Comparative Evaluation of Industrial Competitiveness of Japan, the United States, Europe and Asia: A New Framework of 'Symbiotic Competitiveness' for the 21st Century*

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The concept of industrial competitiveness, which emerged in the United States during the 1980s, has now become a critical issue for many countries. An intensive comparative survey on the industrial competitiveness of Japan, the United States, Europe, and Asia, was carried out in 1999 and 2000, and it clearly revealed each country's comparative strengths and weaknesses. The surveys cover 290 items of industrial technologies categorized in 14 fields from materials, devices, and system engineering, to production technology and management technology. This survey implies that management of technology (MOT), namely innovation management is a critical factor recovering and sustaining competitiveness. It should be noted that the paradigm shift of innovation management from the catch-up "incremental model" to the front-runner "radical model," requires completely different approaches. In this paper, a "cross-generational framework" for next generation innovation model is derived from the linear model to "market finding" Kline model, the to the third "market experiment abduction model" and finally to "market creation" interactive model. Furthermore, a new type of technologist, "techno-producers," who come up with creative objectives and coordinate the practical program to achieve the objective is proposed. The linkage among industry, academia and government, and their higher integration are critical important. Finally, this paper introduces an important concept of "symbolic competitiveness," a philosophical point of view that suggests a redefinition of the current concept of competitiveness for future world prosperity.

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I. INTRODUCTORY REVIEW OF COMPETITIVENESS

The concept of industrial competitiveness, which emerged in the United States during the 1980s, has now become a critical issue for many countries. In the United States, the President's Commission on Industrial Competitiveness began in 1983 to investigate the U.S.'s competitiveness and to advise the President. The first chairperson was John Young, then president of Hewlett-Packard Corporation. On January 15, 1985, the committee published its first report: *Global Competition: the New Reality*, which had a great impact on the U.S. industrial and technological policy. The Council on Competitiveness (COC), which was established in 1991, continued advising the government and industry on industrial competitiveness.¹ In 1999 Report, COC evaluated the competitiveness of each industrialized country as shown in Table 1, and the report strongly warned that although the present data for the United States were favoring the U.S. companies, it was time for the United States to realize that if there were no changes in the national policies and investment in research and technology development, the country might lose its position as a country of innovation within the following ten years.

TABLE 1. THE INNOVATION INDEXES

Rank	1980	1986	1993	1995	1999	2005
1	Switzerland	Switzerland	Switzerland	U.S.	Japan	Japan
2	U.S.	U.S.	Japan	Switzerland	Switzerland	Finland
3	Germany	Japan	U.S.	Japan	U.S.	Switzerland
4	Japan	Germany	Germany	Sweden	Sweden	Denmark
5	Sweden	Sweden	Sweden	Germany	Germany	Sweden
6	Canada	Canada	Denmark	Finland	Finland	U.S.
7	France	Finland	France	Denmark	Denmark	Germany

Source: "The New Challenge to Americas Prosperity: Findings from the Innovation Index" by M. Porter and S. Stern in COC, 1999.

In Europe, studies on competitiveness following the United States began. Germany, France, and Great Britain evaluated their technologies in order to improve their competitiveness. *World Competitiveness Yearbook*, published annually by the International Institute for Management Development (IMD) in Switzerland, has a different viewpoint on international competitiveness, which focuses on the potential of national infrastructure as a whole.

The latest IMD yearbook, published in 2002, concluded that Japan is facing a major decline in its overall competitiveness. One aspect that the yearbook focused on in terms of ranking the countries was each country's overall competitiveness. This

¹ See U.S. President's Commission on Industrial Competitiveness (1985); Reports of COC (1999) and (1994).

was based not only on technological competitiveness but also on the domestic economy, internationalization, government, finance, infrastructure, management, science and technology, and population. Another aspect is that its analysis covers an extremely wide range of criteria; the questionnaire collects both statistical data and opinion surveys, i.e., soft data that reflect the opinions of the executives of many different corporations. The respondents were mainly intellectuals like executive managers while this may or may not imply that the results are affected by economic fluctuations. A framework for evaluating competitiveness is introduced below.

