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Management Innovation for R&D Productivity Improvement

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In order to increase a corporate competitiveness, it is essential to improve R&D productivity. An R&D productivity is defined from an R&D management innovation point of view. Synergistic relationships are derived to show that a synergistic management is very important to improve the R&D productivity. The core technology program management of NEC is used to discuss several essential management functions for making the synergistic management effective.

R&D productivity, corporate competitiveness, synergistic management research productivity, project productivity, core technology program, synergy effect coefficient, quantitative measurement, contract model

Ⅰ. Foreword

Within less than 3 years, we have to leave the 20th century behind and to challenge various difficulties to make the 21st century a much productive age than that we have lived. We are experiencing dramatic environmental changes. They impose on us radical changes in the technology creation that is much more complex than the human race ever experienced. They demand radical technological innovations. To deal with such challenges, we have to innovate new R&D managements.

In the early part of the 1970's, facing the expornential increase of R&D investments in the semiconductor industry and polution problems, I proposed the concept of “symbiotic competition”[1] at the European R&D Management Symposium in 1972. The concept is that, in order to effectively utilize the world limited R&D resources for creating crucial generic technologies, it is desirable to collaborate among universities, industries and governments throughout the world. This is the symbiotic phase of symbiotic competition management. The application of generic technologies is competitively promoted by individual companies in order to meet market needs. This is the competitive phase of symbiotic competition management.

Highly industrialized countries are now facing a dramatic social structural change, from the industrial society to a highly information-oriented society. The nature of technological innovation, which had been aimed mostly on the productivity improvement of material goods and of their transport ever since the dawn of the first industrial revolution, is now shifting to the productivity improvement of knowledge creation, management and services. Heading toward a multimedia age in the 21st century, we have to create a further advanced new management to cope with such paradigm shifts.

This paper will first assume important functions for improving the R&D productivity and define the R&D productivity that is effective from an R&D management innovation point of view. Synergistic relationships are derived to show that a synergistic management is very important to improve the R&D productivity and to shorten the time of product development. The core technology program management of NEC is used to discuss the essential functions in order to make the synergistic management effective.

II. R&D Productivity Definition

In order to derive R&D productivity relationships, the following managerial functions are assumed based on my long practical experiences:

Assumption 1; The R&D productivity depends on how broadly generic technologies are applied to as many new products as possible.

Assumption 2; The broad usage of generic technologies depends on how deeply managements are knowledgeable about mutual correlations between market needs and technologies.

Assumption 3; Hence, the R&D productivity largely depends on the creativity of managements.

In the free market economy, the value of goods and services are determined by the market. The value defined by the industry is usually a wishful presumption. No matter how high-tech and high quality they may claim for their products, if they cannot sell, the products are not meeting market expectations. The market values of technology and product are low. The academic value of technology is not necessarily identical with that of the company. Hence, in order to define the R&D productivity from the management innovation point of view, the sales of products is appropriate for the output of R&D activity.

In the company business accounting, the R&D expenditure is treated as an indirect cost since it is difficult to allocate to each product. This makes difficult to evaluate the productivity of each research cases. When the book keeping of input and output was done by supporting staffs, it was almost impossible and nonsense to measure in detail. However, as the capability of computer advances so rapidly, it is no longer nonsense to measure in detail and to challenge R&D productivity measurement quantitatively; hence to feed back the measures to managers for creating better managements.

