10. Manufacturing field

10.1. Overview

(1) Background

Japan, of course, is a country built on trade, importing raw materials, processing them, and exporting them to other countries. Skilled manufacturing is Japan's lifeblood. In the past, there was a time when simply manufacturing products was the goal, but as society progressed and manufacturing technology evolved, products that are durable, have outstanding design, or provide other added value have come to be demanded. It is no longer easy to stay ahead of China and other relatively low wage countries simply by manufacturing products.

Shifting the focus inside Japan, the existing trend towards an aging society with a low birthrate is accelerating, and future labor shortages are a concern. Many issues related to how to compensate for a labor shortage expected to reach 2 million workers by 2020 must be examined, from increasing the roles of women and the elderly while further saving labor with robot technology to accepting workers from overseas. Furthermore, considering the shift of young people away from manufacturing jobs, education system reform that points out the satisfaction of skilled manufacturing work should also be examined.

(2) The designation process and its meaning and importance

First, we will describe the characteristics of this analysis. Although the process for designating individual topics based on the study framework was the same as that of the 7th Science and Technology Foresight Survey, in the framework we set the terms with the "category" of manufacturing process on the horizontal axis and "relationship" to "purpose" on the vertical axis. In addition, within the framework, we set the area by bundling the individual topics. This resulted in setting the following 9 areas (with "other individual foresight topics" added to make 10).

1. "Manufacturing technology utilizing advanced information technology"
2. "Manufacturing technology using virtual design"
3. "Manufacturing technology for high-value added products"
4. "Nano-machining/micromachining technology"
5. "Recycling-oriented manufacturing technology with a low environmental load"
6. "Human and robot participation in manufacturing"
7. "Manufacturing technology in special environments"
8. "Advanced manufacturing technology for social infrastructure"
9. "Surface modification and interface control technology"
10. "Other individual foresight topics"

The first main point is that individual topics bundled as "information" in the previous survey are scattered in 5 different areas this time. "Manufacturing technology utilizing advanced information technology" is characterized by OS technology for manufacturing, remote control, on-demand manufacturing, and so on. "Manufacturing technology using virtual design" is characterized by research and development based on virtual spaces, etc. "Manufacturing technology for high-value added products" is characterized by tailor-made manufacturing and so on through high-mix, low-volume production with forecasting the need. "Nano-machining/micromachining technology" is characterized by ultra-precision

processing technology, net shape processing technology, and so on. "Human and robot participation in manufacturing" is characterized by upgrading robot technology through work and cognitive support.

Next, looking at "environment" and "energy," which were individual topics in the previous survey, we concentrated most of these in one area, "recycling-oriented manufacturing technology with a low environmental load," while "biology" and "welfare" were assigned to suitable areas. A further difference from the previous survey is the handling of manufacturing technology for heavy structures as "advanced manufacturing technology for social infrastructure." This manufacturing technology for steel, shipping, buildings, and other heavy structures is positioned as important infrastructure technology to maintain and build a safe and secure society. In addition, as "other" topics, we set individual educational topics such as technical education programs related to skilled manufacturing and elementary and middle school education emphasizing math and science.

(3) Results and policies

We will briefly summarize the expected current and medium-term impacts and Japan's research and development from the questionnaire survey results. First, the largest expected impacts either currently or in the medium term (2015–2025) are the contributions of "nano-machining/ micromachining technology" to increased intellectual assets and to the creation of new industries or businesses and the contribution of "recycling-oriented manufacturing technology with a low environmental load " to safe and secure society. In addition to the two areas above, medium-term expectations are high for areas such as "human and robot participation in manufacturing." The largest increase in expectations from the current time to the medium term is in "manufacturing technology in special environments" such as zero gravity environment. Fields with which manufacturing technology should collaborate over the coming 5 to 10 years are first, "information and communications" and second, "nanotechnology and materials." Underlying this is the extreme importance of their relationships with the manufacturing field.

Next, looking at Japan's R&D level, in areas related to information technology (IT), which was indicated as a field for collaboration over the coming 5 to 10 years, responses putting Japan behind the USA stood out ("manufacturing technology using virtual design" and "manufacturing technology utilizing advanced information technology"). Looking at the time axis, long-term fields, with which government should naturally be involved, are seen as suitable, but for manufacturing, the short-term topic of active government involvement in collaboration with the information sector is also seen as desirable.

In addition, the degree of importance index is calculated in the questionnaire survey as the degree of importance to Japan. According to this index, above-mentioned areas such as "recycling-oriented manufacturing technology with a low environmental load," "nano-machining/ micromachining technology," "manufacturing technology using virtual design," and "manufacturing technology utilizing advanced information technology" are among the leaders. Moreover, we note that three topics listed as "other" received high scores. They are "Implementation of a new elementary and secondary education scheme that emphasizes science and mathematics to make Japan a world leader in science and technology (topic no.59)," "A technological education program that ensures the handing down of expertise and craftsmanship by establishing technology for converting implicit knowledge on manufacturing and manufacturing technique (e.g. basic techniques and skills, know-how, experience) into explicit knowledge (topic no. 56)," and "Promotion of human resources mobility that is promoted across industry, academia, and government, leading to a greater number of joint or collaboration projects, and consequently bringing about innovations in manufacturing technology. (topic no. 58)."

In addition to the above, the subcommittee discussed issues that should be addressed, and government support based on the questionnaire survey results. The main points reached were as follows.

For "manufacturing technology utilizing advanced information technology," passing on the skills of experienced workers; for "manufacturing technology using virtual design," software development; for "manufacturing technology for high-value added products," response to the hollowing out of industrial technology accompanying overseas expansion; for "nano-machining/ micromachining technology," tax measures and other responses to intensifying global competition; for "humans and robot participation in manufacturing," research on programming for complex human work; for " recycling-oriented manufacturing technology with a low environmental load," research and development and tax measures for non-fossil energy; for "manufacturing technology in special environments," continuation of basic research; for "advanced manufacturing technology for social infrastructure," development of joining techniques for heavy structures and so on; and for "surface modification and interface control technology," interfacial control research a s basic research on nano- and micro-fabrication.

Finally, as policies to promote science and technology fields (policy proposals), the following can be offered for the manufacturing field.

(1) From the short-term perspective of the coming 5 to 10 years, collaboration with the information sector (IT) is important for the manufacturing field. A total of 5 areas are named ("manufacturing technology utilizing advanced information technology," "manufacturing technology using virtual design," "manufacturing technology for high-value added products," "nano-machining/micromachining technology," and "humans and robot participation in manufacturing"), but support is especially needed for the areas trailing the USA ("manufacturing technology using virtual design" and "manufacturing technology utilizing advanced information technology") and the area related to nanotechnology ("nano-machining/micromachining technology").

(2) Outside the information field, "recycling-oriented manufacturing technology with a low environmental load" is considered important in the manufacturing field. This area is characterized by a high necessity of government involvement for both time of technological realization and time of social application. In addition, it is positioned as a short-term field in terms of time of technological realization, but looking at the field with which it should collaborate, "energy and resources," measures with a long-term perspective beyond 2016 are important, necessitating both short- and long-term initiatives.

