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Dynamics of Technological Knowledge in Product Development Activities

"Knowledge Creation and Knowledge Dynamics in Research and Development (1)"
Intermediate Report

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1. Overview of Survey

1-1. Purpose of Survey

In addition to interest in the international competitive capabilities of Japanese corporations, in recent years a great deal of attention has been focused on product innovation and product development performance as a systematic and strategic area of research. Various special characteristics of product development activities in Japanese corporations have already been noted. Conventional research, however, based on a perspective that assumes passive reaction under western business theory, often either reduces the actions of Japanese corporations to their individual elements, or else depends on an empirical approach; there has not yet been sufficient research performed from a viewpoint that captures the universal aspects of the Japanese characteristics. As long as a universal description of product development is not formed, it will be impossible to attain a deeper understanding of the special Japanese characteristics of the development process, which consists of multi-dimensional complex elements, and we will not be able to present that understanding as a methodology that can be shared internationally.

In light of this problem, we began research on technological knowledge in product development activities for the purpose of constructing concepts concerning those organizational emergence characteristics, using as a starting point the views expressed by Nonaka (1990) for understanding innovation as a process of knowledge creation. In the first stage of our research, we conducted a survey to discover problems regarding product development activities at companies in a broad range of industries. In this intermediate report, we will summarize the information that we have gained from our analysis of the data gathered in this survey.

Note that this survey is the result of "Knowledge Creation and Knowledge Dynamics in Research and Development (1)," which is being conducted by the National Institute of Science and Technology Policy of the Science and Technology Agency as part of "Basic Research on Support for Creativity in Intellectual Production Activities" (1992 to 1994), which is funded by Special Coordination Funds for Promoting Science and Technology.

1-2. Survey Data

(1) Targets of survey and extent of response

This survey (Survey on Dynamics of Technological Knowledge in Product Development Activities) was targeted at the product development departments of all 1,226 companies listed on the Tokyo Stock Exchange that belong to the manufacturing industry as listed in volume 1 of the "Quarterly Company Report" for 1993, and was distributed among the managers of the appropriate departments for their response. The survey was conducted by mail in February and March of 1993, and by March 31, 1993 a total of 677 responses had been received (for a response rate of 55.2%). However, of the companies responding, 21 were not engaged in product development activities; therefore, only the responses from the remaining 656 companies were used for the analysis concerning product development.

(2) Distribution by attributes in response sample

Because this survey targeted all of the main fields of corporate products, it can be expected that the responses would differ according to the characteristics of the product markets that each individual company is involved with. For that reason, in order to make the observed results of the response sample representative of the entire group, it is necessary to investigate any possible bias in the rate of response in different industries. Table 1 shows a breakdown of the companies targeted in the survey and responding to the survey in each industry as a percentage of the total number of companies in each category. With the exception of the food and textile industries, the difference between these percentages for each industry is less than 1%. Therefore, it can be assumed that an analysis based on this survey data will be free from sample error.

Table 2 shows the distribution of the responding companies on the basis of size. Reflecting the fact that all of the companies in the entire group are listed on the Tokyo Stock Exchange, the majority of the responding companies are large corporations; about 70% of the responding companies had sales in excess of 30 billion yen, and about 60% employ at least 1,000 people.

(3) Character of the survey items and data

The items in this survey covered the characteristics of the product markets, technology strategies, product development strategies, the features of the product development organizations, the organizational features of the development process, leadership, and the evaluation of the results of development. The survey data, consisting of 174 variables, made possible a multi-dimensional analysis of product development.

Many of the variables were designed according to a 7-point Likert scale. Because the Likert scale variables reflect the subjective answers of the respondents, it is frequently a problem to determine what type of objective index of measurement should serve as a standard of measurement for the responses. In order to make an evaluation regarding this point in regards to the data obtained from this survey, we examined the relationship between the respondent's evaluation of his company's level of investment in terms of research and development expenditures, etc., (i.e., "Does your company invest more capital and personnel in research and development than other companies?") with the actual ratio of research and development expenditures to sales. As shown in Fig. 1, which illustrates the distribution of the actual ratio of research and development expenditures to sales for each response level used for evaluation of the level of investment, the peak ratio at response level 1 ("don't agree at all") was "less than 2%," at response level 4 ("neither agree nor disagree") was "from 2 to 4%," and at level 7 ("agree completely") was "10% or more." From these results a definite trend is apparent. In addition, Fig. 2 illustrates the distribution of the respondents' evaluation of the level of investment for each level of the actual ratio of research and development expenditures to sales; here the peak response trends from level 4 for "less than 2%" to level 7 for "10% or more." Calculating the chi-square value for this cross-tabulated data yields a result of 180.2, which is a significant result with a discard range of 1% as the standard. In other words, it is apparent that the subjective evaluation scale and the objective categories in this survey data are not independent and that a sufficient statistical relationship exists.

Table 1. Breakdown of Target Companies and Responding Companies by Industry

(units: number of companies, percent)

	Target companies	Responding companies	Response ratio by industry
Foods	105 (8.6)	49 (7.2)	46.7
Textiles	79 (6.4)	35 (5.2)	44.3
Pulp/paper	34 (2.8)	16 (2.4)	47.1
Chemicals	185 (15.1)	108 (16.0)	58.4
Integrated chemicals	109 (8.9)	65 (9.6)	59.6
Pharmaceuticals	43 (3.5)	24 (3.5)	55.8
Other chemicals	33 (2.7)	19 (2.8)	57.6
Petroleum products/rubber products	34 (2.8)	16 (2.4)	47.1
Ceramics	59 (4.8)	31 (4.6)	52.5
Steel	57 (4.6)	30 (4.4)	52.6
Non-steel metals	37 (3.0)	22 (3.2)	59.5
Metal products	62 (5.1)	33 (4.9)	53.2
Machinery	187 (15.3)	108 (16.0)	57.8
Electric machinery	197 (16.1)	113 (16.7)	57.4
Transportation vehicles	87 (7.1)	50 (7.4)	57.5
Automobiles	62 (5.1)	36 (5.3)	58.1
Other transportation vehicles	25 (2.0)	14 (2.1)	56.0
Precision machinery	35 (2.9)	24 (3.5)	68.6
Other industries	68 (5.5)	42 (6.2)	61.8
Total	1,226 (100.0)	677 (100.0)	55.2

Table 2. Distribution of Responding Companies by Size

(unit: percent)