FIGURE 1. FRAMEWORK OF COMPETITIVENESS INDEXES

Figure 1 shows a simple business model where industrial activities take place in a country in such a way that each company fosters its capability within the national infrastructure for better performance. The model shows the differences between the evaluations of each organization: While the IMD and World Economic Forum base their evaluations on the national infrastructure as its competitive potential, the COC bases its evaluation on performance. The IMD's index is designed to measure the effectiveness of the national environment in terms of promoting foreign investment. In other words, it measures the level of attractiveness of the country with regard to drawing investment from foreign countries. On the other hand, the COC focuses on the actual performance. Thus, no matter how stable the country's infrastructure is, if firms are not active, the performance turns out to be not as good as expected. From this particular point of view, Japan's performance has not yet declined as much as the IMD's evaluation predicted. This will be made clear later in this paper. Nevertheless, if the infrastructure on which corporate activities are based deteriorates and the base potential decreases, the corporations in the country will eventually decide to move out their manufacturing bases overseas. As the hollowing out of manufacturing sectors continues, domestic corporate activities will eventually suffer. As this discussion suggests, evaluation methods should be carefully chosen to meet situations and purposes. We should always keep in mind the inconsistency of self-evaluation, the possibility of misjudging cause-and-effect relationship, the risk inherent in the use of a unified index, and the purpose of evaluation. We should also be careful about what level of competitiveness we are looking at; corporate competitiveness or the overall com-

petitiveness of a whole nation.

It is necessary to clearly define what competitiveness means. In a project on "*Framework Conditions for Industrial Competitiveness*" conducted by the Organization for Economic and Co-operation and Development (OECD), a working definition of competitiveness was defined as "... the ability of companies, industries, regions, nations or supranational regions to generate, while being and remaining exposed to international competition, relatively high factor income and factor employment levels on a sustainable basis (OECD 1997)." According to Yoichiro Hara and other scholars, "international competitiveness" should be regarded as the "competitiveness that a nation has," and "competitiveness enables business sections based in a country to keep the country's advantageous position in both the domestic and world markets continuously from this present over to the future."

II. EVALUATION OF JAPAN'S INDUSTRIAL COMPETITIVENESS

In order to identify Japan's strong and weak areas with regard to industrial technology, and to collect fundamental data necessary for providing political advice on establishing strategies, we conducted surveys from 1999 to 2000. Using the collected data, we compared Japan with the United States, Europe and other Asian countries in terms of both technological and global market level. First, the industrial technologies were segmented into 290 items under 14 fields, covering various professional technology fields that include materials, devices, software and system engineering, production technology and management of technology. The respondents were corporate executive managers, researchers in universities, and corporate consultants.²

Outline of the Survey

The questionnaire sheets were sent to the chief technology officers of the member firms of Japan Techno-Economics Society (JATES), who were able to deliver the sheets to the suitable technical planning and research and development (R&D) management staff in the corporate headquarters or technical management staff in different divisions. As the evaluation categories and questions were widely ranged, respondents were asked to respond to the questions on the areas or items strongly related to their responsibilities. They were also given opportunities to provide opinions on the area; beyond their expertise and other business areas of the companies they represented.

The questions covered every aspect of industrial technology from new materials, devices, systems, software, services, and production systems to management technologies including human resources. In terms of major industrial technologies or products, we compared Japan's product competitiveness with that of the United States, Europe, and other Asian countries, both in the technological potential and the product market.

² For the details, see Japan Research Institute, 2000; Japan Machinery Federation, 1999; and JATES, 1994.

TABLE 2-1. INDUSTRIAL TECHNOLOGIES (1/2)