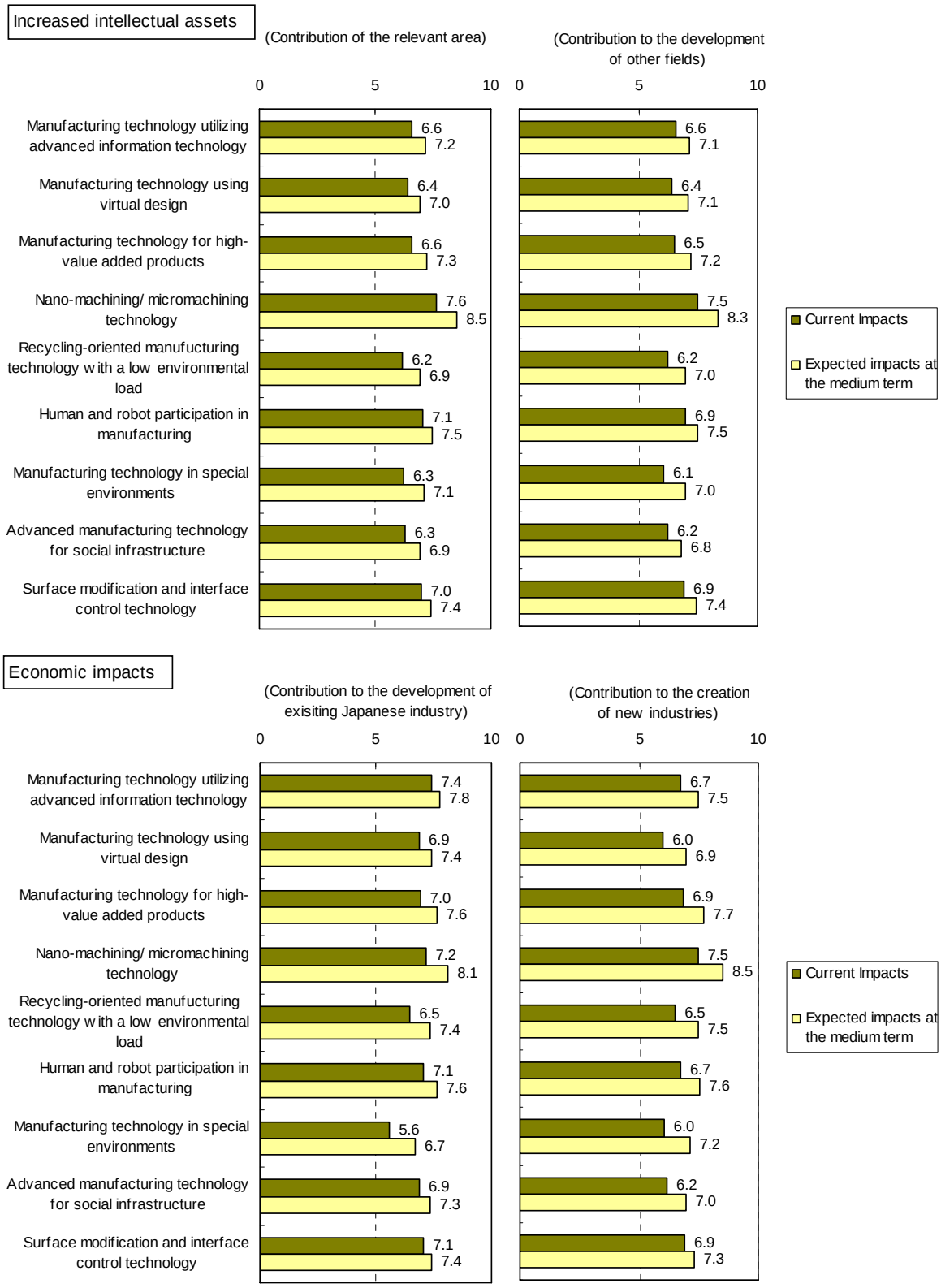
(3) A large majority of answers in the manufacturing field indicated expectations for government involvement and support through strengthened industry-academia-government and interdisciplinary collaboration, expanded funding, and so on. In concrete terms, promotion of research and development by industry consortiums and the creation of centers by universities and public agencies were named as means of strengthening such collaboration. In addition, support through taxation, subsidies, and procurement was named as a concrete means of government involvement.

(4) The importance of education reform such as "implementation of a new elementary and secondary education scheme that emphasizes science and mathematics" and "development of an education program for handing down expertise" in order to develop outstanding human resources was pointed out. Active government support of this aspect is expected.

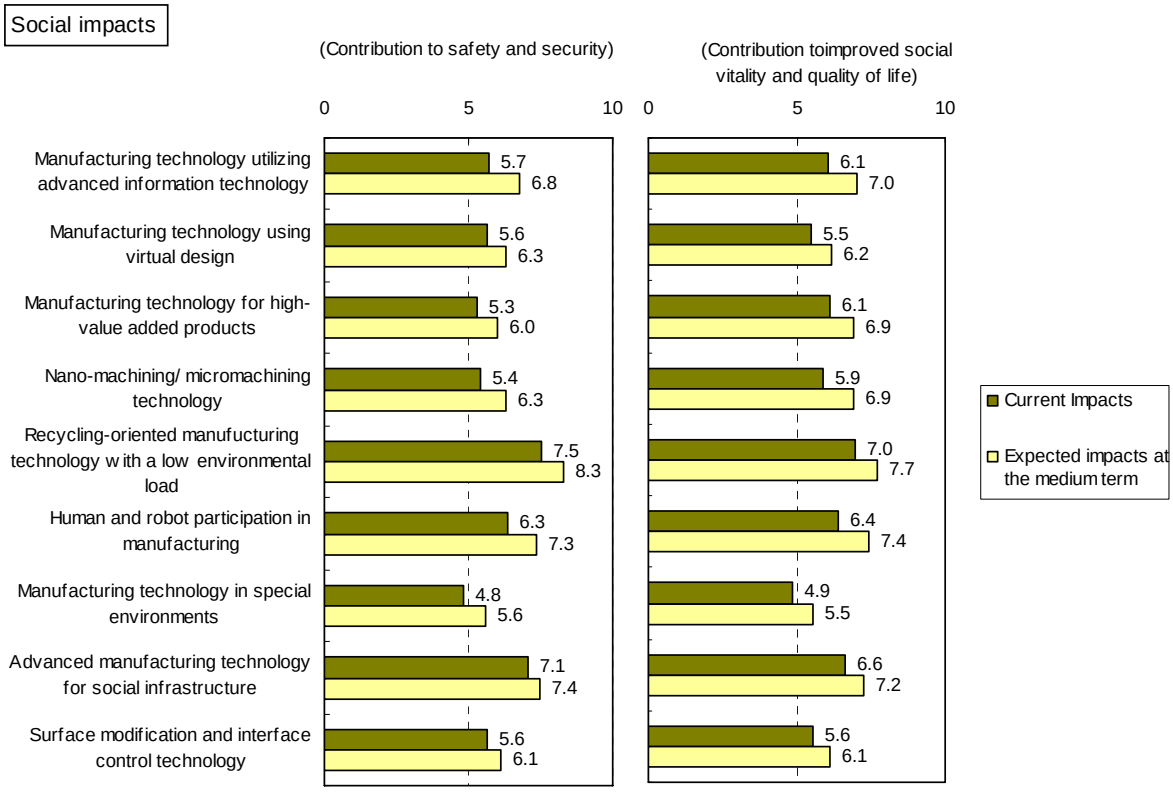
(KOBAYASHI Toshio and HIRAMATSU Kaneo)