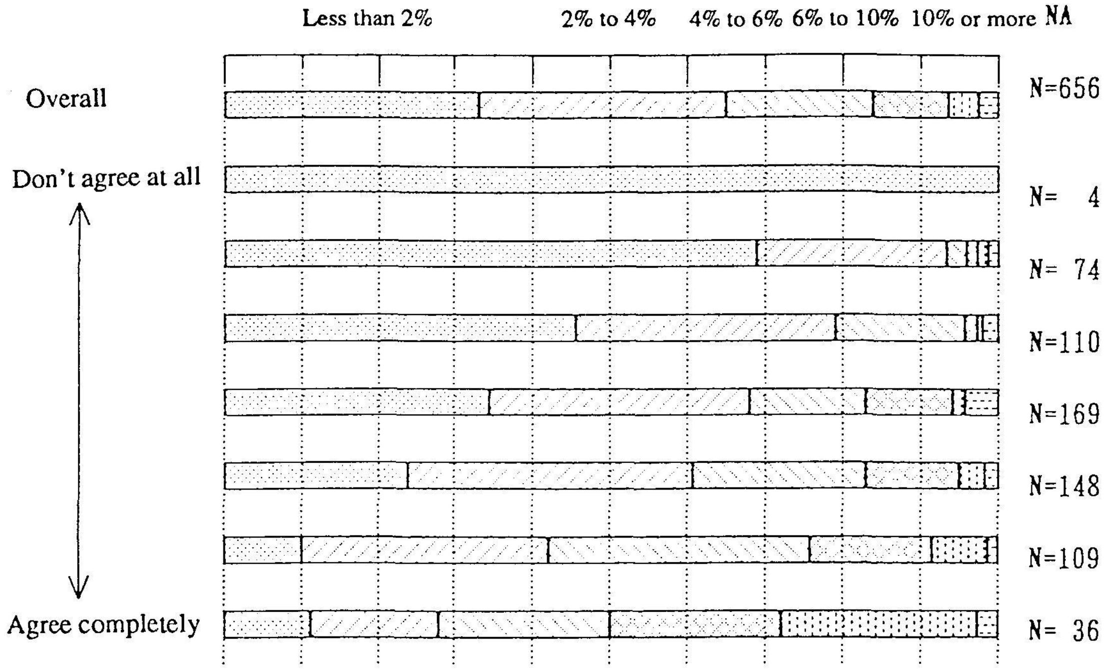
(1) By annual sales

Less than 10 billion yen	8.4
10 billion yen to 30 billion yen	26.4
30 billion yen to 100 billion yen	33.4
100 billion yen to 300 billion yen	18.8
300 billion yen or more	13.0
Total	100.0

(2) By number of employees

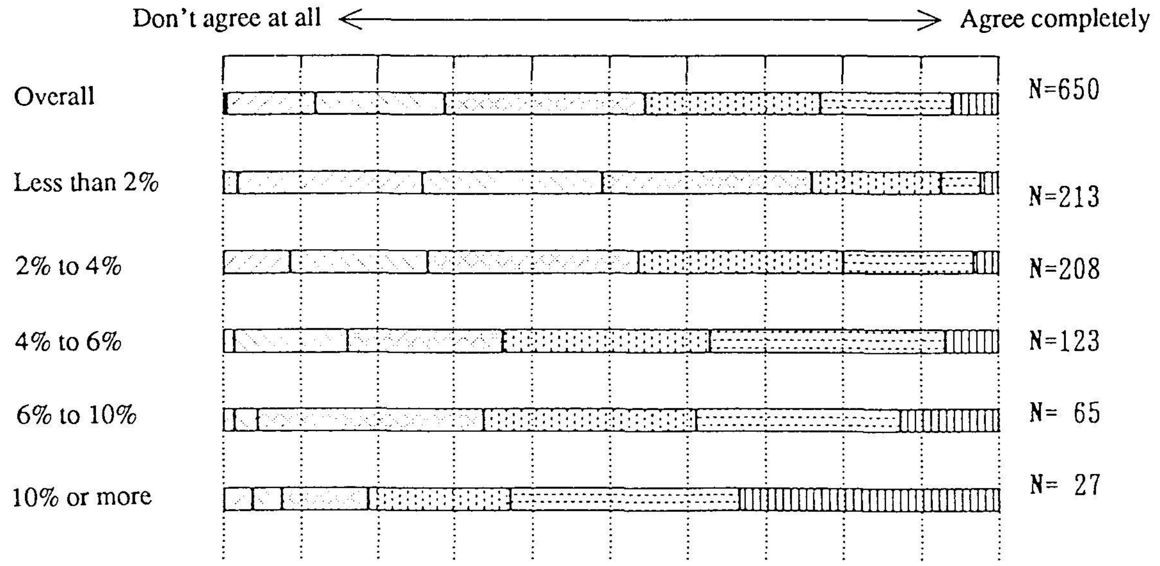
Less than 300 employees	9.7
300 employees to 1,000 employees	31.9
1000 employees to 5,000 employees	43.4
5000 employees to 10,000 employees	9.2
10,000 employees or more	5.8
Total	100.0

Fig. 1 Ratio of Research and Development Expenditures to Total Sales, Classified by Evaluation of Level of Investment in Research and Development Expenditures, Etc. (unit: percent)



Note: The vertical axis shows the level of the respondents' evaluation regarding the question, "Does your company invest more capital and personnel in research and development than other companies?"

Fig. 2 Evaluation of Level of Investment in Research and Development Expenditures, Etc., Classified by Ratio of Research and Development Expenditures to Total Sales (unit: percent)



Note: The horizontal axis shows the level of the respondents' evaluation regarding the question, "Does your company invest more capital and personnel in research and development than other companies?"

1-3. Definition of Terms

The definitions of certain terms as they are used in this survey are provided below.

"Elemental technologies," "specialized fields of technology"

These terms mean technologies that are equivalent to specialized fields of individual technologies, and are used to refer to technologies that correspond to the subsystems that form part of the overall technological system of the product. These technologies are equivalent to technologies at the level of the individual components that make up the larger product. For example, in the case of automobiles, the "elemental technologies" or "specialized fields of technology" are defined as the technologies relating to the individual subsystems, such as the engine, suspension, and brakes.

"Technical function departments"

This term refers to the technical development and design departments and teams that are formed for each specialized field of technology.

"Development planning/integration departments"

This term refers to the departments that oversee new product development projects and new product development activities as a whole, such as a development planning office or a product planning office.

2. Theoretical Hypothesis

While this data makes a multi-dimensional analysis of product development activities at Japanese corporations possible, we decided to first use the data to attempt to verify the conceptual model of knowledge creation described earlier. An overview of Nonaka's model (1990) follows.

There are two types of knowledge: "tacit knowledge," which is subjective and difficult to verbalize, and "explicit knowledge," which is objective and can be verbalized. The circular interaction of both of these types of knowledge leads to the creation and expansion of knowledge. There are a variety of conceivable patterns for interaction between tacit and explicit knowledge. The process of converting tacit knowledge to explicit knowledge can be called "externalization," while the process of converting explicit knowledge to tacit knowledge can be called "internalization." In addition, a pattern in which different pieces of explicit knowledge are linked together to create new knowledge can be referred to as "combination," while the process of sharing tacit knowledge can be referred to as "socialization." Knowledge creation encompasses all conversion patterns governing the interaction of tacit and explicit knowledge, and is the process by which knowledge produced by a particular subject is developed/sublimated into knowledge between subjects.

The factors that drive the knowledge creation process can be divided into three phases: the individual level, the group level and the organization level. Knowledge creation at the individual level, which is the ultimate source of organizational knowledge creation, is promoted through the intentions and autonomy of the individual members that make up the organization. Tacit knowledge acquired at the individual level is conceptualized as a factor promoting interaction between individuals through discussion, and thus becomes shared knowledge at the group level. The conceptualized knowledge then undergoes a process of verification at the organizational level. During this phase, the redundancy of information creates trust between subjects, which brings out the dynamism that leads to the self-structuring of the system that creates knowledge.

Furthermore, Nonaka, et al (1992), presented an organizational model, the "hypertext organization," that promoted this process of knowledge creation. This organizational model consists of three layers: the knowledge base layer, the business system layer, and the project team layer. Unlike the hierarchical business system, however, this model permits the formation of cross-functional project teams, designed for specific purposes, which are constantly feeding the intellectual results of their projects back into the knowledge base.

In our research, in order to analyze the dynamics of technological knowledge through the stages of product development, we have established a new theoretical hypothesis by further expanding the universality of the model of the hypertext organization and transposing the three-layer structure of the organization onto a three-layer structure of technological knowledge.