Item No.	Item Name	Item No.	Item Name	Item No.	Item Name
1. NM (new material)					
1	NM01 High function metal	51	EM09 New plastic technology of metal and composite material	101	SW16 Super-parallel architecture
2	NM02 High function polymer	52	EM10 Molecular and precise control technology	102	SW17 Integrated software for machine control system
3	NM03 Surface thin layer technology	53	EM11 Evaluation, analysis, and instrumentation	103	SW18 Cooperated development technology of software
4	NM04 Fullerene	54	EM12 Design and simulation technology	104	SW19 High function robotics
5	NM05 High-tensile steel	55	EM13 Optical reactive process technology	105	SW20 CAD/CAM software
6	NM06 Amorphous alloy	56	EM14 Limit environment creation technology	106	SW21 Digital cash (IC card) system
7	NM07 Superconducting material	4. ED (electronic device)		107	SW22 Software engineering
8	NM08 Fine ceramics	57	ED01 Logic LSI	108	SW23 Agent technology
9	NM09 Advanced glass	58	ED02 Microprocessor	109	SW24 JAVA
10	NM10 High molecule separation film	59	ED03 Mass semiconductor memory	110	SW25 Middleware
11	NM11 Engineering plastic	60	ED04 System LSI	7. CS (information communication equipment and system)	
12	NM12 Composite material	61	ED05 Semiconductor manufacturing process technology	111	CS01 Wide-band communication
13	NM13 Non-linear photoelectric material	62	ED06 High frequency device	112	CS02 Optical communication
14	NM14 Ferromagnetic material	63	ED07 Intellectual sensor	113	CS03 Communications satellite
15	NM15 Molecular function material	64	ED08 Actuator	114	CS04 Digital satellite broadcasting
16	NM16 Supermicrochemical advanced composite material	65	ED09 Micro/nanotechnology	115	CS05 Portable mobile communication terminal and system
17	NM17 New alloy and intermetallic compound	66	ED09 Electronic packaging and interconnection	116	CS06 CATV
18	NM18 Hydrogen absorbing alloys	67	ED10 Laser technology	117	CS07 Technology for ATM switching system
19	NM19 Material of new function carbon system	68	ED11 Optical fiber	118	CS08 Next generation high-speed mass LAN (G bit)
20	NM20 Silicon chemical material	69	ED12 Semiconductor laser	119	CS09 The next generation Internet
21	NM21 Catalyst	70	ED13 CCD	120	CS10 Efficient router
22	NM22 Protein coating	71	ED14 Superconducting device	121	CS11 The backbone net
23	NM23 Material modeling theory and use	72	ED15 Quantum device (single electron, super-lattice, etc.)	122	CS12 LAN
2. BT (biotechnology)		73	ED16 Power electronics element	123	CS13 ITS (communication)
24	BT01 Gene conversion technology	5. IT (information equipment and system)		124	CS14 Information security technology (code etc.)
25	BT02 Creation of high function ferment	74	IT01 Super computer	125	CS15 Tele-working systems
26	BT03 Flora and fauna cell engineering	75	IT02 Personal computer	126	CS16 Digital cash communication system
27	BT04 Building bio data bank	76	IT03 Wearable computer	127	CS17 Ground wave digital broadcasting
28	BT05 Search and separation of new natural genetic resource	77	IT04 Video server	128	CS18 Key network
29	BT06 Highly developed use technology of in vivo reaction	78	IT05 Biocomputer	129	CS19 Access network
30	BT07 Biofunction imitation material	79	IT06 Printer	130	CS20 Notice assignment of digital contents
31	BT08 Bio Chemical technology	80	IT07 Scanner	131	CS21 Generative platform for information contents
32	BT09 Bio process separation and refinement technology	81	IT08 Magnetic storage	132	CS22 Extra system of Intranet
33	BT10 Creation of bioactivation protein	82	IT09 Optical memory	133	CS23 Concept of communication service
34	BT11 Bio-compatibility material	83	IT10 Magneto-optical disk	134	CS24 Electronic commerce (EC) system
35	BT12 Human genome analysis (making to DB)	84	IT11 Flat panel display	8. CA (information appliance)	
36	BT13 Synthetic medicine creation technology	85	IT12 PCK system	135	CA01 Digital video (steer.) camera
37	BT14 Human genome diagnosis (DNA chip technology etc.)	6. SW (software system)		136	CA02 DVD
38	BT15 Bioreactor	86	SW01 OS	137	CA03 High detailed TV broadcasting (HDTV etc.)
39	BT16 Biosensor	87	SW02 Up-to-date software development language	138	CA04 Electronic musical instruments
40	BT17 Genetic recombination (farm products)	88	SW03 Processor architecture	139	CA05 Home computer game machine
41	BT18 Brain science and technology	89	SW04 Client server architecture	140	CA06 Game software and animation
42	BT19 Biomechanical technology	90	SW05 Application software	141	CA07 Tapestry and extra thin type television
3. EM (electronic & optical material)		91	SW06 Large-scale application software	142	CA08 Stereoscopic television set
43	EM01 Silicon material	92	SW07 Modeling and simulation	143	CA09 Home robot (The nursing robot is excluded)
44	EM02 Gallium and arsenic	93	SW08 Computer graphics	144	CA10 Home network
45	EM03 Electronic packaging material	94	SW09 Pattern and speech recognition processing	9. EN (energy)	
46	EM04 Ferromagnetic material	95	SW10 Natural language processing	145	EN01 Applied technology of superconducting
47	EM05 Optical material	96	SW11 Data mining	146	EN02 Gas turbine (The cogeneration is included)
48	EM06 Material for optoelectronic memory	97	SW12 Intellectual optimization system	147	EN03 Fuel cell
49	EM07 Superconducting material	98	SW13 Human interface	148	EN04 Up-to-date electricity supply system
50	EM08 Atomic precise control technology	99	SW14 Independently integrative information processing technology	149	EN05 Solar heat energy technology
		100	SW15 Information processing on intranet/network system	150	EN06 Photovoltaic generation

TABLE 2-2. INDUSTRIAL TECHNOLOGIES (2/2)