If we set P as the sales and α as the R&D contribution factor, αP is the output of R&D. A comprehensive corporate R&D productivity η_t is defined as

$$\eta_t = \alpha P / I = f\ (\eta_1,\ \eta_2,\ \eta_3,\ \eta_m,\ \eta_a) \quad (1)$$

where I is the total R&D investment; η_1, the research productivity; η_2, the development productivity; η_3, the product development productivity; η_m, the manufacturing productivity; η_a, the administration productivity. Since P is the sum of every product sales and I is the sum of every R&D project, αP and I are rewritten as

$$\alpha P = \alpha_1 P_1 + \alpha_2 P_2 + \alpha_3 P_3 + \cdots\cdots\cdots + \alpha_{(n-1)} P_{(n-1)} + \alpha_n P_n$$

$$I = I_1 + I_2 + I_3 + \cdots\cdots\cdots + I_{(n-1)} + I_n$$

The comprehensive corporate R&D productivity η_t is rewritten as

$$\eta_t = (\sum_{i=1}^{n} \alpha_i P_i) / (\sum_{i=1}^{n} I_i) \quad (2)$$

The comprehensive R&D productivity is useful for the top corporate management to evaluate an R&D performance; however, it is not adequate to improve the R& D management. Hence we shall modify the above definition and introduce a research productivity and a project productivity.

2. 1 Research Productivity

Except the mission oriented basic research that is often originated at the stage of product development to understand basic science for refining basic technology and for improving product yield and reliability, it takes many years before the outcomes of research activity contribute to product sales. Hence the research is aimed at creating new basic scientific knowledge and technologies, and eventually contribute to as many product developments as possible. In order to measure the productivity of research order No.1, its output must be the sum of its contributions to every product sales through various research and development projects.

Defining an equivalent sales contribution facor for all corporate sales as

$$\alpha_1 P = \sum_{i=1}^{n} \alpha_{1i} P_i \qquad (3)$$

where α_1 is the equivalent sales contribution factor of research order No.1, and α_{1i} is the sales contribution factor of research order No.1 to SBU (Strategic Business Unit) No. i. These factors are also named as the synergy effect coefficients.

The productivity of research order No.1 is defined as

$$\eta_1 = \alpha_1 P / R_1 = (\sum_{i=1}^{n} \alpha_{1i} P_i) / R_1 \qquad (4)$$

where R_1 is the total input to the research order No.1. The productivity increases as the number of summation (n) increases. It tells the importance of synergistic management in order to improve the productivity of research.

2. 2 Project Productivity

It is easiest to define and measure the productivity of final product development since such development is done by concentrating every possible engineering resources within a limited specified time period and its output is the sales of the developed product. Hence we define the productivity of such a project as a project productivity as follows:

project productivity of project No. 1

$$= P_1 / I_1 = {}_p\eta_1 \qquad (5)$$

where $P_1 = \varepsilon P_1 + {}_i P_1$, εP_1 is the project contribution on sales, iP_1 is the net income from the intellectual property rights produced in the project and I_1 is the total input of the project, necessary to complete the product development. I_1 is the sum of the direct input to the project, I_{10}, and the technology transfer cost of generic technologies from laboratories and other groups, I_1g. Hence the project productivity of project No.1 is rewritten as

$${}_p\eta_1 = (\varepsilon P_1 + {}_i P_1) / (I_{10} + I_{1g}) \qquad (6)$$

If the product development is completely confined within the project and all necessary technologies are developed in the project, the input $\overline{I_1}$ is $\overline{I_{10}}$ and

$$\overline{I_1} = \overline{I_{10}} > (I_{10} + I_{1g}) > I_{10} \qquad (7)$$

As shown in Eq. 4, if the synergistic management is effectively coordinated, I_1g is much smaller than the cost expended in the project to acquire the same technologies. It is also clear that the time needed to complete the project is much shorter, when the project manager seeks broadly to utilize every available technical resources, than that usually takes, neglecting cross organizational collaborations. The popular management of concurrent engineering is a part of what we call the synergistic management.

III. Core Technology Program Management

At the Central Research Laboratories of NEC, the core technology program[2] was initiated in 1975, aiming to establish a technological strategy and to match it with the business strategy. In order to accomplish the objectives, the need was soon became apparent to create necessary generic technologies and to establish them by the time when the business divisions demand such technologies. Even though research managers have to identify probable future new product candidates far ahead of business plans, since the success probability of the future new product candidates is relatively low, the managers have to be alert to switch the target of technology application from a primary target to the next as the business climate changes. At the same time, he has to sell research outcomes to as many SBUs as possible. This management resulted in the synergestic management.