In other words, product development activities can be understood as a knowledge creation process that, through the commercialization of a specific product, ties together a knowledge base that exists both as an internal and external resource of a company. In this process, the company's technological strategy and product development strategy both combine together individual resources of knowledge, and provide a framework for the conversion of knowledge into new knowledge. However, the combination and conversion of knowledge often extends beyond the strategic framework and becomes filled with the possibility of even more dynamic expansion. Therefore, a company's core competence at performing the knowledge creation process can be thought of in terms of three layers: the existence of the knowledge base as individual resources, the superiority of the company's strategic knowledge framework, and the dynamics of knowledge conversion that extend beyond the knowledge framework on which the process is based.

This knowledge layer hypothesis also has the following universal significance. Polanyi described three actions that he called the triad of tacit knowledge: reading the meaning from the target (sense-reading), using narrowly defined language to express that meaning (sense-giving), and grasping the meaning by reading that language again. In addition, in each of these actions, there is a behavior called "integration" in which a person creates an artificial construct that would not be apparent just from the existence of the individual detailed elements that are perceived, and then through that construct grasps the meaning of the whole. (Kurimoto, 1988)

This understanding of the cognitive process can also be applied to the knowledge transfer process that occurs between knowledge layers in our hypothesis. In other words, new knowledge is grasped through knowledge conversion in the development process, and "sense-reading" is the action of storing this new knowledge in the knowledge base layer. "Sense-giving" is the action of forming a valid strategic or structural framework from the development experiences stored in the knowledge base layer, and in the development process the aims of the knowledge framework are expressed through the formation (in the knowledge conversion process) of a whole that exceeds the detailed elements of the knowledge framework. In short, an organization that demands knowledge creation is an organization that is equipped with structures that reflect the human cognitive process.

In order to completely verify the original hypothesis described above, a great deal of time and effort will be required, the majority of which must be left to future research. As a prologue to this research, this report will focus on the results that were obtained from our examination of the statistical significance of the indices that represent each knowledge layer versus product development performance indices.

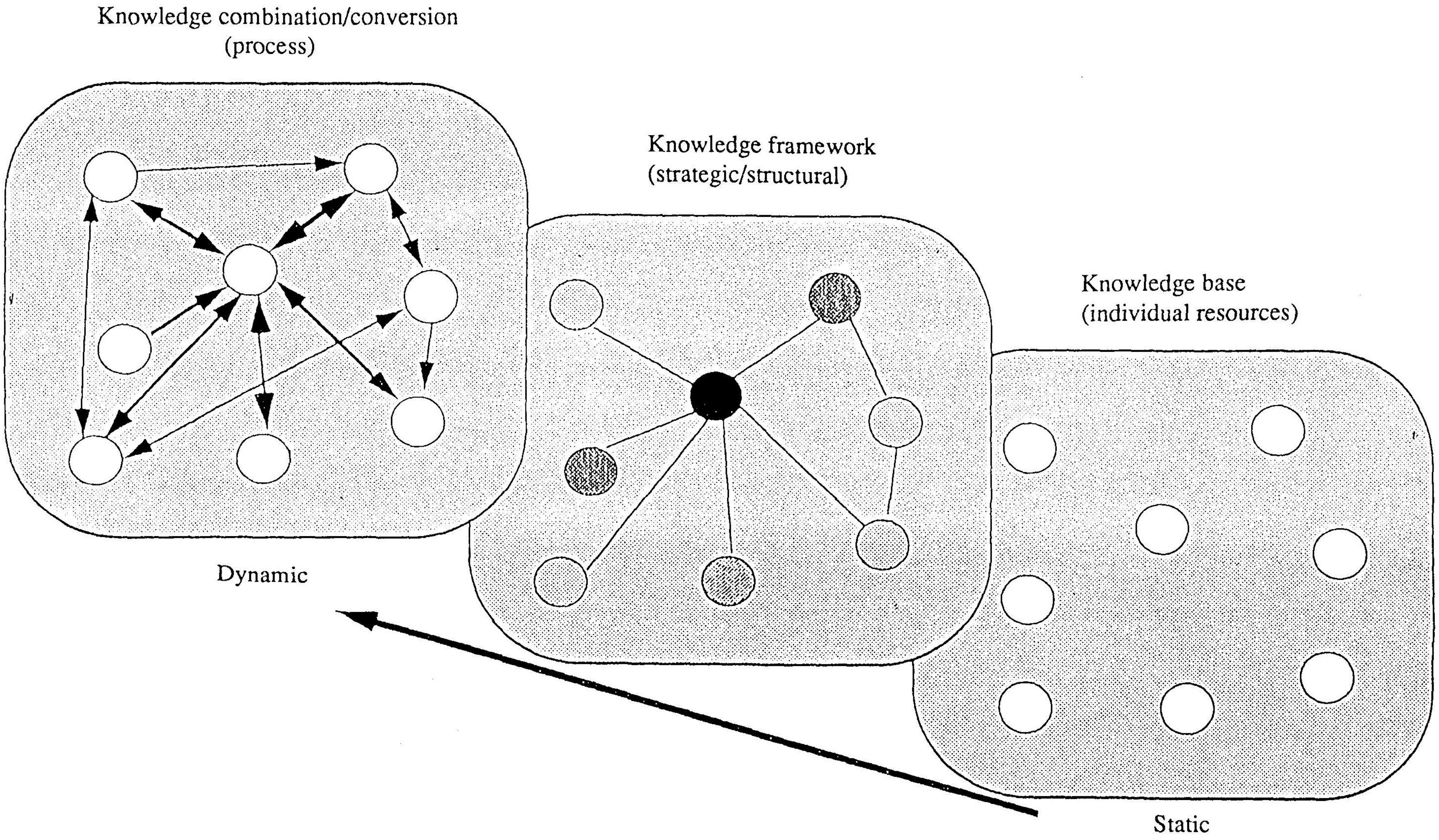


Fig. 2 Knowledge Layer Hypothesis

Source: Kusunoki, Nagata, Nonaka (1993)

3. Analysis Results

3-1. Factor Analysis of Product Development Performance

We first extracted the common factors leading to superiority in product development performance by performing a factor analysis, and then analyzed the characteristics of each knowledge layer that includes many of these common factors.

(1) Common factors

The results of our factor analysis using the 17 items of survey data concerning product development performance are described below. Based on the factor structure after rotation by Varimax method shown in Table 3, we can define five major common factors. The first factor concerns elements relating to profitability, as clearly contributions to sales and profits are common to successful performance. The second factor, concerning elements related to "accumulation of futuristic technology/know-how," "construction of management tools and research and development systems," "ripple effects in other product markets," and "growth of researchers and engineers," can be viewed as consisting of elements demonstrating capabilities for broad-ranging responsiveness. The third factor has a high correlation with "reduction of development costs" and "reduction of development periods," which indicates that this factor concerns the efficiency of product development itself. The fourth factor, based on elements related to "improving the level of functionality and quality" and improvements and revolutionary changes in specific parts of products, can be viewed as a factor that promotes incremental innovation. Finally, the fifth factor can be understood as a factor that accelerates radical innovation, as it involves elements concerning "broad-based breakthroughs" and "creation of unique product concepts."

(2) Product development performance and the knowledge base

First, we examined the relationship between the knowledge base and each of the factors that we had extracted. As an index of the size of the knowledge base, we used variables concerning the level of investment in research in terms of capital and personnel, the historical accumulation of development experience, and the number of patents possessed. Once we had calculated the average value for the factor scores for each response level category (1 to 7) for each of these variables, we found that the factor scores had a tendency to increase at higher response levels for all of the variables. In other words, the greater the possessed size of the knowledge base, the better the product development performance.

Next, for the sake of simplicity, we decided to examine only the level 7 factor scores and compare the relative importance of each variable with the development performance. (This same method is used in all of the analyses discussed subsequently.) Table 4 shows a summary of our results, from which the following observations can be made.