10.2. Main results

A. Impacts

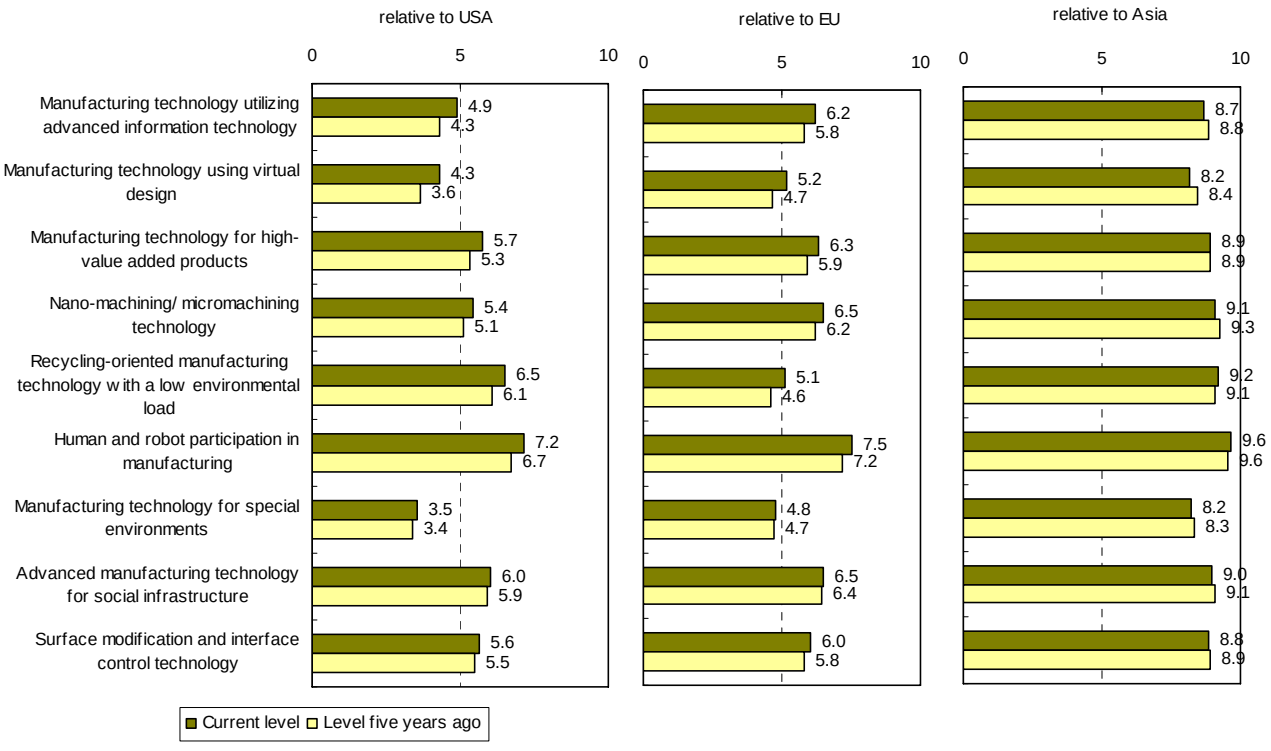


*Responses are indexed on a 10-point scale.



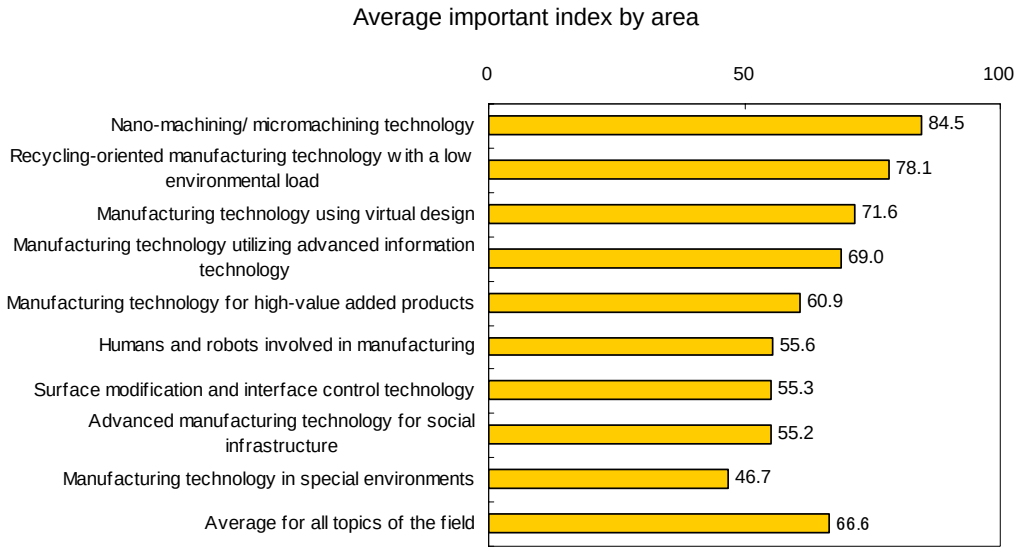
*Responses are indexed on a 10-point scale

B. Japan's R&D Level



*Responses are indexed on a 10-point scale.

C. Importance to Japan



The most important 10 topics

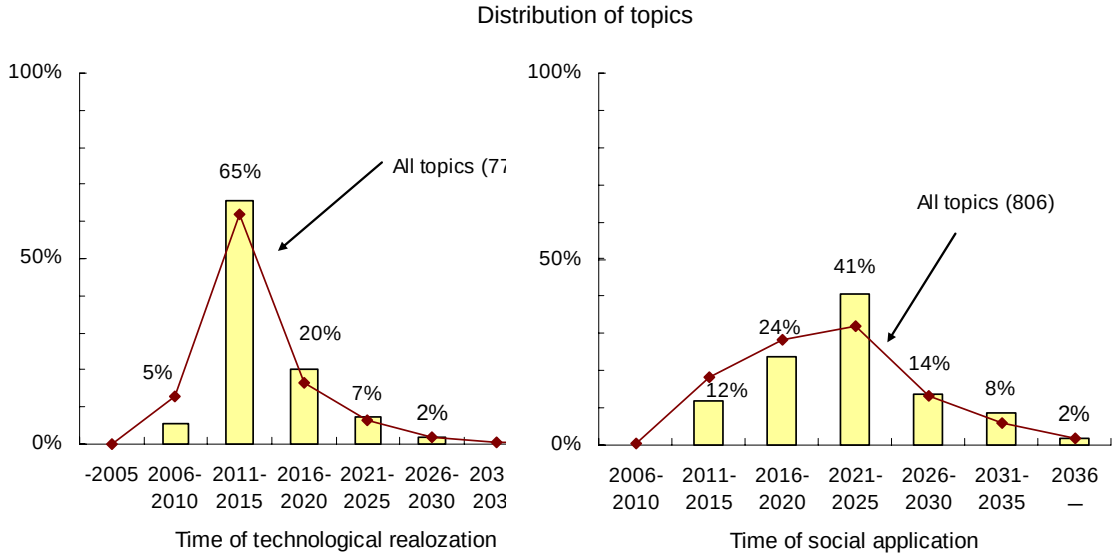
	Topic	Index	Year T*	Year S*
1	27: Widespread use of production processes using low CO_2 emitting energy sources such as non-fossil energy (wind, geothermal, photovoltaic, solar heat, waste heat, etc.), cogeneration systems, stationary fuel-cell systems etc..	95	2014	2023
2	59: Implementation of a new elementary and secondary education scheme that emphasizes science and mathematics to make Japan a world leader in science and technology.	95		2013
3	56: A technical education program that ensures the handing down of expertise and craftsmanship by establishing technology for converting implicit knowledge on manufacturing and manufacturing technique (e.g. basic techniques and skills, know-how, experience) into explicit knowledge.	94	2013	2019
4	58: Promotion of human resources mobility that is promoted across industry, academia, and government, leading to a greater number of joint or collaboration projects, and consequently bringing about innovations in manufacturing technology.	93		2013
5	28: Manufacturers' responsibility for collecting and disposing of discarded products is defined by law, and recycling systems in which more than 90% of used material is thermal- or material-recycled become widespread. Design for recycle/disassemble technology, easy assemble & disassemble production technology , selective collection system technology etc. enable it to achieve.	91	2013	2021
6	17: Super high precision process technology (for processing, analyzing, testing, and in-situ monitoring) at the angstrom level achieved through advances in beam technology (ion, electron, laser, etc.), machine control technology, and sensor technology.	91	2012	2018
7	25: An "inverse" manufacturing system that combines "arterial" (production) and "venous" (disposal) activities in which the production system (design→produce→use→scrap) and the resources recycling system (collect→disassemble/sort→reuse→produce) are integrated.	90	2013	2021
8	18: Packaging technology at the few micron level for achieving super-small wearable equipment for use anywhere, anytime by a combination of optoelectronics, microelectronics, and micromachinery.	89	2013	2021
9	07: An advanced virtual manufacturing system and its operation system to support optimization, efficiency improvement, license application, and other processes of production activities such as design, development, manufacture, operation, maintenance, and disposal.	87	2012	2018

