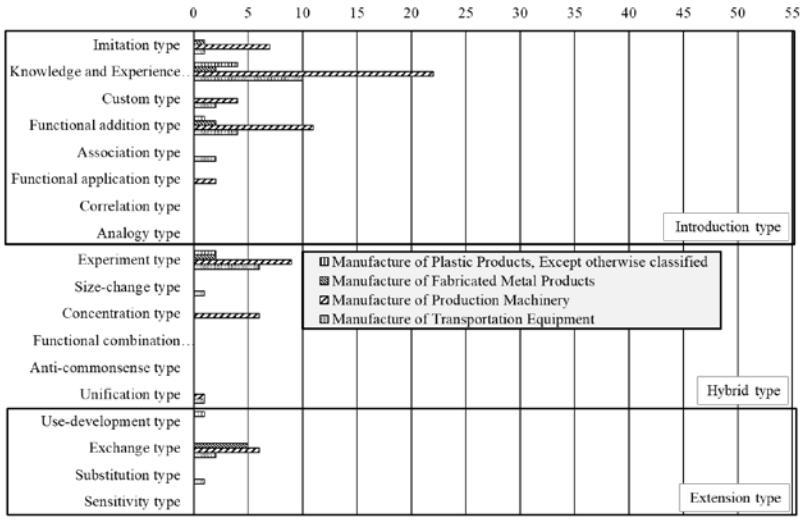

Figure 3 : Selection area and AB Combination Type Classification of Industry

Areas by SD	A*B Combination type		Manufacture of Plastic Products, Except otherwise classified	Manufacture of Fabricated Metal Products	Manufacture of Production Machinery	Manufacture of Transportation Equipment
Inspiration Area	Introduction type		0	1	10	19
		Imitation type	0	0	0	1
		Knowledge and Experience type	0	0	3	10
		Custom type	0	0	0	2
		Functional addition type	0	0	0	4
		Association type	0	0	3	2
		Functional application type	0	0	1	0
		Correlation type	0	1	1	0
		Analogy type	0	0	2	0
	Hybrid type		0	0	5	8
		Experiment type	0	0	0	6
		Size-change type	0	0	0	1
		Concentration type	0	0	0	0
		Functional combination type	0	0	2	0
		Anti-commonsense type	0	0	0	0
		Unification type	0	0	3	1
	Extension type		0	0	2	3
		Use-development type	0	0	1	0
		Exchange type	0	0	0	2
		Substitution type	0	0	1	1
		Sensitivity type	0	0	0	0

Table 10 : Inspiration area and AB Combination Type Classification of Industry

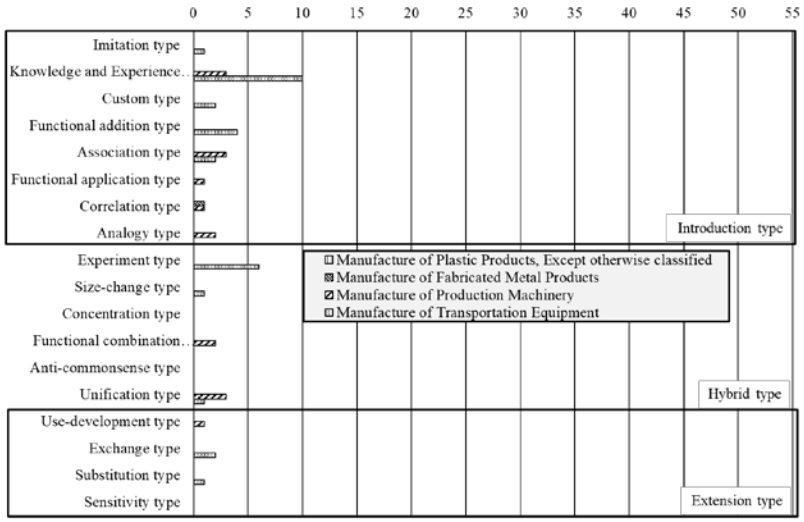

Figure 4 : Inspiration area and AB Combination Type Classification of Industry

9 CONCLUSION

In this study, we summarized the characteristics of creative acts in each of the four manufacturing industries using examples of creative acts performed daily in 19 cases in the manufacture of plastic products, except otherwise classified, 32 cases in the manufacture of fabricated metal products, 166 cases in the manufacture of production machinery, and 71 cases in the manufacture of transportation equipment industry obtained from the interview survey. As a result, there was no significant difference in the tendency of creation within companies in different manufacturing industries.

In the K-type classification, which summarizes the relationship between each information element in the equation of creation and the trigger K, which is the cue for the creative act to take place, it was confirmed that there were many cases of K=A type in all industries. From the K=N type cases, it was confirmed that the cases were mainly related to the concept of improving work efficiency for the company's products, improving organizational management, and sales strategies, and that these cases were presented to other members by managers and factory leaders. Therefore, it is important for managers and factory leaders to produce concepts in order to promote creative behavior in the company.

Next, SD found that the creation of Awareness Area and Selection Area was well done in all industries. In other words, it was found that the method of searching for known information was to find improvement measures through personal knowledge and advice from familiar people such as references.

In the AB combination type classification, which summarizes from which information domain the known information B was searched, it was found that overall, the creation of the introduction type was done more. Among the Introduction type, there were many examples of Knowledge and Experience type creations overall. Together with the results of SD, we can recognize the importance of skilled workers who have a wealth of experience and knowledge, and how to pass on their wealth of experience and knowledge in the creative process.

In the AB combination type classification of SD area, the Awareness Area was mainly used for the creation of Introduction type and not much for Hybrid type and Extension type. In the Selection Area, the number of creation cases of Hybrid type and Extension type increased more than in the Awareness Area. Although the Inspiration Area was less than the Selection Area, it was possible to confirm the creation of the Introduction type, Hybrid type, and Extension type. Even in the same manufacturing industry, the location of the search for known information B changed somewhat if the industry changed, but there was no significant difference in the trend.

As an issue for the future, the results of the interviews showed a bias in the number of cases created by industry. The trend will become clearer when the number of cases is further increased.

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