1) All common factors, except for radical innovation, have a positive correlation with level of investment in research in terms of capital and personnel, historical accumulation of development experience, and number of patents possessed. In other words, the emergence of radical innovation does not depend on the size of the possessed knowledge base as do the other types of development performance.

2) Of the three variables that indicate the size of the possessed knowledge base, the one exhibiting the strongest correlation with development performance is the number of patents possessed.

Table 3. Results of Factor Analysis of Product Development Performance (factor load after rotation by Varimax method)

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Contribution to sales	0.8861	0.0630	0.1574	0.1244	0.0632
Contribution to profits	0.8588	0.1098	0.2423	0.0839	0.1174
Advanced marketing	0.3853	0.2129	0.2088	0.1753	0.5112
Product cost reduction	0.3319	0.0453	0.3710	0.2169	0.0617
Improvement of functionality and quality	0.2448	0.1530	0.1538	0.6288	0.0298
Improvement in specific parts of products	0.1049	0.1479	0.1209	0.7687	0.0656
Revolutionary changes in specific parts of products	0.1226	0.2720	0.1080	0.5981	0.4147
Broad-based breakthroughs	0.1783	0.2819	0.2480	0.3053	0.5061
Reduction of development costs	0.1141	0.0952	0.7331	0.1526	0.1243
Reduction of development period	0.2521	0.0900	0.7543	0.1295	0.1390
Improvement of development investment efficiency	0.3306	0.2110	0.7482	0.0521	0.0652
Creation of unique product concepts	0.2349	0.4787	0.2519	0.0801	0.4511
Accumulation of futuristic technologies/know-how	0.1306	0.6193	0.1567	0.3059	0.2375
Ease and speed of transition to mass production	0.2430	0.2244	0.4093	0.1691	0.0224
Construction of management methods and research and development systems	0.2152	0.4869	0.3404	0.1084	0.0184
Ripple effect in other product markets	0.1089	0.5031	0.2013	0.1177	0.2052
Contribution to growth of researchers and engineers	0.0829	0.6223	0.1243	0.3512	0.1194

Table 4. Relationship Between Product Development Performance and the Knowledge Base

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Large investment in research in terms of capital and personnel	❍	❍	❍	❍	
Historical accumulation of development experience	❍	❍	❍	❍	
Possession of large number of patents	●	●	●	●	

Note: The ❍ indicates that the average value of the factor score at level 7 was between 0.1 and 0.2; the ● indicates that the average value was 0.2 or more.

(3) Product development performance and the knowledge framework

A similar analysis was performed concerning the characteristics of the knowledge framework. Fourteen data items concerning the development organization were used as the variables that indicate the characteristics of the knowledge framework. Table 5 shows a summary of the results of our analysis, from which the following observations can be made.

1) The first point to gain our attention was that items concerning the operation of a resilient organization, such as "flexibility to change system and management rules," and "system that can form emergency projects," and items concerning the systemization of the knowledge base, such as "system for systematic accumulation of know-how," and "system for creating a data base for problems," have a strong relationship with factors 1 through 4. These two sets of organizational characteristics are the essence of the hypertext organization mentioned earlier. In other words, these results provided verification of the fact that the organizational characteristics that result in superior product development performance provide systems that give rise to flexible project organizations independent of the normal hierarchical organization, and systems that systematically circulate throughout the knowledge base the knowledge and know-how gained through the development process.

2) While supplying engineers and development staff with "clear definitions of duties" is related to superior product development performance, "fractionalizing the development organization" according to each elemental technology is not always effective. In other words, it is vital to allow a certain amount of redundancy (i.e., a certain amount of leeway outside the boundaries of the elemental technology) among the duties of the members of the development organization, while at the same time supplying them with a clear definition of what those duties are.

3) "Rotation of engineers among fields of specialization" and "rotation among fields of function" have a complementary relationship. The former is related to the factors of improving profitability and development efficiency, while the latter is related to the factors of response capability and incremental innovation.

4) Having "authority for development department to assemble personnel" when necessary is related to superior product development performance, but performing "work that goes beyond development in its narrow sense" is not always effective. In other words, it is vital to provide organizational flexibility so that development departments can assemble staff, while at the same time it is essential to establish an environment that allows the person in charge of development to focus on the development work.

Table 5. Relationship Between Product Development Performance and the Knowledge Framework (Organizational Characteristics)

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Degree of fractionalization of the development organization					
Frequency of reforming of organizations			○		
Clear definitions of duties	○	○	○	○	
Flexibility to change system and management rules	●	●	●	●	
Rotation of engineers among fields of specialization		○		○	
Rotation among fields of function	○		○		
Continuity in terms of staff in next stage of product development					
Clear formation of development organization by departments					
System that can form emergency projects	○	○	○	○	
Authority for development department to assemble personnel	○		○	○	
Work authority of development department that goes beyond development in its narrow sense					
System for systematic accumulation of know-how	●	○	●	●	
System for creating a data base for problems	○	○	○	○	
Practice of shifting staff to the manufacturing departments					

Note: The ○ indicates that the average value of the factor score at level 7 was between 0.1 and 0.2; the ● indicates that the average value was 0.2 or more.

Table 6. Relationship Between Product Development Performance and Project Evaluation Items

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Development cost					
Development time					
Improvement of product functions and quality			○		
Technological newness	○	○	○		
Ease of transition to mass production					
Relationship with sales channels			○		
Match with user needs					
Contribution to construction of core technologies	●	●	●	●	○
Synergistic effects with other products	○	○	○	○	
Potential for long-term product expansion	○	○	○	○	

Note: The ○ indicates that the average value of the factor score at level 7 was between 0.1 and 0.2; the ● indicates that the average value was 0.2 or more.

In addition, we also examined project evaluations as one aspect of the special characteristics of the knowledge framework. Here we have analyzed in the same way the variables for importance for the ten items concerning evaluation of a project at its start and while it is in progress. From the results shown in Table 6, the following points can be observed.

1) The three evaluation items, "contribution to construction of core technologies," "synergistic effects with other products, and "potential for long-term product expansion," are related to product development performance in various ways. "Contribution to construction of core technologies" in particular has a strong relationship with factors 1 to 4, and of special interest is the fact that this item has an exceptional relationship with factor 5. While each of these three items has significance for project evaluation from a long-term standpoint, an evaluation designed to accomplish short-term objectives, such as "development cost," "improvement of product function and quality," and "ease of transition to mass production", on the other hand, is not necessarily linked to superior product development performance.

2) Evaluating "technological newness" is also essential for attaining diverse product development performance.

3) In order to attain development efficiency (factor 3), it is particularly important to perform multi-dimensional analyses.

(4) Product development performance and the knowledge conversion process

We next performed the same type of analysis on the knowledge layer in the product development process, or, in other words, the knowledge conversion process. While it is difficult to specify indices that represent the activity level of knowledge conversion, here we used as representative indices the variables that reflect the frequency of information exchanges within the development department and between departments.

Excluding direct contact with the user by the development department, the results in Table 7 show that all opportunities for information exchange are related to either all of factors one through four, or at least three factors. It seems impossible to attach positive or negative significance to information exchanges.

Table 7. Relationship Between Product Development Performance and Knowledge Conversion (Information Exchange)

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Between individual technical function departments	○	○	○	○	
Technical function department and development planning integration department	○	○	○		
Current development department and next development department	○	○	○	○	
Product development department and manufacturing department	○	○	○	○	
Product development department and marketing department	○		○	○	
Product development department and user					

Note: The ○ indicates that the average value of the factor score at level 7 was between 0.1 and 0.2; the ● indicates that the average value was 0.2 or more.