	Topic	Index	Year T*	Year S*
10	02: A support system that explicitly shows experts' decision-making process, skills, and know-how for reuse and leaning by non-experts.	87	2012	2018

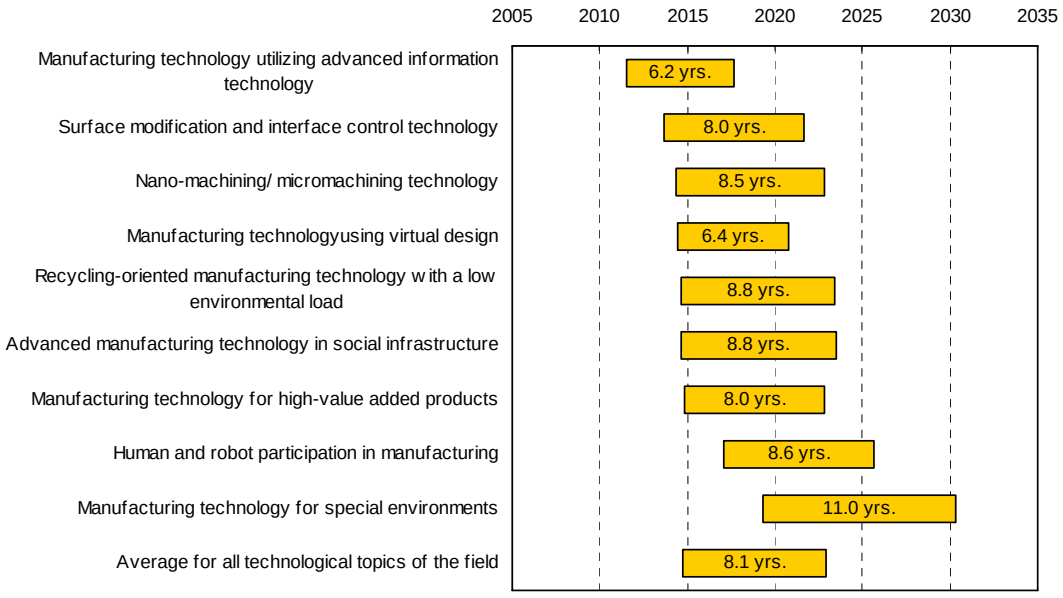
*Year T: Time of technological realization Year S: Time of social application

Responses were indexed on a 100-point scale.

D. Time of realization



Gap between technological realization and social application



Topics with short or long periods until social application

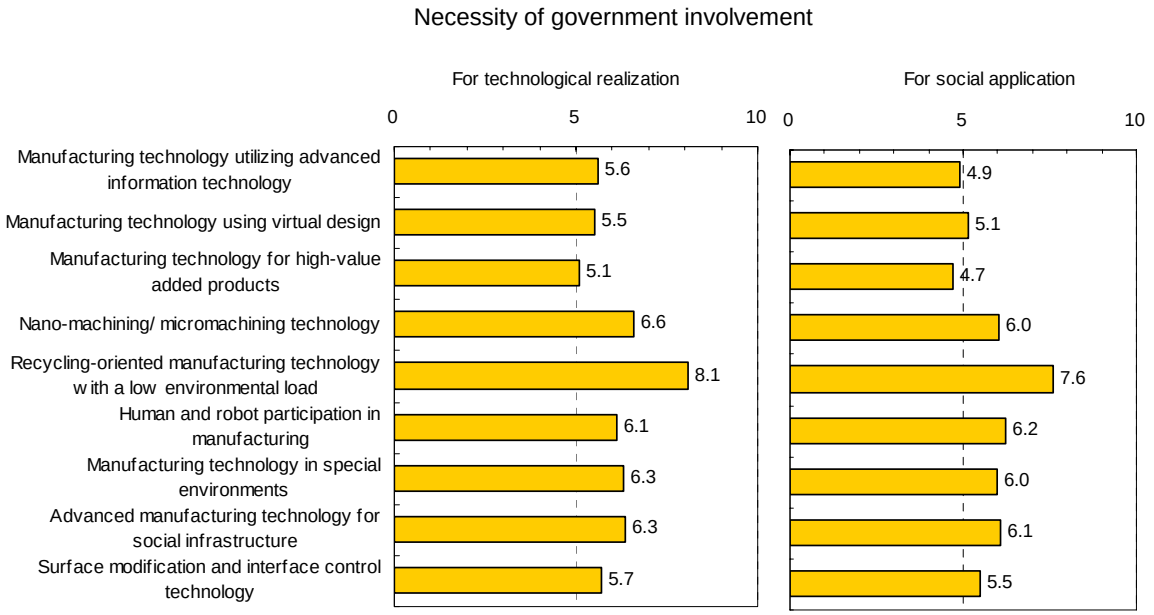
Topic	Year T*	Period*	Area
43: An efficient manufacturing process that uses or mimics microorganism functions.	2017	12	Manufacturing technology in special environments
20: Technology for manufacturing high-value added products by using the bottom-up approach (self-organization) for supermolecular structure control at the nano level.	2016	11	Nano-machining/ micromachining technology

Topic	Year T*	Period*	Area
36: Manufacturing and process design technologies resulting from the discovery of new laws based on life science.	2023	11	Human and robot participation in manufacturing
42: Manufacturing process technology that utilizes gravity-free, minimal gravity, or other special environments.	2020	11	Manufacturing technology in special environments
49: Technology for desert revegetation and food production in desert areas to help avoid food crises resulting from population growth.	2018	11	Advanced manufacturing technology for social infrastructure