Item No.	Item Name	Item No.	Item Name	Item No.	Item Name
151	EN07 New primary cell	201	EV10 Biodegradable plastic	261	PD21 CAD/CAM application
152	EN08 Wind power generation	202	EV11 Desalination device of sea water	262	PD22 Superplasticity processing
153	EN09 Biomass	203	EV12 Removal technology of mine and a kind mine	263	PD23 Super cleanliness technology
154	EN10 Large-scale particle accelerator	204	EV13 Detoxification and reproduction of pollution soil	264	MG (management, maintenance, and safety)
155	EN11 Nuclear power generation technology	205	EV14 Nuclear waste treatment technology	265	MG01 Standardization
156	EN12 Highly effective electric generating system	206	EV15 Maintenance engineering	266	MG02 Intellectual property management
157	EN13 Electricity storage system	207	EV16 Quiet engineering (noise measures etc.)	267	MG03 Research and development of commercializer
158	EN14 Geothermal power generation system	208	EV17 Overall ecological monitoring	268	MG04 Concept creation of new goods
159	EN15 Sodium solar battery	209	EV18 Desulfurization technology	269	MG05 Integrated project management
160	EN16 Fossil electric power generation	210	EV19 Removal technology of suspended particulate matter	270	MG06 Reclaiming
161	EN17 Tidal power and wave activated power generation	211	EV20 Gas turbine, core, and nuclear reactor radiation	271	MG07 Security chain management
162	EN18 Integrated energy saving technology	212	EV21 Two-stage diesel and diesel gas-diesel engine	272	MG08 Outsourcing
163	EN19 Ocean power storage	213	EV22 Organic compound pollution control technology	273	MG09 Introduction of marketing, marketing, and manufacturing
164	EN20 Wave power generation/pumping and storage	214	EV23 Technology related to LCA	274	MG10 Government of Science, Government and Academia
165	EN21 Coal development technology (leading to gas)	215	EV24 Heating and air supply, hot steam, liquid, and steam	275	MG11 Business process re-engineering
166	EN22 New secondary cell	216	EV25 Inorganic liquid battery, metal electrode, and solid	276	MG12 Vibration system
167	EN23 Heat pump technology	217	EV26 Remote sensing	277	MG13 Regional industrial accumulation
168	EN24 Energy-saving technology for house	218	EV27 Watch technology using satellite	278	MG14 Management of Technologies (MOT)
169	EN25 Combined cycle technology	219	IF (traffic, construction, and infrastructure)	279	MG15 Knowledge management and knowledge center
170	EN26 Waste garbage power generation	220	IF01 Decrease of fuel consumption of engine	280	MG16 Engineer education and qualification system
171	EN27 Regional air conditioning system	221	IF02 Atomic hydrogen and high voltage discharge	281	MG17 System of engineer promotion
172	EN28 Decentralized energy system	222	IF03 Improvement of car recycling	282	MG18 International language education (English etc.)
173	ME01 Cancer treatment technology and medicine	223	IF04 Electric automobile and natural gas vehicle	283	MG19 Ethics in science and technology
174	ME02 AIDS treatment, prevention, and remedy	224	IF05 Hybrid car	284	MG20 Debate about ethical ideas etc.
175	ME03 Medical application imaging technology	225	IF06 Car navigation technology	285	MG21 Business model: The business process is reduced
176	ME04 Vascular endoscopes	226	IF07 JET	286	MG22 Corporate governance
177	ME05 Imaging diagnostic technology	227	IF08 Super high speed railway (Shinkansen)	287	MG23 New business development and commercialization
178	ME06 Remote medical treatment system	228	IF09 Vehicle control system (ABS, ASV, and SRS etc.)	288	MG24 Group management
179	ME07 Gene therapy	229	IF10 Unmanned new mobile system	289	MG25 Livelihood management: New response to disaster
180	ME08 Vaccine manufacturing from genetic engineering	230	IF11 Bridge construction	290	MG26 Global management
181	ME09 Self-diagnosis medicine	231	IF12 Tunneling technology	291	MG27 Improvement and reform management
182	ME10 Medical organ	232	IF13 High-rise building		
183	ME11 Medical application information	233	IF14 High-rise and high-speed elevator		
184	ME12 Nursing robot	234	IF15 Construction of mapping and location system		Adder from 1990
185	ME13 Information system for medical treatment and research	235	IF16 Airship technology		
186	ME14 Medical equipment and system for surgery	236	IF17 Rocket for satellite launch		
187	ME15 Antibody medicine	237	IF18 Engine for aircraft		
188	ME16 Life improving medicine	238	IF19 Space use technology		
189	ME17 Genetic disease genome analysis medicine and	239	IF20 Sea structure		
190	ME18 Organ transplant	240	IF21 Oceanic development		
191	ME19 Reproduction medical treatment	241	IF22 Resource inquiry		
192	EV (environmental engineering)	242	PD (production engineering)		
193	EV01 Desulfurization and NO removal system of engine smoke	243	PD01 Precision bearing		
194	EV02 Numerical value processing and control technology	244	PD02 High-speed machining		
195	EV03 Numerical value processing and control technology	245	PD03 Laser processing machine		
196	EV04 Waste plastic recycling technology	246	PD04 Super precision metal mold		
197	EV05 Bio-processed	247	PD05 Precision manufacturing technology		
198	EV06 Uniform distribution measures technology	248	PD06 Non-Destructive Inspection		
199	EV07 Carbon dioxide stabilization technology	249	PD07 Assembly model		
200	EV08 Sewage disposal and reuse technology	250	PD08 High-speed prototyping		
201	EV09 Wastewater treatment and utilization of microphile	251	PD09 LDM/MSCAR		
202	EV10 Wastewater treatment and utilization of microphile	252	PD10 Low pollution system automobile exhaust gas		