3. 1 Planning of Core Technology Program and Manager Education

Planning the core technology program, about 50 middle managers were concurently assigned to the R&D Planning Office in order to survey the trend of market and science and technology. Every SBU of the company and science and technology trends were surveyed and analyzed to draw correlation matrixes as shown in Fig.1 and to define the core technologies that support the current core businesses to be competitive for at least 10 years and emerging new businesses to grow as core businesses.

During the 2 years period of surveying and analyzing the market-technology matrix, the team members acquired significant knowledge on SBUs, their future and correlations between them and technologies. They also established sufficient contact points to form the synergy networks for better collaborations and technology transfers as shown in Fig.2 . It has been an excellent training ground for them and eventually for improving the R&D productivity.

3. 2 Determination of Synergy Effect Coefficient

The most important and difficult work of productivity measurement is how to determine the synergy effect coefficients or the contribution factors. Here I propose a method of determining the synergy effect coefficient.

Every applied research group goes marketing their R&D outcomes to as manySBUs as possible and transfer technologies to them. In order to improve the research productivity further, the cross organizational joint development projects have been organized to develop the core product models that can easily and quickly be refined to final products by SBUs. The values of technologies transfered and the costs of joint development projects have been tried to recover from SBUs. Up to now the negotiations have been made at various hierarchical levels depending on budgetary scales. Since the headquarters still taxes the business divisions for the administration costs, including the corporate R&D costs for future technologies, it is difficult to collect appropriate values of technology transfers. The Central Research Laboratories are now receiving about 35 percent of the total expenditure from the business divisions.

In order to make the technology sales easier and to evaluate the value of technology, I propose the use of computer networks and a virtual money system when the contracts of technology transfer and technical support are negotiated and closed. Figure 3 shows a research contract model between a research group and a SBU. A SBU engineer searches a technical solution through a technical information network. If the engineer finds an appropriate solution, he/ she negotiates the value of technology with a technology owner. When the both parties reach an agreement, the customer requests detailed technical information and service. The owner provides the agreed service and the both prties input the agreed value in terms of virtual money into the R&D productivity evaluation data base.

Tab. 1 shows an example of R&D productivity evaluation table. The equivalent sales contribution factor α is determined by using accumulated technology values. It is easily suspected that if the virtual money is used to value the technology, it is usually overestimated. However, as the productivity evaluation practice is matured, such errors can be reduced substantially since if the technology customer overestimates the technology values, the input to the product development project increases and the project productivity decreases. The technology sales in virtual money can be used to evaluate an equivalent research productivity prior to the research outcomes result in tangible sales.

Ⅳ. Management for Productivity Improvement

It is apparent from the R&D productivity rlationships that the productivity depends mostly on the management. How creative technology may be , if the market does not accept the prooduct using that technology, the vlue of that technololy in the company is almost nothing and the R&D productivity decreases. On the other hand, if the manager coordinates mediocre technologies to develop a very successful product, the value of that technology in the company is very high and the productivity increases.

Many laboratory managers tend to concentrate their management efforts to create very innovative technologies. It is very important to improve the technological potential; however, it is only a part of management responsibility from the R&D productivity improvement management point of view. As shown in Eq. 1, the R&D productivity is the comprehensive result of all organizations involved. Even though the research manager does not have direct responsibility on product marketing, he/she has to give supporting hands to marketing groups whenever necessary.

The management innovation for R&D productivity improvement calls for the serious need of reforming the conventional management philosophy. The manager has to recognize the following facts:

1. Product values and technology values are determined by the market,
2. The technology must be created to meet the market needs,
3. The R&D productivity depends on how broadly technologies are applied to as many products as possible,
4. The synergistic management improves the productivity, and
5. The R&D managers have to acquire the depth knowledge of market-technology correlations.