Topic	Year T*	Period*	Area
09: Construction of a life cycle assessment (LCA) database of the materials used for a product and technology for performing LCA of a designed product based on such a database.	2011	4	Manufacturing technology using virtual design
04: A lifetime tracking system for industrial products in which each component of manufactured products contains an IC chip that stores identification information (e.g. manufacturer, materials, components, changes in performance/properties, user).	2008	5	Manufacturing technology utilizing advanced information technology
05: Technology for remotely maintaining and inspecting equipment and facilities with advanced, complex functionality.	2009	5	Manufacturing technology utilizing advanced information technology
06: Japan's original manufacturing software for supporting autonomous adaptability, large variety small volume production, and short delivery time.	2010	5	Manufacturing technology utilizing advanced information technology
02: A support system that explicitly shows experts' decision-making process, skills, and know-how for reuse and leaning by non-experts.	2012	6	Manufacturing technology utilizing advanced information technology
07: An advanced virtual manufacturing system and its operation system to support optimization, efficiency improvement, license application, and other processes of production activities such as design, development, manufacture, operation, maintenance, and disposal.	2012	6	Manufacturing technology using virtual design
08: Digital mock-up technology with which, for the aim of shortening the design and R&D periods and reinforcing product competitiveness, all product evaluation parameters including strength, performance, reliability, environment-friendliness, and productivity can be assessed.	2012	6	Manufacturing technology using virtual design
11: High-speed mold making technology for producing (and finishing) a prototype mold according to a 3D image within 10 minutes.	2012	6	Manufacturing technology using virtual design
16: Technology for forming and machining a one-off product without using a mold.	2012	6	Manufacturing technology for high- value added products
17: Super high precision process technology (for processing, analyzing, testing, and in-situ monitoring) at the angstrom level achieved through advances in beam technology (ion, electron, laser, etc.), machine control technology, and sensor technology.	2012	6	Nano-machining/ micromachining technology
32: Technology for using robots in dangerous or hazardous work in manufacturing processes to ensure human operators' safety.	2011	6	Human and robot participation in manufacturing
51: Technology for forming super-hard thin film (e.g. diamond thin film) on a complex surface to be applied to the sliding surface of bearings and special tools.	2012	6	Surface modification and interfacial control technology
56: A technical education program that ensures the handing down of expertise and craftsmanship by establishing technology for converting implicit knowledge on manufacturing and manufacturing technique (e.g. basic techniques and skills, know-how, experience) into explicit knowledge.	2013	6	-

*Year T: Time of technological realization Period: Period until social application (years)

E. Effective measures that should taken by government



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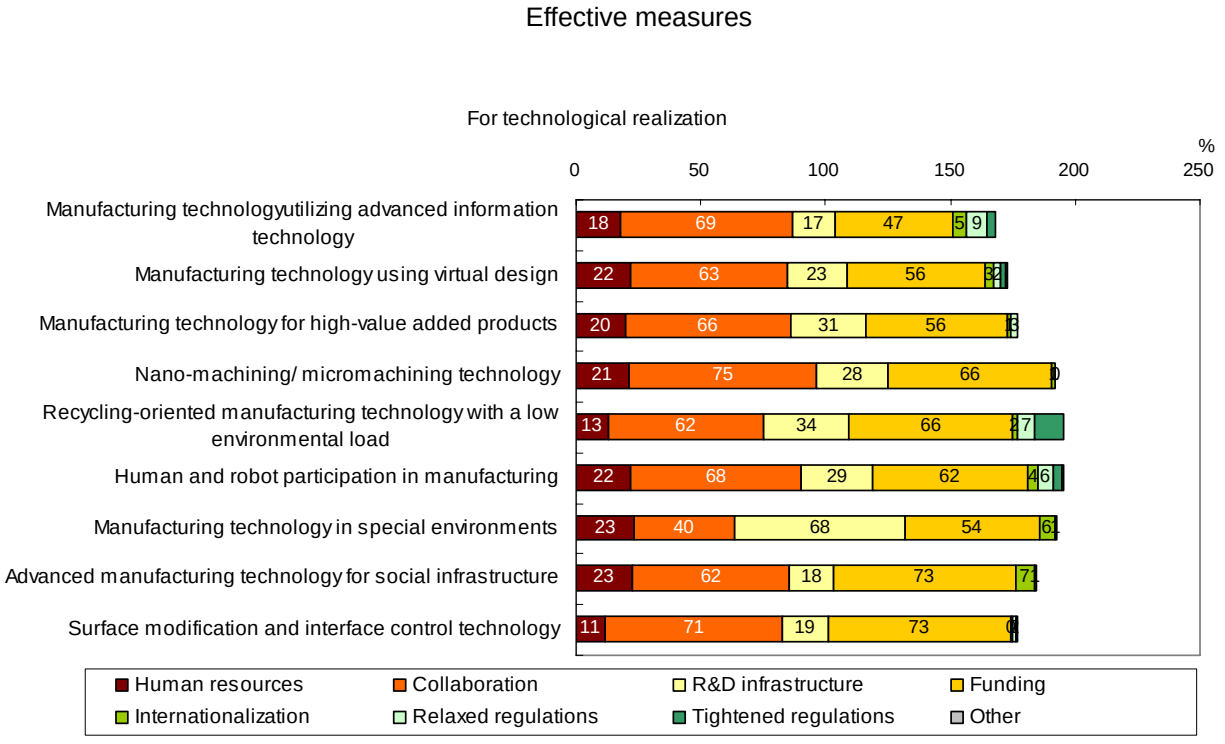
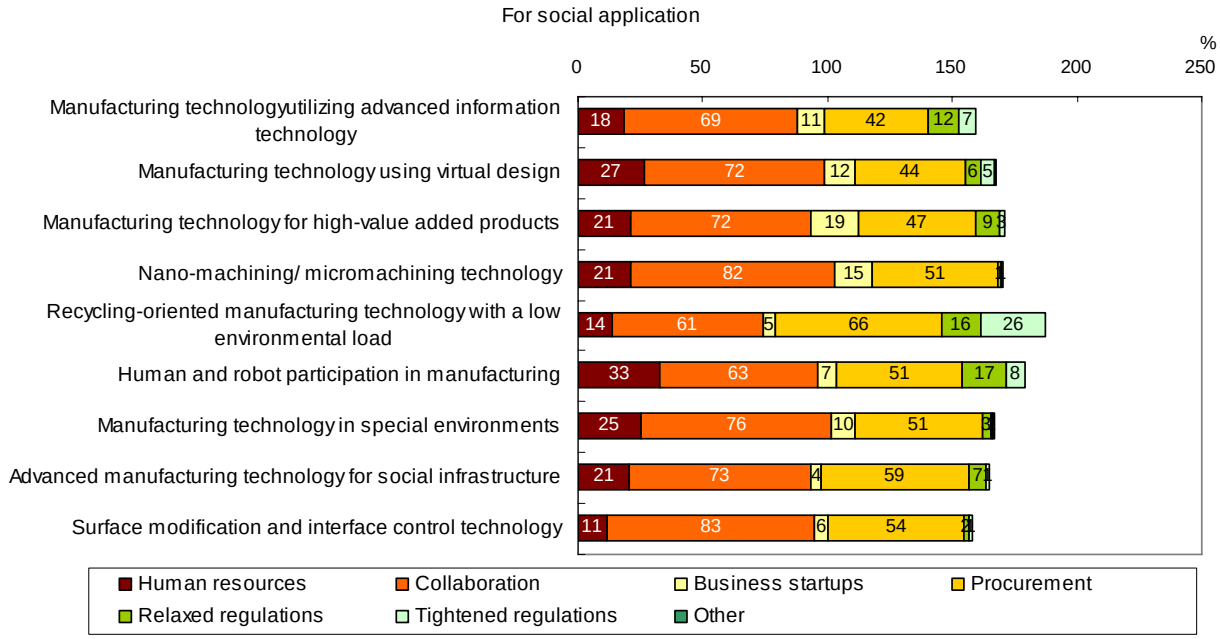