Table 8. Relationship Between Product Development Performance and Manner of Development Leader's Behavior

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Clarifies basic policies and concepts		○		○	
Creates own product concept					
Aggressively executes own ideas					
Emphasizes harmony among subordinates					
Makes aggressive choices regardless of risks	○	○	○	○	○
Respects initiative of subordinates	○	○	○	○	
Respects original and unconventional ideas					
Encourages spirit of competition among subordinates	●	●	●	●	○
Manages development progress in detail	○	○	○	○	
Faces debates with subordinates head on	○	○	○	○	
Accepts responsibility for failures of subordinates	○	○	○	○	
Treats subordinates as equals					
Has connections with top management					
Stands for interests of product development department					
Has strong influence with departments performing other jobs					
Aggressively interacts with departments performing other jobs					
Respects logical thinking		○		○	
Participates in work at development lab					
Walks around the development lab daily				○	
Spreads his own philosophy with conviction					

Note: The ○ indicates that the average value of the factor score at level 7 was between 0.1 and 0.2; the ● indicates that the average value was 0.2 or more.

Let's examine the representative index that reflects the activity level of knowledge conversion from another angle. In the promotion of knowledge conversion in the development process, the development leader in particular can be thought to play an important role as a catalyst. Therefore, we analyzed the relationship between development performance and the daily behavior of development leaders who had received good evaluations within the company.

From the results shown in Table 8, the following points can be observed.

1) The first point that gains attention is that behavior that exhibits respect for subordinates, such as "respects initiative of subordinates," "faces debates with subordinates head on," and "accepts responsibility for failures of subordinates", along with "encourages spirit of competition among subordinates" are all related to diverse product development performance. "Encourages a spirit of competition among subordinates" is also related to radical innovation. It is clear from this survey data that a company with a development leader who is superior at handling his subordinates achieves superior development performance.

2) In addition, another point that is apparent is that the behavior labelled as "makes aggressive choices regardless of risks" is related to all of the common factors, including radical innovation.

3) In addition to the above, response capability (factor 2) and incremental innovation (factor 4) are also related to the leader who "clarifies basic policies and concepts" and "respects logical thinking."

4) To achieve incremental innovation, it is also effective if the development leader "walks around the development lab daily."

3-2. Regression Analysis Concerning Product Development Performance

In the factor analysis described above, we studied the relationships between the common factors of product development performance and the knowledge layers for each layer. Next, we will compare the importance placed on each knowledge layer for development performance. In other words, we will regard the performance indices as dependent variables and the indices that represent the characteristics of each knowledge layer as independent variables, make an estimation of a double regression model, and study the significance of the regression parameters, allowing us to judge the relative importance among the independent variables.

The original series data for the performance indices is integrated into five variables according to the factor patterns that were made clear by the previous factor analysis, and then data based on the average values of the responses for each sample are used for the dependent variables. Three knowledge base indices, five knowledge framework indices, and four knowledge conversion indices were selected as the independent variables. (See note 2 for Table 9.) Just like the dependent variables, the knowledge framework indices and the knowledge conversion indices are integrations of multiple variables; the integration patterns are based on the results of the factor analysis performed separately on each item group.

Table 9. Results of **Multivariate Regression Analysis**

Independent variables \ Dependent variables	Profitability	Response capability	Development efficiency	Incremental innovation	Radical innovation
Knowledge base					
Research expenditures/research personnel	0.05	0.03	0.03	0.04	0.01
Historical accumulation of development experience	0.01	0.06	0.03	0.10 (**)	0.05
Patents	0.07	0.04	-0.02	-0.00	0.11 (**)
Knowledge framework					
Personnel rotation	-0.01	0.08 (*)	0.17 (**)	0.01	0.05
Structuring of development organization	0.03	-0.01	-0.02	-0.00	-0.01
Data base system	0.03	0.08 (**)	0.03	0.04	0.06
Emergency project system	0.09 (*)	0.00	0.12 (**)	0.04	0.12 (**)
Flexibility of development organization	-0.05	-0.01	-0.04	-0.04	-0.03
Knowledge conversion					
Information exchanges within the development department	0.21 (**)	0.04	0.08	0.13 (**)	0.04
Information exchanges between development departments	0.13 (*)	0.08 (*)	0.09	0.15 (**)	0.09 (*)
Flexibility of the development process	-0.02	-0.06 (*)	0.04	-0.06 (*)	-0.03
Creation of prototypes	0.10	0.11 (**)	0.11 (**)	0.07 (*)	0.16 (**)
Final coefficients	0.14	0.20	0.18	0.25	0.26

Note 1: The numeric values are the partial regression coefficients. "**" indicates significance with a discard range of 1% as standard, and "*" indicates significance with a 5% standard.

Note 2: The dependent and independent variables are average values for each sample for which the original series data was integrated as shown below. The integration patterns follow the factor patterns that were obtained from the results of the factor analysis. However, the original series data was used as is for the variables belonging to the knowledge base.

Integrated data	Original series data
Profitability	Contribution to sales Contribution to profitability
Response capability	Accumulation of futuristic technologies/know-how Ripple effect in other product markets Contribution to growth of researchers and engineers
Development efficiency	Reduction of development costs Reduction of development period Improvement of development investment efficiency
Incremental innovation	Improvement of functionality and quality Improvement in specific parts of products Revolutionary changes in specific parts of products
Radical innovation	Advanced marketing Broad-based breakthroughs Creation of unique product concepts
Personnel rotation	Rotation of engineers among fields of specialization Rotation among fields of function
Structuring of development organization	Degree of fractionalization of the development organization Clear definitions of duties
Data base system	System for systematic accumulation of know-how System for creating a data base for problems
Emergency project system	Emergency project system Authority for development department to assemble personnel
Flexibility of development organization	Frequency of reforming of organizations Flexibility to change system and management rules
Information exchanges within the development department	Between individual technical function departments Technical function department and development planning integration department Current development department and next development department
Information exchanges between development department	Product development department and manufacturing department Product development department and marketing department Product development department and user
Flexibility of the development process	Frequency of changes in basic policies during the development process Frequency of changes in designs and specifications in the development process
Creation of prototypes	Effort to create prototype early Effort to make transition to mass production through test production line, etc.

Table 9 is a summary of the estimated results of the regression model using the 12 independent variables with each of the dependent variables. From these results, the following points can be observed. (See notes.)

1) One overall trend is that the congruence of the variables concerning knowledge conversion is high compared with the variable groups for the other knowledge layers. In other words, the dynamics of knowledge conversion are especially important for the core competence of the company in product development activities.

2) Among the variables concerning knowledge conversion, "information exchanges between departments" and "prototype creation" in particular are significant for a variety of performance indices. It is also interesting to note that these two variables are also significant for radical innovation. "Information exchanges within a department" also contribute to profitability and incremental innovation.

3) "Flexibility of the development process" has a negative effect on response capability and incremental innovation. In other words, it is not a good idea to change basic policies and designs/specifications during the development process.

4) Of the variables concerning the knowledge framework, focusing on the items that reflect the essence of the hypertext organization reveals that: "emergency project system" is significant for profitability, development efficiency, and radical innovation; "data base system" is significant for response capability; and both share a complementary relationship. In addition. "personnel rotation" contributes to response capability and development efficiency.