We also took the development processes, market conditions on entry, and market size and profitability for each item into account. The questionnaire was sophisticated enough to identify the critical technologies, which are the key to improving industrial competitiveness, and it was helpful in figuring out what factors brought the country the current level of competitiveness. The response sheets were designed to identify the leading corporations, universities, and research laboratories of each specialized technology. Tables 2-1 and Table 2-2 are the lists of the industrial technologies and products consisting of 290 items covering the 14 fields.³

Results of Survey and Analysis

There are two main scores for each country in JATES's survey; one is "level of technology"; and the other, "competitiveness in market." Each score is determined by the average of all item scores in the respective fields.

FIGURE 2. COMPETITIVENESS EVALUATIONS AMONG JAPAN, THE UNITED STATES, EUROPE, AND ASIAN COUNTRIES

Competitiveness in Level (Field Name)	Field (Mark)	U.S.		Europe		Asia	
		Present	Future	Present	Future	Present	Future
1: NM (New Material)	NM	0.4	0.4	0.8	0.7	1.6	1.5
2: BT (Biotechnology)	BT	-0.8	-0.6	-0.3	-0.1	1.3	1.2
3: EM (Electronic/Optical Materials)	EM	0.2	0.3	0.6	0.6	1.6	1.4
4: ED (Electronics Device)	ED	0.0	0.1	0.6	0.5	1.4	1.0
5: IT (Information Equipment/System)	IT	0.4	0.4	1.0	0.9	1.5	1.2
6: SW (Software/System)	SW	-0.8	-0.5	0.0	0.1	0.9	0.9
7: CS (Communication System)	CS	-0.6	-0.4	0.0	0.1	1.4	1.2
8: CE (Information Appliance)	CE	1.2	0.9	1.4	1.1	1.7	1.3
9: EN (Energy)	EN	0.2	0.2	0.2	0.2	1.4	1.2
10: ME (Medical Engineering)	ME	-0.6	-0.3	-0.3	-0.1	1.4	1.4
11: EV (Environment Engineering)	EV	0.2	0.3	0.0	0.2	1.3	1.2
12: IF (Traffic/Construction/Infrastructure)	IF	0.5	0.5	0.5	0.5	1.6	1.4
13: PD (Production Engineering)	PD	0.5	0.5	0.6	0.5	1.5	1.3
14: MG (Management/Human Resource, Etc.)	MG	-0.9	-0.5	-0.5	-0.2	0.6	0.6

³ For the details of each report, see JATES Report, 1999; 2000; and Kameoka, 1999; Kameoka et al., 1999.

Competitiveness in Markwt (Field Name)	Field (mark)	U.S.		Europe		Asia	
		Present	Future	Present	Future	Present	Future
1: NM (New Material)	NM	0.3	0.3	0.6	0.6	1.4	1.3
2: BT (Biotechnology)	BT	-0.8	-0.7	-0.3	-0.2	1.1	1.1
3: EM (Electronic/Optical Materials)	EM	0.4	0.4	0.7	0.6	1.4	1.2
4: ED (Electronics Device)	ED	0.0	0.0	0.6	0.5	1.1	0.8
5: IT (Information Equipment/System)	IT	0.4	0.3	1.0	0.9	1.2	0.9
6: SW (Software/System)	SW	-0.9	-0.6	-0.1	0.1	0.9	0.9
7: CS (Communication System)	CS	-0.8	-0.6	-0.1	0.0	1.2	1.1
8: CE (Information Appliance)	CE	1.3	1.0	1.4	1.2	1.7	1.1
9: EN (Energy)	EN	0.0	0.1	0.1	0.1	1.2	1.0
10: ME (Medical Engineering)	ME	-0.7	-0.4	-0.5	-0.2	1.2	1.3
11: EV (Environment Engineering)	EV	0.1	0.2	0.0	0.2	1.2	1.1
12: IF (Traffic/Construction/Infrastructure)	IF	0.4	0.3	0.4	0.3	1.4	1.2
13: PD (Production Engineering)	PD	0.4	0.4	0.5	0.4	1.3	1.1
14: MG (Management/Human Resource, Etc.)	MG	-0.8	-0.5	-0.4	-0.2	0.5	0.5

Source: JATES, 2000.