F. Time-line of topics

Technological realization

Year	topic
2008	04: A lifetime tracking system for industrial products in which each component of manufactured products contains an IC chip that stores identification information (e.g. manufacturer, materials, components, changes in performance/properties, user).
2009	05: Technology for remotely maintaining and inspecting equipment and facilities with advanced, complex functionality.
2010	06: Japan's original manufacturing software for supporting autonomous adaptability, large variety small volume production, and short delivery time.
2011	09: Construction of a life cycle assessment (LCA) database of the materials used for a product and technology for performing LCA of a designed product based on such a database.
	32: Technology for using robots in dangerous or hazardous work in manufacturing processes to ensure human operators' safety.
2012	02: A support system that explicitly shows experts' decision-making process, skills, and know-how for reuse and leaning by non-experts.
	07: An advanced virtual manufacturing system and its operation system to support optimization, efficiency improvement, license application, and other processes of production activities such as design, development, manufacture, operation, maintenance, and disposal.
	08: Digital mock-up technology with which, for the aim of shortening the design and R&D periods and reinforcing product competitiveness, all product evaluation parameters including strength, performance, reliability, environment-friendliness, and productivity can be assessed.
	11: High-speed mold making technology for producing (and finishing) a prototype mold according to a 3D image within 10 minutes.
	14: A reconfigurable manufacturing system in which production volume can be quickly and flexibly adjusted to each of many different products.
	16: Technology for forming and machining a one-off product without using a mold.
	17: Super high precision process technology (for processing, analyzing, testing, and in-situ monitoring) at the angstrom level achieved through advances in beam technology (ion, electron, laser, etc.), machine control technology, and sensor technology.
	31: Digitization and advanced industrial robots reshape the job market and the employment practices in the manufacturing sector.
	33: A system that issues an alert when a possibility of human error is detected through real-time analysis of human behavior across the shop floor.
	51: Technology for forming super-hard thin film (e.g. diamond thin film) on a complex surface to be applied to the sliding surface of bearings and special tools.
2013	15: On-demand manufacturing technology for pharmaceutical drugs and chemicals based on microreactors.

Year	topic
	18: Packaging technology at the few micron level for achieving super-small wearable equipment for use anywhere, anytime by a combination of optoelectronics, microelectronics, and micromachinery.
	19: Technology for net shape forming with an accuracy of around ±1 μm through casting、sintering, and plastic working.
	25: An "inverse" manufacturing system that combines "arterial" (production) and "venous" (disposal) activities in which the production system (design→produce→use→scrap) and the resources recycling system (collect→disassemble/sort→reuse→produce) are integrated.
	28: Manufacturers' responsibility for collecting and disposing of discarded products is defined by law, and recycling systems in which more than 90% of used material is thermal- or material-recycled become widespread. Design for recycle/disassemble technology, easy assemble & disassemble production technology , selective collection system technology etc. enable it to achieve.
	30: Technology that achieves energy and space savings through a major plant downsizing (1/2 to 1/10 of current size) or a dramatic improvement in plant serviceability by introducing modules in workflows, recombining modules, and constructing module-to-module communications systems.
	37: An operator support system that creates work environments friendly to all workers including women, the elderly, and the disabled.
	46: Technology for bonding dissimilar materials (e.g., composite material and steel) in heavy structures.
	53: Proliferation of dry processing technology with which no lubricant or processing fluid is necessary for machining and plastic working.
	56: A technical education program that ensures the handing down of expertise and craftsmanship by establishing technology for converting implicit knowledge on manufacturing and manufacturing technique (e.g. basic techniques and skills, know-how, experience) into explicit knowledge.
2014	03: An autonomous adaptive system with high flexibility, safety, and serviceability in which networked machines and devices adjust to the system's internal and external environments.
	21: Technology that allows manufacturing processes to practically use the measurement of length, displacement, and surface roughness down to the angstrom level and the time measurement down to the femtosecond level.
	26: Assessment technology on the potential damage and risk associated with industrial parks and individual companies and production facilities, even assuming local impacts of chain-reaction and/or complex accidents.
	27: Widespread use of production processes using low CO2 emitting energy sources such as non-fossil energy (wind, geothermal, photovoltaic, solar heat, waste heat, etc.), cogeneration systems, stationary fuel-cell systems etc..
	44: Technology for manufacturing heavy structures such as large equipment, buildings, and vessels by using light-weight, high-strength composite materials instead of conventional steel materials.
	45: High-strength, high-durability bonding technologies, such as plastic bonding, that can substitute for welding in heavy structures.
	48: Technology for construction of vessels, bridges, thermal power plants and other large structures with no need for modification and maintenance, by simulating and accurately predicting deformations by gravity, temperature, heat input in bonding, and residual stress in steel, and incorporating the results into the initial design.
	50: Technology for dramatically (three or more times longer than current level) extending the life of production facilities through innovations in material surface properties.
	54: Machine element technology that allows significant regulation of holding stiffness and damping properties through the use of functional materials such as electroviscous fluid.
	55: Micromachining/ultra micromachining technology that can change material's surface properties, such as wettability and optical quality, according to the aim of the machine element.
2015	23: Optimizing technology on energy usage in a production process by means of large-scale energy storage system (superconductivity technology, a flywheel, a capacitor, etc.).
	39: Manufacturing technology based on robots that can adapt to change in the operational environment with real-time 3D image processing and force control functions.
	47: Low-deformation/-distortion (1/1000 of conventional level) bonding technology based on liquid-phase or solid-state diffusion that can substitute for conventional hot-melt bonding in heavy structures.
	52: Self-lubricating machine elements become commercially available, widely eliminating the need for lubricating the processing machines.
2016	01: Technology that allows machine to improve performance autonomously through the use of intelligent materials and parts whose properties adapt to the external environment and of systems incorporating such elements.

Year	topic
	20: Technology for manufacturing high-value added products by using the bottom-up approach (self-organization) for supermolecular structure control at the nano level.
	24: A low-entropy eco-factory taking everything into consideration of impacts on ecosystems including whole product life from birth to disposal.
2017	12: Technology for making customized products for which distinctive characteristics (e.g. physical constitution, sensibilities, five senses, stress, genetic information) of individuals are measured, analyzed and used for product design.
	43: An efficient manufacturing process that uses or mimics microorganism functions.
2018	22: Manufacturing technology for achieving innovative functions and properties through nanoscale manipulation and control of atoms and molecules or through control of materials structure or arrangement.
	49: Technology for desert revegetation and food production in desert areas to help avoid food crises resulting from population growth.
2019	29: Product/material manufacturing technology and system technology that achieve safety, cleanness, high energy efficiency, and high cost effectiveness based on natural and biological mechanisms.
	35: A common global language (including software) to express manufacturing information and knowledge is established, resulting in an interface technology through which communications (including intentions) between humans, machines, and information systems can be conducted accurately across different cultures and languages.
2020	13: Simulation technology for detecting and embodying values in need among people before specific needs are formulated.
	42: Manufacturing process technology that utilizes gravity-free, minimal gravity, or other special environments.
2021	38: Production system technology based on robots with s elf-repair capability.
	41: Manufacturing process technology that utilizes functions of microorganisms inhabiting ultrahigh pressure, high pH, or other extreme environments.
2023	36: Manufacturing and process design technologies resulting from the discovery of new laws based on life science.
2025	10: A design/development support technology that can detect human brain waves to express thoughts of humans on a computer.
2028	40: Technology for controlling robots in human-robot cooperative tasks using high-accuracy detection of human brain waves.

Social application

Year	topic
2013	04: A lifetime tracking system for industrial products in which each component of manufactured products contains an IC chip that stores identification information (e.g. manufacturer, materials, components, changes in performance/properties, user).
	57: University and higher-education systems in which students can choose freely from broad production-related technical fields (materials, design, information, electronics, mechanical, and analysis/assessment technologies, quality engineering, business administration, etc.) and earn credits.
	58: Promotion of human resources mobility that is promoted across industry, academia, and government, leading to a greater number of joint or collaboration projects, and consequently bringing about innovations in manufacturing technology.
	59: Implementation of a new elementary and secondary education scheme that emphasizes science and mathematics to make Japan a world leader in science and technology.
2014	05: Technology for remotely maintaining and inspecting equipment and facilities with advanced, complex functionality.
2015	06: Japan's original manufacturing software for supporting autonomous adaptability, large variety small volume production, and short delivery time.
	09: Construction of a life cycle assessment (LCA) database of the materials used for a product and technology for performing LCA of a designed product based on such a database.
2017	32: Technology for using robots in dangerous or hazardous work in manufacturing processes to ensure human operators' safety.
2018	02: A support system that explicitly shows experts' decision-making process, skills, and know-how for reuse and leaning by non-experts.
	07: An advanced virtual manufacturing system and its operation system to support optimization, efficiency improvement, license application, and other processes of production activities such as design, development, manufacture, operation, maintenance, and disposal.