5) Although the congruence of the variable group for the knowledge base is the lowest, "historical accumulation of development experience" is exceptionally significant for incremental innovation, and "patents" are exceptionally significant for radical innovation. The results of the tabulation of product development performance factor scores for each response level for these variables suggest that radical innovation has a low dependence on the knowledge base, but if the results are weighted in consideration of the independent variables for the layers other than the knowledge base, then the knowledge base has a relatively high level of importance for the emergence of radical innovation when compared with other types of development performance. In short, we cannot ignore that an accumulated technological foundation is clearly an important element of revolutionary ability.

4. Conclusions and Future Issues

A summary of the major points indicated by the results of our analyses is provided below.

1) There are five common factors concerning product development performance: profitability, response capability, development efficiency, incremental innovation and radical innovation.

2) The emergence of radical innovation does not depend on the size of the possessed knowledge base to the same extent as other types of development performance. However, it cannot be denied that the accumulated knowledge base is clearly an important element of revolutionary ability.

3) The organizational characteristics that result in superior product development performance provide systems that give rise to flexible project organizations independent of the normal hierarchical organization, and systems that systematically circulate throughout the knowledge base the knowledge and know-how gained through the development process. These two types of systems exist in a complementary relationship.

4) It is best to allow a certain amount of redundancy (leeway outside the boundaries of the elemental technology) in the duties of the development organization.

5) Rotation of engineers among fields of specialization and rotation among fields of function have a complementary relationship in achieving diverse development performance.

6) It is vital to provide organizational authority to development departments to assemble staff, while at the same time establishing an environment that allows the person in charge of development to focus on the development work.

7) Evaluations before and during a project should be performed from a long-term standpoint, such as the level of contribution to the construction of core technologies. Evaluations designed to accomplish short-term objectives are ultimately not linked to superior product development performance.

8) Superior development performance is attained under a development leader who respects subordinates while at the same time encourages a spirit of competition.

9) A development leader should clarify basic policies and concepts, and make aggressive choices regardless of the risks.

10) The core competence of a company that attains a high level of product development performance lies especially in the dynamics of knowledge conversion. Knowledge conversion is promoted by efforts to exchange information among departments and to create prototypes.

Through the analyses discussed in this paper, we were able to analyze the special characteristics of knowledge layers that result in superior product development performance, and also to observe the emergence characteristics of technological knowledge in product development activities.

However, our analysis has only just begun. In the future we will analyze in detail the mutual relationships between the knowledge layers and between the performance indices, while at the same time performing a similar survey and analysis on European and U.S. companies. We will then seek to combine the results of these analyses into a new universal descriptive concept of the knowledge creation process in product development activities.

Note: In Kusunoki, Nagata, and Nonaka (1993), a regressive model is estimated for which the dependent variables and independent variables were selected with foresight. The strategic significance gained from the summary of those estimated results, which was not pursued in this analysis, is summarized below:

1) Of the variables concerning the knowledge framework, the independence of the technological strategy (the self-sufficiency of the technology, etc.) was significant for several of the performance indices. In other words, the results suggested that good performance cannot be attained if technological resources are procured externally.

2) While noncontinuity of technological strategy had a positive effect on performance, noncontinuity in product development strategy had a negative effect. In short, the results suggested that technological strategy and product development strategy cannot both be viewed in the same light.

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Questionnaire on Dynamics of Technological Knowledge in Product Development Activities

Simple Aggregate Results

Science and Technology Policy Institute,
Science and Technology Agency

Example: Simple tabulation of the results for question 4 and beyond

Because this survey mainly asks for responses on a seven-point scale, for the sake of convenience we will form the responses into three groups, "1 to 2," "3 to 5," and "6 to 7," and show the structural ratio of the distribution of the responses. In other words, when the scale is used to represent evaluational responses to an item by means of cardinal numbers, the group "1 to 2" is used in tabulation for a response of "not true at all," "3 to 5" for "not sure," and "6 to 7" for "completely true." In addition, when the scale is used to represent evaluations of a relative nature between two opposing items, "1 to 2" is used as a vote for the item on the left, "6 to 7" for the one on the right, and "3 to 5" for neither. These responses can then be used to show a structural ratio of the frequency of the responses.

2. Features of Market of Products

Q4. This question relates to the environment surrounding your main product line. To what extent do the following statements apply to the situation in your company? Please circle the number you feel is appropriate.

		Not at all	... Can't say either way...	Completely so
(1)	Future technical trends are fluid and major technical innovations can be expected.	9.7	61.8	28.5
(2)	New product development and technical development are the keys to competitiveness.	2.3	30.7	67.0
(3)	The products and technologies constitute an extremely complicated system.	13.8	62.0	24.2
(4)	Product development and technical development require massive investments of capital.	12.4	63.5	24.1
(5)	The life cycle of products is short and newly developed products immediately become out of date.	16.1	58.8	25.1
(6)	All companies are engaged in fierce competition over product development.	4.5	42.2	53.3

3. Technical Strategy

Q5. This question relates to the technical developments behind product development. To what extent do the following statements apply to the state of technical development in the major product line in your company?

Compared with other companies, the following applies to technical development in our main product line:

		Not at all	... Can't say either way ...	Completely so
(1)	We invest a tremendous amount of capital and manpower in it.	12.0	65.6	22.3
(2)	We tackle issues in advance, and have a long history and substantial accumulation of technical expertise.	5.1	63.2	31.7
(3)	We have acquired a large number of patents.	13.3	68.8	17.9

Q6. Please indicate where the basic policy or strategy concerning technical development in your main product line (not specific product development) falls between each of the following pairs of statements.

		Can't say either way		
(1) Pursuit of leadership in technical development	27.1	61.6	11.3	Pursuit of merits as technical follower
(2) Positive introduction of technical findings developed outside the company	11.9	64.5	23.5	Emphasis on self-reliance in technology
(3) Technical development pursued based on specific long-term orientation	19.1	69.5	11.3	Orientation of technical development is fluid and basic policy line is frequently changed
(4) Emphasis on accumulation of technical know-how itself	7.8	50.2	42.0	Emphasis on commercialization of technology
(5) Positive attitude toward joint technical development with other companies	12.5	70.0	17.4	Technical development performed independently and autonomously
(6) Gradual development of new technology based on existing technology	40.3	55.6	4.1	Positive attitude toward fundamental rearrangement of technical foundation of company
(7) Comprehensive approach to all types of technology relating to main product line	13.2	64.6	22.2	Concentration of development capabilities in competitive core technologies and promotion of technologies derived from same
(8) Systematic accumulation of technology by the categories of constituent technologies (specialized fields of technology)	16.7	53.5	29.8	Flexible approach to key technical development based on intuition and surveys
(9) Focus on the logic of technology itself without being influenced by outside factors	2.8	49.0	48.2	Technical development considerably restricted by specific product development activities and demands from production and marketing

(10) Technical development steadily tackled in areas suited to accumulation of existing technology	17.4	67.9	14.7	Emphasis on future outlook even in areas where there is currently no accumulated technology

4. Product Development Strategy

Q7. The next question relates to the activities in your company regarding the development of new products (not technical development in individual technical function divisions). Please indicate where the basic policy or strategy of new product development in your main product line falls between each of the following pairs of statements.