Figure 2 shows that the level of technological competitiveness of Japan is slightly lower than that of the United States, but the gap will be narrow in the future. Compared to the European countries, it has a modestly higher level in most of the cases. Japan has much higher score in every area than other Asian countries though the gap will likely to become narrow in the future. In the area of Consumer Electronics (CE), Japan holds an extremely strong position and is strong in Production Technology (PD) as well; in the field of New Materials (NM) and Electrical Devices (ED), Japan is relatively strong. In the field of Infrastructures (IF) such as traffic systems and environment, Japan is comparably strong and will improve performance in the near future. However, in Biotechnology (BT), Software Development (SW), Communication Systems (CS), and Medical Engineering (ME), Japan is relatively weak compared to the leading countries. Figure 3 shows the technological levels according to each country's strengths and weaknesses.

This survey introduced the field, which is categorized as "Management Technology and Human Resources (MG)," by taking up such new items as managerial methodologies and practical skills and techniques. It is worth pointing out that the survey shows the weakness of Japanese companies in management and human resources, which contrasted the prior survey results praising Japanese management systems. The result

of the global comparison shows that in this field, Japan scored lower than it did in any other fields. The items in which Japan keeps almost the same level as the United States and the European countries do are R&D commercialization (266), integration of R&D, product design and production (272), and technologist-training systems (280). However, in the items such as standardization (264), management of intellectual property (265), integrated project management (268), benchmarking (269), supply-chain management (270), knowledge creation (278), and systems for cooperation among the industrial, governmental, and academic sectors (273), Japan is considerably inferior to the United States. The field shows a much smaller gap between Japan and the rest of Asia. Moreover, Japan is behind in foreign language education (English, for instance). In terms of "venturing system (275)," which is one of the hottest current items, Japan's potential is just about the same as that of other Asian countries.

FIGURE 3. COMPETITIVENESS OF JAPANESE INDUSTRIAL TECHNOLOGIES

Source: JATES 2000.

It is obvious that in the critical items that determine competitiveness, such as "management of technology (MOT)" and "corporate strategy," Japanese companies will have to face the problematic points. Accordingly, improvement of the quality of technology management should be seriously taken into account. The management of technology should be regarded as the most important factor as Japan seeks to recover world competitiveness.

Through the survey results, it can be concluded that the average potential level of Japan can best contribute to the future world economy by making the optimal combination of the complementary technologies. The problems lie in the lack of strategic goal setting and management system, as well as the underlying social structure that promotes new innovations. The country would be able to have more opportunities

to contribute to the world economy by overcoming these problems.

III. A CROSS-GENERATION FRAMEWORK: NEW INNOVATION PROCESS MODEL

How to generate a new innovation is the key factor in obtaining competitiveness. Stephen Kline proposed a chain-linked innovation model in 1985, which had a great impact on science and technology policy and corporate technology management, and challenged the traditional linear model of innovation, which had been accepted for many years (Kline 1985; Kline and Rosenberg 1986). The former is a technology-push model and the latter is a market-pull model.

A cross-generational synthetic framework, which is newly introduced here for better understanding of the innovation processes, suggests that the Kline model actually takes the place of the first linear model as the market grows mature. This framework is derived from the "market experiment" model in which new products or services can be detected only by having experiments in the real market. Further, it suggests a "market creation" model in which new products and services are created in the market by interactive synergy among consumers and producers. These future innovation models manifest a new type of technologist that I term "techno-producer," who plays an important role as an innovator in a highly advanced techno-flow market that is designed for such a complex future innovation process.

Paradigm Shift of Innovation Management

The paradigm of the management of technology in Japan is on the brink of an overall shift. How to create an original product target to generate a radical innovation is now the central issue for technology management. This is completely different in nature from the conventional management for incremental process. It is critically important to establish a new management system that surpasses the conventional style by focusing on concept creation and rapid and dynamic decision-making to achieve agile management. The linkage between research and technology development (RTD) and the corporate business strategy, RTD networking and outsourcing is extremely crucial in establishing a new management system. Higher integration of industry, academia and government are also important.

Among others, strategic planning for creating new innovations is important for Japan as well as for the world economy. The main focus of this paper is on the innovation model of the next generation, which will work more effectively in the intensive IT-related-knowledge based industry and society.

Innovation process is complex and uncertain. There have been a lot of arguments for many years about whether to choose the technology-push "linear model" or the market-pull "chain-linked model." Our primary concern in this paper is how to generate

new innovations in order to enhance industrial competitiveness and contribute to the world economy. Our interest in the study is to determine what kind of innovation model would become dominant in the future.