Year	topic
	08: Digital mock-up technology with which, for the aim of shortening the design and R&D periods and reinforcing product competitiveness, all product evaluation parameters including strength, performance, reliability, environment-friendliness, and productivity can be assessed.
	11: High-speed mold making technology for producing (and finishing) a prototype mold according to a 3D image within 10 minutes.
	16: Technology for forming and machining a one-off product without using a mold.
	17: Super high precision process technology (for processing, analyzing, testing, and in-situ monitoring) at the angstrom level achieved through advances in beam technology (ion, electron, laser, etc.), machine control technology, and sensor technology.
	51: Technology for forming super-hard thin film (e.g. diamond thin film) on a complex surface to be applied to the sliding surface of bearings and special tools.
2019	14: A reconfigurable manufacturing system in which production volume can be quickly and flexibly adjusted to each of many different products.
	31: Digitization and advanced industrial robots reshape the job market and the employment practices in the manufacturing sector.
	56: A technical education program that ensures the handing down of expertise and craftsmanship by establishing technology for converting implicit knowledge on manufacturing and manufacturing technique (e.g. basic techniques and skills, know-how, experience) into explicit knowledge.
2020	19: Technology for net shape forming with an accuracy of around ±1 μm through casting、sintering, and plastic working.
	33: A system that issues an alert when a possibility of human error is detected through real-time analysis of human behavior across the shop floor.
	37: An operator support system that creates work environments friendly to all workers including women, the elderly, and the disabled.
2021	15: On-demand manufacturing technology for pharmaceutical drugs and chemicals based on microreactors.
	18: Packaging technology at the few micron level for achieving super-small wearable equipment for use anywhere, anytime by a combination of optoelectronics, microelectronics, and micromachinery.
	25: An "inverse" manufacturing system that combines "arterial" (production) and "venous" (disposal) activities in which the production system (design→produce→use→scrap) and the resources recycling system (collect→disassemble/sort→reuse→produce) are integrated.
	28: Manufacturers' responsibility for collecting and disposing of discarded products is defined by law, and recycling systems in which more than 90% of used material is thermal- or material-recycled become widespread. Design for recycle/disassemble technology, easy assemble & disassemble production technology , selective collection system technology etc. enable it to achieve.
	30: Technology that achieves energy and space savings through a major plant downsizing (1/2 to 1/10 of current size) or a dramatic improvement in plant serviceability by introducing modules in workflows, recombining modules, and constructing module-to-module communications systems.
	34: In the manufacturing sector, women account for 50% of researchers and engineers.
	53: Proliferation of dry processing technology with which no lubricant or processing fluid is necessary for machining and plastic working.
2022	03: An autonomous adaptive system with high flexibility, safety, and serviceability in which networked machines and devices adjust to the system's internal and external environments.
	44: Technology for manufacturing heavy structures such as large equipment, buildings, and vessels by using light-weight, high-strength composite materials instead of conventional steel materials.
	45: High-strength, high-durability bonding technologies, such as plastic bonding, that can substitute for welding in heavy structures.
	46: Technology for bonding dissimilar materials (e.g., composite material and steel) in heavy structures.
	48: Technology for construction of vessels, bridges, thermal power plants and other large structures with no need for modification and maintenance, by simulating and accurately predicting deformations by gravity, temperature, heat input in bonding, and residual stress in steel, and incorporating the results into the initial design.
	54: Machine element technology that allows significant regulation of holding stiffness and damping properties through the use of functional materials such as electroviscous fluid.
	55: Micromachining/ultra micromachining technology that can change material's surface properties, such as wettability and optical quality, according to the aim of the machine element.
2023	21: Technology that allows manufacturing processes to practically use the measurement of length, displacement, and surface roughness down to the angstrom level and the time measurement down to the femtosecond level.

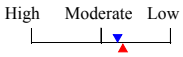
Year	topic
	26: Assessment technology on the potential damage and risk associated with industrial parks and individual companies and production facilities, even assuming local impacts of chain-reaction and/or complex accidents.
	27: Widespread use of production processes using low CO2 emitting energy sources such as non-fossil energy (wind, geothermal, photovoltaic, solar heat, waste heat, etc.), cogeneration systems, stationary fuel-cell systems etc..
	50: Technology for dramatically (three or more times longer than current level) extending the life of production facilities through innovations in material surface properties.
2024	01: Technology that allows machine to improve performance autonomously through the use of intelligent materials and parts whose properties adapt to the external environment and of systems incorporating such elements.
	23: Optimizing technology on energy usage in a production process by means of large-scale energy storage system (superconductivity technology, a flywheel, a capacitor, etc.).
	39: Manufacturing technology based on robots that can adapt to change in the operational environment with real-time 3D image processing and force control functions.
	47: Low-deformation/-distortion (1/1000 of conventional level) bonding technology based on liquid-phase or solid-state diffusion that can substitute for conventional hot-melt bonding in heavy structures.
	52: Self-lubricating machine elements become commercially available, widely eliminating the need for lubricating the processing machines.
2025	24: A low-entropy eco-factory taking everything into consideration of impacts on ecosystems including whole product life from birth to disposal.
2027	12: Technology for making customized products for which distinctive characteristics (e.g. physical constitution, sensibilities, five senses, stress, genetic information) of individuals are measured, analyzed and used for product design.
	20: Technology for manufacturing high-value added products by using the bottom-up approach (self-organization) for supermolecular structure control at the nano level.
2028	22: Manufacturing technology for achieving innovative functions and properties through nanoscale manipulation and control of atoms and molecules or through control of materials structure or arrangement.
2029	13: Simulation technology for detecting and embodying values in need among people before specific needs are formulated.
	29: Product/material manufacturing technology and system technology that achieve safety, cleanness, high energy efficiency, and high cost effectiveness based on natural and biological mechanisms.
	35: A common global language (including software) to express manufacturing information and knowledge is established, resulting in an interface technology through which communications (including intentions) between humans, machines, and information systems can be conducted accurately across different cultures and languages.
	43: An efficient manufacturing process that uses or mimics microorganism functions.
	49: Technology for desert revegetation and food production in desert areas to help avoid food crises resulting from population growth.
2031	38: Production system technology based on robots with s elf-repair capability.
	41: Manufacturing process technology that utilizes functions of microorganisms inhabiting ultrahigh pressure, high pH, or other extreme environments.
	42: Manufacturing process technology that utilizes gravity-free, minimal gravity, or other special environments.
2034	36: Manufacturing and process design technologies resulting from the discovery of new laws based on life science.
2035	10: A design/development support technology that can detect human brain waves to express thoughts of humans on a computer.
2036-	40: Technology for controlling robots in human-robot cooperative tasks using high-accuracy detection of human brain waves.