		Can't say either way		
(1) Getting a new product on the market first	32.7	61.2	6.1	Catching up with new products developed by other companies
(2) Emphasis on technical novelty of products and improvement of technical functions	9.7	60.7	29.6	Emphasis on reducing costs and meeting market needs
(3) Emphasis on overall assembly of product and level of quality and function	22.8	67.2	10.0	Emphasis on giving product outstanding functions and features in specific areas
(4) Establishes consistent long-term orientation in developing product line.	18.6	68.9	12.6	Changes basic concept and policy of development with each product developed
(5) Repeated product development and continuous quick improvement of products	33.6	63.5	2.9	Achievement of product innovation during specific periods
(6) Emphasis on product development based on accumulation of existing technology	34.9	57.0	8.1	Technology for products developed according to need, based on principle of "new product development first"
(7) Immediate commercialization of results of development of individual element technologies	9.7	76.3	14.0	Conditions for commercialization of individual element technologies are linked with individual technologies and degree of perfection

(8) Product development carried out analytically, methodically, and systematically	16.3	69.5	14.2	Product development carried out fluidly and nonsystematically
(9) Development of one product finished completely before development of succeeding products and next generation products	9.8	61.5	28.7	Product development carried out with development of succeeding product overlapping considerably
(10) Sensitive response to trends in product development of other companies	40.9	55.0	4.1	Development carried out following "company's own way" without regard to trends in other companies
(11) Almost all components required for product development developed and produced in-house	26.1	64.9	9.0	Major reliance on supply of components developed and produced by other companies
(12) Product concepts of other companies strongly influence direction of product development	12.8	78.9	8.3	Results of development of individual element technologies determine direction of product development
(13) Emphasis on innovations and improvement of functions of specific portions of product or specific specifications of product	6.9	71.2	21.9	Emphasis on innovation and improvement of functions of product as a whole
(14) Concentration of development capabilities on specific development goals	20.2	66.2	13.6	Comprehensive pursuit of diverse development goals

5. Features of Product Development Organization

Q8. This question relates to the features of your product development organization. Which divisions, the "technical function divisions" or the "development planning oversight divisions," have the power and leadership in new product development in your main product line?

Technical function divisions only	Both substantially the same	Development planning oversight divisions only
28.7	54.8	16.5

Q9. To what extent do the following statements apply to the features of the new product development organization in your main product line?

		Not at all ..	. Can't say either way ...	Completely so
(1)	The development organization is broken down into divisions in charge of element technologies (specialized fields of technology).	22.9	48.2	28.9
(2)	The organization is frequently changed to correspond with the development situation.	24.0	64.1	11.9
(3)	The nature and scope of the jobs which individual engineers and development staff are in charge of are clearly defined.	12.4	63.9	23.7
(4)	The system or management rules are newly set or revised in accordance with need.	14.7	69.7	15.6
(5)	There is active rotation of personnel so engineers experience a wide spectrum of specialized fields of technology.	28.2	66.1	5.6
(6)	There is active rotation of personnel enabling experience of a wide spectrum of fields such as production, sales, and marketing.	37.1	58.8	4.1
(7)	The development staff of one product continues the development of the next generation successor product.	10.1	64.7	25.2
(8)	The development organization is not clearly arranged by division, but constitutes a single mixed entity.	52.8	38.9	8.3
(9)	There is a system enabling quick formation of an independent emergency project or team from the ordinary line in accordance with need.	15.1	55.9	29.0
(10)	The development division is empowered to assemble the necessary manpower from different divisions.	45.4	49.8	4.7
(11)	The development division is empowered to proceed freely with work (research or prototypes) exceeding the narrow definition of development.	12.7	56.6	30.7
(12)	There is a system for accumulating know-how obtained in the development process.	17.7	70.3	11.9
(13)	There is a system for recording problems and findings after the end of a development project in order to build a data base.	26.5	61.0	12.5

(14) There is a system or custom of shifting development staff to the production, marketing, or other divisions after the end of a development project.	39.8	53.1	7.0

Q10. Does your company have an independent division in charge of basic research not aimed directly at product development? If so, please answer question 10-2 to inform us about your basic research division.

1.	No, we do not have a basic research division.	53.4
2.	Yes, we have a basic research division. →	46.6

Q10-2.

	Not true at all	... Can't say either way ...	Completely so
(1) The researchers in the basic research division and the researchers and engineers engaged in product development frequently exchange information.	10.8	52.1	37.0
(2) There is active rotation of personnel to transfer researchers and engineers from the basic research division to the development division.	19.3	70.5	10.2
(3) There is active rotation of personnel to transfer researchers and engineers from the development division to the basic research division.	27.3	67.4	5.3
(4) The findings of the basic research division contribute tremendously to the product development in the main product line.	12.5	63.3	24.3
(5) Issues of basic research are frequently suggested from the work of the development division and production division.	18.7	69.5	11.8

6. Organizational Features of Development Process

Q11. This question relates to the main decision-making body in the process of new product development in your main product line. When dividing product development activities into the following six stages, what kind of influence or initiative do the divisions mentioned below have in major decisions at each stage of product development? Please select the appropriate numbers from among the choices given below and write them in the blanks in the table.

Choices
1. No influence at all
2. Almost no influence
3. Not that much influence
4. Can't say
5. Some influence
6. Great influence
7. Very great influence

Division / Stages of product development	Technical Functions	Development Planning and Oversight	Production Divisions/ Factories	Sales and Marketing	Top Management
1) Development of product concept	3.2 37.3 59.5	4.8 29.9 65.3	45.7 51.1 3.2	5.2 37.5 57.3	10.1 35.4 54.6
2) Basic planning of product (determination of specifications etc.)	0.8 20.8 78.4	6.6 34.2 59.2	29.6 59.2 11.2	10.1 49.3 40.6	22.1 54.2 23.7
3) Concrete product development (design etc.)	0.5 13.6 86.0	10.0 48.3 41.7	17.2 62.5 20.3	24.2 57.7 18.1	28.0 55.4 16.6
4) Prototypes and testing	1.4 12.5 86.1	14.9 50.6 34.5	8.9 45.6 45.5	26.1 57.5 16.4	28.1 59.5 12.4
5) Development and design of production process	2.7 28.8 68.5	18.1 56.7 25.2	0.9 17.7 81.4	35.0 53.9 11.1	20.9 54.3 24.8
6) Marketing	6.6 55.6 37.8	10.1 50.8 39.1	12.7 47.9 39.4	1.6 13.2 85.2	6.4 32.0 61.5

Q12. In your main product line, to what degree time-wise do the different stages of new product development mentioned above overlap?

Proceed completely sequentially	Can't say either way	Proceed with large overlap
5.4	61.2	33.4

Q13. In your main product line, to what extent are the following items stressed as criteria for evaluation or checking when starting new product development or during the process of the development?

1 = Not considered important at all
4 = Can't say either way
7 = Considered very important

(1)	Development costs	3.4	45.0	51.6
(2)	Development time (schedule)	0.5	31.5	68.0
(3)	Improvement of functions and quality of product	0.6	23.2	76.2
(4)	Technical novelty	1.8	59.1	39.1
(5)	Ease of transition to production	2.5	56.4	41.1
(6)	Relationship to strengths in marketing and sales channels	1.7	46.8	51.5
(7)	Agreement with user needs	0.5	20.4	79.1
(8)	Contribution to creation of long-term core technology	5.2	78.6	16.2
(9)	Synergistic effects with other businesses and product lines in the company	7.8	72.9	19.3
(10)	Possibility of long-term product growth and business growth	3.1	63.6	33.3

Q14. This question relates to the degree of coordination of activities and the exchange of information among divisions in the process of new product development in the main product line of your company. How often are activities coordinated and information exchanged between the following divisions?

1 = Do not occur often at all
4 = Can't say either way
7 = Occur extremely often

Within the product development division			
(1) Between individual technical function divisions	4.2	52.8	43.1
(2) Between technical function divisions and development planning oversight divisions	3.7	52.6	43.7
(3) Between current product development division and next generation successor product development division	5.3	71.2	23.6
Between the product development division and other divisions			
(4) Product development division and production division	3.4	59.4	37.3
(5) Product development division and sales and marketing division	2.6	47.5	49.9
(6) Product development division and users	7.7	54.2	38.2

Q15. The next question relates to the need for coordination of activities among divisions and the exchange of information during the process of new product development. How often do problems or infighting occur which require coordination or exchange of information among divisions?