The R&D productivity is very difficult to measure quantitatively; however, we have to innovate a method of measuring the productivity quantitatively and have to challenge the improvement of management processes. The qualitative measure is still important; however, it is not suffice to innovate the management for meeting the drastic social reforms that we have been facing.

Ⅴ. Extension to Intellectual Works

The research and development is the most creative intellectual work. Hence the concept of R&D productivity and its quantitative measures can be extended to most intellectual works such as administrative office works and information services. Since the tangible values of intellectual works are very difficult to define quantitatively, it has long been avoided to define the productivity of intellectual works and the qualitative measures have been used to improve the effectiveness of the works. The R&D productivity was no exception.

If the key words in the management guidances for R&D productivity improvement, descrived in the previous chapter, are replaced by administration key words, they can be management guidnces for administration office productivity improvement as follows:

1. Service values of administration groups are determined by operating groups and are not the powers of controling operating groups,

2. The technology, especially management information technology, must be created and necessary information be assembled to meet management needs,
3. The administration productivity depends how broadly minimum necessary information is applied to assist as many as possible managements,
4. The synergistic management improves the productivity, and
5. The administration managers have to acquire the depth knowledge of business-management information correlations.

The administration service is essential to maintain the health of corporation; however, it is not directly related to the corporate business as the research activity is. The service should be aimed to improve the productivities of corporate top managements and of operating groups rather than suppressing the productivity of operating group by controlling them. The information networks of administration departmens are not well coordinated as yet and they often collect essentially the same information separate from operating groups by orders. Such uncoordinated data collections disturbe the work of operating groups and suppress their productivity rather than supporting the productivity improvement. If the management information data base system is well designed and cooperatively managed, the minimum necessary information can be shared and effectively applied to support top management needs and business operations. This greatly improves the administration productivity and hence the comprehensive corporate productivity.

REFERENCE

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Fig. 1 An exaxmple of market-technology matrix

CORRELATION TABLE BETWEEN CORE TECHNOLOGY AND MARKET

	Size	STD / Core Tech. / Market	Ⅰ				Ⅱ					Ⅲ • • •	
			a	b	c	d	e	f	g	h	i	j	• •
★	\Mill.	**1**	○	◎	○		○	◎	◎	○		◎	
★		**2**	○	◎	◎	○	◎	○	○			◎	
★		**3**	○	◎	◎	◎		◎	○		○	○	
¥		**4**		◎			○		◎	◎		○	
¥		**5**	○	◎					○	○	◎	◎	
¥		**6**	◎	◎		○			◎		◎	○	
?		**7**	○	◎	○	◎	◎	○	○	◎	○	◎	
X		**8**	○	◎					◎			◎	
		• • • •											