For this purpose, this paper proposes a cross-generational innovation model that suggests a future direction, and a new type of technologist called a “techno-producer,” whose main role is to set creative objectives and coordinate the practical programs with technology-based innovator. The goal of the techno-producer should be to achieve the innovative objectives in a “highly advanced techno-flow market” that should be provided as a social infrastructure to enhance technological knowledge transfer based on the market mechanism.

Linear Model to Kline Model

The “linear model” of innovation has been widely spread among scientists, engineers, corporate management, and many other people in various countries. This model puts the “research” activity ahead of the innovation process and the ‘development’ process comes after the “research” activity. Then, it leads to the “production” and finally to the “marketing” process, as shown in Figure 4.

FIGURE 4. LINEAR MODEL OF INNOVATION

Kline and Rosenberg (1986) proposed a new “chain-linked” innovation process model against the conventional “linear model” accepted for many years. Innovation is complex, uncertain, somewhat disorderly, and subject to changes of many sorts. Innovation is also difficult to measure and demands close coordination of adequate technical knowledge and excellent market judgment in order to satisfy economic, technological, and other types of constraints—all simultaneously. The process of innovation must be viewed as a series of changes in a complex system not only of hardware, but also of market environment, production facilities and knowledge, and the social contexts of the innovation organization.

Figure 5 shows the “chain-linked model” that represents the central chain-of-innovation stemming from “market finding.” The path begins with a product concept based on the market finding. Then, the invention, analytic design, detailed design and test come after the first step. It continues through production, redesign, distribution and marketing, with feedback. The characteristics of this model are: first, the innovation process is engineering and it is separated from the research process of knowledge creation in the upper science layer; secondly, as the Kline model made clear, the starting point of innovation is the market finding; thirdly, it provides the feedback for the previous stages. The chain-link between the knowledge layer of research and the innovation process layer is very important.

FIGURE 5. CHAIN-LINKED INNOVATION PROCESS MODEL

The Kline model clearly explains the LCD display industry case of Japan, one of the typical examples of success in recent innovation that showed the importance of “demand articulation” in adjusting technologies to the market demands, as shown in Figure 6.

FIGURE 6. SPIRAL INNOVATION PROCESS OF LCD DISPLAY

Fumio Kodama named it a “trickle-up innovation” that continues market-driven innovation with such a spiral advancement process (Kodama 1991).

Cross-Generational Interpretation of the Innovation Models

The technology-oriented linear model and the market-driven chain-linked model have been discussed among many researchers from dichotomous viewpoints. However, it could be interpreted as one generation taking over another as the market grows over time. Accordingly, the linear model is interpreted as the first-generation model in this generational framework, and the Kline model as the second-generation model. In the first generation, market needs are obvious to the researchers and engineers when finding the technologies necessary to the demand. However, as the market grows and becomes mature in the second generation, careful market experiments and observations are necessary to find market needs. In the third generation, market needs can no longer be grasped only by observation but also by placing products on the real market as a trial.

The market matures stepwise from the first generation, "linear model," in which the market is self-evident, to the second generation, "Kline model," in which the market is found by observation, then to the third generation, "experimental model," in which the market is explored by market experiments.

Accordingly, this framework no longer treats the linear model and the Kline chain-linked model as dichotomous or conflicting perspective, but it puts them in the generational stage of market advancement.

FIGURE 7. A CROSS-GENERATIONAL INNOVATION PROCESS MODEL

Next Generation Innovation Model: A Cross-Generational Viewpoint

The recent case studies of Japanese innovations, such as the 'i-mode' mobile phone, Sony's PlayStation game, and their marketing strategies, provide good examples for the third experimental and fourth interactive models. These models comply with the recent marketing strategies using Internet websites to meet user's demand and create a new interactive platform equipped with interactive chances and places ("Ba" in Japanese) (Nonaka et al. 2001).

This implies that for an innovator to lead the next generational innovation, it is necessary for a person to be capable of generating such concepts by "abduction,"

a new way of thinking. Figure 8 shows a generational innovation process model, which proceeds from the third-generation “abduction model” to the fourth-generation “interactive model,” each of which requires a different type of innovation development management.

FIGURE 8. NEXT-GENERATION INNOVATION MODEL

In the third generation, market demands can no longer be determined only by observation but also by experimenting via placing some exploratory products in the market. As the market grows mature, its demands become weak and uncertain and it sometimes needs to be stimulated. In the fourth generation, new markets should be created. In other words, the market undergoes different stages from “self-evident market,” to “market finding,” to “market experiment,” and finally to “market creation” stage. It is safe to say that the types of innovation processes also change according to the market maturity. Thus, in the next generational models, the linear model and Kline model are no longer dichotomous in terms of “technology-push” vs. “market-pull” models. Instead, the maturity level of the market characterizes them. In order for a company to lead innovation in the third or fourth generation process, it must be able to generate new product concepts. This requires a new type of technologist called “techno-producer” as an innovator, who leads the creative activities needed for the market experiments and creation.