1 = Do not occur often at all
4 = Can't say either way
7 = Occur extremely often

Within the product development division			
(1) Between individual technical function divisions	8.2	67.7	24.1
(2) Between technical function divisions and development planning oversight divisions	5.8	66.0	28.2
(3) Between current product development division and next generation successor product development division	12.4	74.8	12.8

Between the product development division and other divisions...

(4)	Product development division and production division	4.6	58.3	37.1
(5)	Product development division and sales and marketing division	3.2	56.5	40.3
(6)	Product development division and users	10.8	60.7	28.6

Q16. This question relates to the methods by which divisions are coordinated to solve problems and by which information is exchanged. To what extent do the following statements apply to the way divisions of your company are coordinated as concerns your main product line?

			Can't say either way		
(1)	Coordination is through official reports and meetings.	16.1	65.3	18.7	Coordination is through daily discussions and other interaction.
(2)	Coordination is through exercise of official authority and organizational routes.	12.3	73.0	14.7	Coordination is informal and in an open atmosphere.
(3)	Coordination is through unilateral orders.	3.2	78.8	17.9	Coordination is through repeated dialogue between divisions.
(4)	Coordination comes after problems become concrete and specific.	8.9	73.2	17.9	Coordination is immediately performed as necessary even if problems are still vague.
(5)	Quick resolution or compromise is sought	16.7	79.0	4.3	Problem is thoroughly discussed even if it takes time.
(6)	Emphasis is on coordination and "harmony" of members.	11.3	82.7	6.0	It is considered important to actively bring out opposing opinions.
(7)	Persuasiveness based on a consistent line of logic becomes important.	6.3	81.9	11.8	Sharing of experience by "doing things together for now" becomes important.

Q17. To what extent do the following statements apply to the process of new product development in your main product line?

		Not at all	... Can't say either way ...	Completely so
(1)	The product concept and basic direction of development are sometimes frequently changed in the process of development.	17.1	72.4	10.6
(2)	Changes in design and specifications are frequently made in the process of development.	8.0	75.2	16.9
(3)	A strict evaluation is performed at each phase of product development.	11.8	72.7	15.5
(4)	The degree of documentation (reports, daily journals, plans, etc.) is high.	10.9	73.0	16.1
(5)	The backgrounds and personalities of the engineers and development staff are diverse.	6.5	80.0	13.5
(6)	Product development is promoted by strong leadership of a specific handful of "stars."	9.2	72.7	18.1
(7)	There is a competitive atmosphere among the divisions involved in product development and the development staff.	12.8	81.0	6.1
(8)	An effort is made to prepare a visible prototype at as early a stage as possible.	4.3	70.3	25.4
(9)	A prototype line is provided in the development division, or other steps are taken to start up production at an early stage.	11.5	71.2	17.3
(10)	Individual element technologies or components are smoothly assembled into products.	5.5	85.0	9.5
(11)	Positive use is made of computers (CAD, data bases, etc.).	10.1	60.0	29.9
(12)	Engineers engage in positive debates and exchange information with engineers of different specialized fields of technology.	8.1	76.6	15.3
(13)	Engineers stick to their own specialities.	8.3	76.0	15.8
(14)	A clear grasp is maintained of the relationship among individual element technologies and components.	5.1	84.7	10.3

(15) No clear distinction is made between new product development and development of individual element technologies. Rather, they are mixed together as one.	6.3	72.0	21.7
(16) Positive use is made of user information obtained from marketing surveys.	5.2	62.7	32.1

7. Leadership

Q18. What kind of things do you consider important for someone to become a leader of product development in your main product line? Please circle the number showing the degree of emphasis for each of the following:

1 = Not considered important at all
4 = Can't say either way
7 = Considered very important

(1) Achievements and experience as researcher or engineer in specific technical function division	2.6	48.5	48.9
(2) Achievements and experience in development planning supervision division	6.1	71.9	22.1
(3) Achievements and experience in factory and production division	14.7	75.9	9.4
(4) Achievements and experience in sales and marketing division	19.4	71.7	8.9
(5) Breadth of experience in diverse divisions	10.4	76.3	13.3
(6) Youth and freshness	12.0	76.5	11.5
(7) Clear philosophy and world view	15.0	72.2	12.7

Q19. The next question relates to the leader of product development in your main product line who is the most highly regarded in your company. How far do the following statements fit the daily pattern of behavior of that development leader?

	Not at all ...	Can't say either way ...	Completely so
(1) Keeps clear basic policy and ideas of product development	1.1	44.0	54.9
(2) Creates clear product concepts himself	1.6	47.4	51.0
(3) Moves aggressively to implement his ideas in the process of product development	0.6	49.7	49.7

(4)	Stresses harmony among subordinates	2.7	71.5	25.9
(5)	Makes daring choices without regard to risk	1.6	66.0	32.4
(6)	Respects initiative of subordinates	3.0	72.7	24.3
(7)	Respects unique and original ideas	4.7	75.9	19.4
(8)	Stirs up competitive spirit among subordinates	4.2	82.9	12.8
(9)	Carefully manages state of progress of development	5.0	73.1	22.0
(10)	Engages in thorough discussions with subordinates	1.3	64.6	34.1
(11)	Bears responsibility for failures of subordinates	2.7	54.4	43.0
(12)	Deals with each subordinate as "one of the gang" rather than as a "superior"	4.4	66.6	29.0
(13)	Has influence with the top management	3.3	58.7	38.0
(14)	Performs the role of representing the interests of the product development division	2.3	65.5	32.1
(15)	Has strong influence in other divisions (production and sales) as well	1.6	60.6	37.8
(16)	Aggressively goes out to interact with other divisions	1.1	52.3	46.6
(17)	Respects logical thought	1.6	59.8	38.7
(18)	Actively participates in work of own development section	1.6	49.1	49.3
(19)	Walks around development section on a routine basis	1.6	56.1	42.3
(20)	Enthusiastically preaches own philosophy	5.8	75.4	18.9

8. Evaluation of Product Development

Q20. How do you evaluate the results of recent product development in your main product line? Please answer for each of the following:

1 = Extremely poor/Not achieved at all
4 = Can't say either way
7 = Extremely good/Completely achieved

(1)	Contribution to sales	5.7	54.6	39.8
(2)	Contribution to profits	7.5	60.5	32.1
(3)	Creation of future markets (speed of timing of creation of markets)	5.8	71.5	22.7
(4)	Reduction of costs of products	3.5	76.5	20.0
(5)	Improvement of functionality and quality	0.9	67.3	31.7
(6)	Improvement of technology and functionality/quality in specific parts of products	1.1	61.4	37.5
(7)	Remarkable technology and innovation of functions in specific parts of products	1.5	71.5	27.0
(8)	Breakthrough in overall product or technology	4.3	79.0	16.7
(9)	Reduction of development costs	5.8	83.4	10.8
(10)	Reduction of development time	6.1	77.9	16.0
(11)	Improvement of efficiency of investment in development	7.1	78.9	14.0
(12)	Creation of unique, new product concept	5.8	73.2	21.0
(13)	Accumulation of future-oriented technology and know-how	3.5	73.4	23.1
(14)	Ease and speed of transition to production	3.8	77.6	18.5
(15)	Establishment and improvement of new management techniques and research and development system	7.7	84.8	7.5
(16)	Ripple effect to markets for other products	4.3	81.6	14.1
(17)	Contribution to growth of researchers and engineers	2.1	69.1	28.8