Fig. 3 Research contract negotiation through workflow network

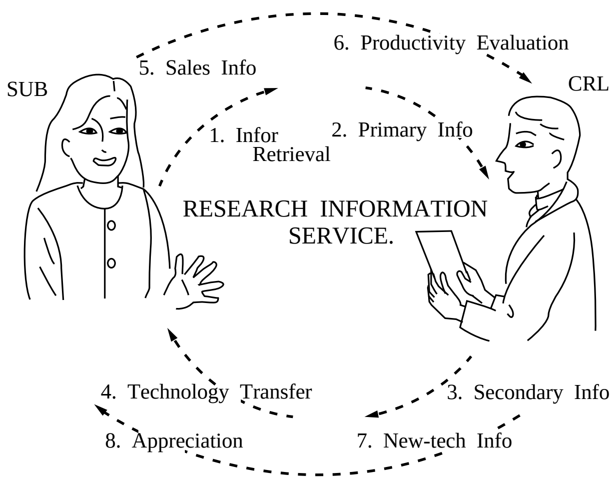
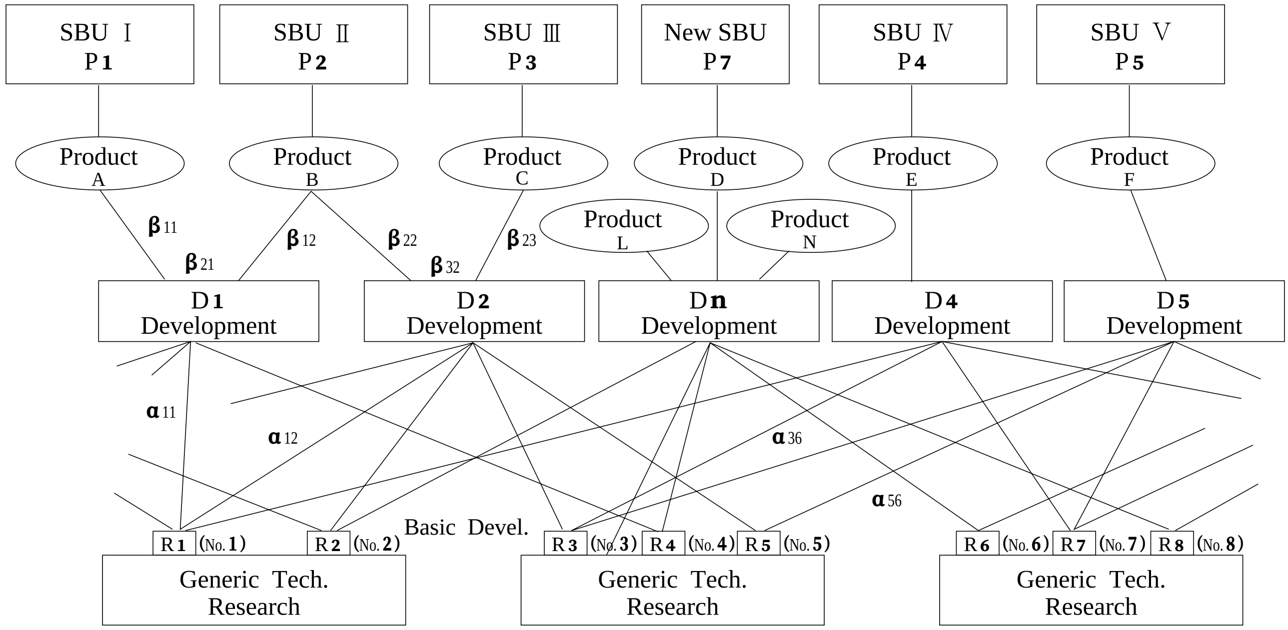


Fig. 2 Synergy networks of R&D activity



Tab. 1 An simulation example of research productivity measurement

Product Sales (P_1)	SBUs	Core Tech. 1 (Semicon)		Core Tech. 2 (Peri.)		Core Tech. 3 (Communications)		
		Memory	MPU	Patern	Voice	Massnedia	Network	VR
		R_1	R_2	R_3	R_4	R_5	R_6	R_7
335000	A SBU Prod. A	1000		9580	1000	1000	1000	
300000	B SBU Prod. B		15000	15000				15000
2310000	C SBU Prod. C		150000		10000	150000		
150000	D SBU Prod. D	3000		3000		3000	3000	3000
450000	E SBU Prod. E	15000						
220000	F SBU Prod. F	2000						
750000	I SBU Prod. K	25000	25000			25000		
200000	J SBU Prod. L	5000	5000		5000		5000	
R&D Output $\Sigma\alpha_1 P_1$		51000	195000	27580	16000	179000	9000	18000
R&D Input R_1		15000	120000	45000	25000	600000	9100	182000
Productivity η_1		3.4	1.63	0.61	0.64	0.3	1	0.1