IV. STRATEGY FOR NEXT GENERATION INNOVATION SYSTEM

It is important for policy-makers and technology managers to have access to reliable databases, which show the level of science and technology and industrial competitiveness that are crucial for the formulation of strategic frameworks. For industrial and economic restoration, strategic goals and implementation of the programs must be set up first to quickly reflect the industrial sector.

JATES, for example, recently tried to promote this whole process aggressively with close cooperation with different types of industries by funding the Industrial Science and Technology Competitiveness Committee that would start a systematic approach

to develop industrial strategies (Li, Ishii, and Kameoka 2001). The basic concept of the committee installation was a triangular structure composed of three partners: supervisors of experienced intellectuals, corporate executives with knowledge in practice, and young core workgroups of technology managers to develop strategic programs.

Time for Techno-Producers to Prevail

A techno-producer, who sets up the strategic and creative goals for creating new industries, acts like a composer or conductor in an orchestra in the sense that he needs not only to generate new concepts and construct strategies but also to lead the process of innovation. Techno-producers, shown in Figure 9, play two roles of setting creative goals and leading the activities to achieve the goals.

FIGURE 9. TECHNO-PRODUCER

Techno-producers are asked to play their parts inside their corporate structures as well as across corporate boundaries to promote cooperation among the industrial, governmental, and academic sectors. It is important for a country to develop an innovation platform on which producers create their strategic concepts and participate in sharing strategic goals as actively as possible. To facilitate the activities, a sophisticated infrastructure has to be built to enhance the flow of technological knowledge across organizational and national borders. In order to promote this type of new infrastructure and to enhance technology transfer based on the market mechanism, a "highly advanced techno-flow market" should be established.

Shaping social infrastructure for R&D including these elements is very important for Japan to prompt itself to build a science-and technology-based nation as prescribed by the basic science and technology law established in 1999. It provides an effective way to avoid its economic stagnation and contribute more to the world economy,

by refraining from homogeneous and excessive competition in both knowledge-intensive information industry and traditional manufacturing industry.

According to the recent survey on industrial competitiveness, Japan has a great technological potential to improve its competitiveness in its industries, and thus has more chances to grow its market if techno-producers create strategic objectives and present inspiring targets. Although there are some weaknesses in Japanese industrial technologies, the nation's overall potential is strong enough to make valuable contributions to the world economy and prosperity.

Concept of Competitiveness for the 21 Century

At the beginning of the 21st century, it is worth taking a look at what competitiveness is for and what it should be like from a philosophical viewpoint. What is competitiveness? Hiroshi Inose raised a significant point that explains the concept of competitiveness. He wrote:

The word 'compete' derives from a Latin word "*competere*," The prefix "*com*" means "*together*," and "*petere*" means "*pursue*." Consequently, "*competere*" means to "*pursue together*." However, what is to pursue? The answer is human ideals. When people pursue ideals, they help each other and strive for goals together. In correcting errors and weaknesses, and acknowledging each other's insights and strengths, they see the true competitiveness. Thus, competitiveness should come from the power for self-discipline instead of the motivation imposed by commanding power, tricks, or fraud tactics, just because their purpose is to pursue human ideals (Inose et al. 2000).

He clarified an idea of "comprehensive competitiveness" by integrating the human and social sciences and the natural sciences, and proposed that this new concept of competitiveness based on the oriental *kyosei* thought would stimulate new thinking beyond the current western concept of competition (Kaku 1997). He said that Japan, from this time on, should always keep this new idea in mind and work to prompt people all over the world to understand this for their happiness in the 21st century (JATES 2000).

V. CONCLUSION

From the analysis based on the surveys, although there are some weaknesses in Japanese industrial technologies, Japan's overall potential is strong enough to make valuable contributions to the world economy. The results showed that the weaknesses were the lack of innovation management, which produces new concept products by linking available technologies, and the unawareness of the relationship between corporate

cultures and social environment that support the creative activities. These shortcomings could be remedied by improving the corporate knowledge of technology and innovation management. This becomes imperative because the basis of industrial competitiveness has started to shift from natural science and technology to humanities and new social infrastructure is needed to facilitate the flow of advanced technological knowledge.

The newly introduced framework of cross-generational innovation model is derived from the next generation innovation models; the "market experiment" model for the third innovation stage, and the "market creation" model for the fourth stage characterized by interactive platform. The next generational innovators are a new type of technologist, the so-called "techno-producers" who play a crucial role as concept creators, in a sophisticated national innovation system equipped with highly advanced technological knowledge.

Creating new industries by promoting innovations is critically important for a country to prosper. This paper provided a new approach to generate innovations, and introduced the basic concept of "symbiotic competition" with others to prodromote the world cooperation in the 21st century.

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