Appendix: Results of R1 and R2

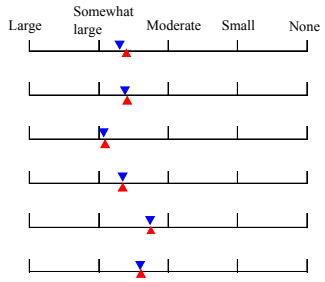
I. Manufacturing technology utilizing advanced information technology

1. Questions regarding the relevant area

1) Degree of expertise in the area

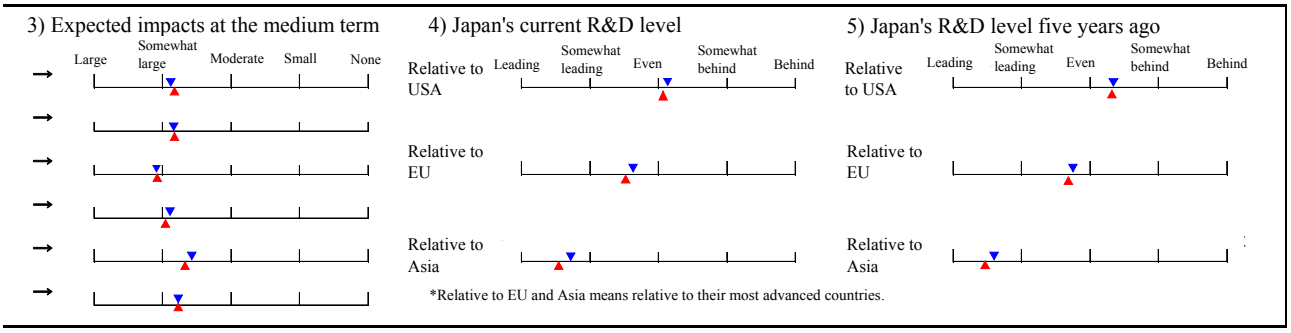


2) Current impacts



2. Questions regarding toipcs

No	Topic	Questionnaire	Respondents (persons)	Degree of expertise (%)				Importance to Japan					Time of technological realization									
				High	Moderate	Low	None	Index	High	Moderate	Low	None	Already realized	2006–2010	2011–2015	2016–2025	2026–2035	2036–	Will not be realized	Do not know
1	Technology that allows machine to improve performance autonomously through the use of intelligent materials and parts whose properties adapt to the external environment and of systems incorporating such elements.	1	127	9	31	60	-	68	40	52	8	0									2	7
		2	124	4	21	75	-	57	16	80	4	0									0	2
		E	5	100	0	0	-	90	80	20	0	0									0	0
2	A support system that explicitly shows experts' decision-making process, skills, and know-how for reuse and leaning by non-experts.	1	156	21	38	41	-	80	63	31	5	1									2	3
		2	139	12	31	57	-	87	74	25	1	0									1	2
		E	17	100	0	0	-	97	94	6	0	0									0	0
3	An autonomous adaptive system with high flexibility, safety, and serviceability in which networked machines and devices adjust to the system's internal and external environments.	1	131	16	36	48	-	71	45	49	6	0									0	3
		2	126	8	22	70	-	63	27	71	1	1									1	2
		E	10	100	0	0	-	75	50	50	0	0									0	0
4	A lifetime tracking system for industrial products in which each component of manufactured products contains an IC chip that stores identification information (e.g. manufacturer, materials, components, changes in performance/properties, user).	1	149	10	32	58	-	63	34	49	16	1									1	3
		2	139	5	25	70	-	64	29	67	4	0									0	0
		E	7	100	0	0	-	79	57	43	0	0									0	0
5	Technology for remotely maintaining and inspecting equipment and facilities with advanced, complex functionality.	1	141	12	27	61	-	60	30	51	18	1									0	3
		2	133	5	26	69	-	59	21	74	5	0									0	1
		E	7	100	0	0	-	61	29	57	14	0									0	0
6	Japan's original manufacturing software for supporting autonomous adaptability, large variety small volume production, and short delivery time.	1	139	19	25	56	-	75	53	39	8	0									1	2
		2	129	8	23	69	-	85	72	26	2	0									0	1
		E	10	100	0	0	-	94	89	11	0	0									0	0

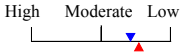


Countries at the leading edge					Regarding technological realization													Time of social application							Regarding social application													
					Necessity of gov't involvement				Effective measures that should be taken by gov't																	Necessity of gov't involvement				Effective measures that should be taken by gov't								
Japan	USA	EU	Asia	Other	High	Moderate	Low	None	Human resources development	Strengthened industry-academic-government and interdisciplinary collaboration	Development of R&D infrastructure	Expansion of R&D funding	Internationalization of R&D activities	Relaxation or elimination of relevant regulations	Tightened or new regulations	Other	2006–2010	2011–2015	2016–2025	2026–2035	2036–	Will not be applied	Do not know	High	Moderate	Low	None	Human resources development	Strengthened industry-academic-government and interdisciplinary collaboration	Improvement of environment for business startups	Support through taxation, subsidies, and procurement	Relaxation or elimination of relevant regulations	Tightened or new regulations	Other
(%)					(%)				(%)													(%)		(%)				(%)							
36	53	10	0	1	19	46	29	6	28	51	39	48	3	6	2	0						1	10	18	29	38	15	28	40	25	35	15	2	1
15	84	1	0	0	3	66	27	4	17	60	26	56	1	2	0	0						0	3	2	24	69	5	21	68	15	41	7	2	0
40	60	0	0	0	20	60	0	20	25	75	75	50	0	0	0	0						0	0	20	20	40	20	50	100	50	25	0	0	0
48	38	14	0	0	24	41	25	10	43	54	28	44	7	1	1	1						2	5	20	34	28	18	43	44	18	38	6	4	2
76	22	2	0	0	14	67	15	4	42	70	14	47	2	2	0	0						1	3	10	53	30	7	50	67	9	41	1	1	0
70	24	6	0	0	41	53	0	6	50	75	25	69	6	0	0	0						0	6	12	70	12	6	56	69	13	56	0	0	0
37	54	9	0	0	16	46	31	7	22	50	34	46	8	11	0	1						0	5	13	41	36	10	23	54	19	35	15	6	0
20	79	1	0	0	5	71	20	4	16	73	19	53	3	3	0	0						1	1	3	54	40	3	15	77	9	42	9	0	0
20	70	10	0	0	30	60	0	10	44	56	44	67	22	11	0	0						0	0	20	60	10	10	33	56	22	56	33	0	0
52	38	9	0	1	24	36	27	13	11	44	19	31	26	25	20	1						1	5	27	32	27	14	15	36	19	36	31	35	2
81	15	4	0	0	14	60	23	3	6	68	9	28	19	24	16	0						0	0	17	50	29	4	5	56	12	43	26	35	1
71	0	29	0	0	43	43	14	0	0	43	29	86	43	14	0	0						0	0	43	29	14	14	0	50	33	50	33	50	0
33	59	8	0	0	13	30	46	11	17	48	33	40	9	18	4	1						1	4	9	31	47	13	19	53	12	34	31	12	0
17	82	1	0	0	3	40	52	5	6	67	18	46	3	14	2	1						0	1	3	32	59	6	4	72	5	38	28	2	0
29	71	0	0	0	0	43	43	14	0	83	33	50	0	0	0	0						0	0	0	14	72	14	0	100	0	67	0	0	0
64	33	2	0	1	19	30	39	12	33	57	26	49	7	10	1	0						1	1	17	28	40	15	31	50	27	41	15	2	2
82	18	0	0	0	6	38	51	5	19	75	17	55	2	6	1	0						0	1	5	24	64	7	16	75	18	44	3	0	0
89	11	0	0	0	20	50	30	0	30	60	20	70	0	0	0	0						0	0	20	50	30	0	0	80	50	50	0	0	0

II. Manufacturing technology using virtual design

1. Questions regarding the relevant area

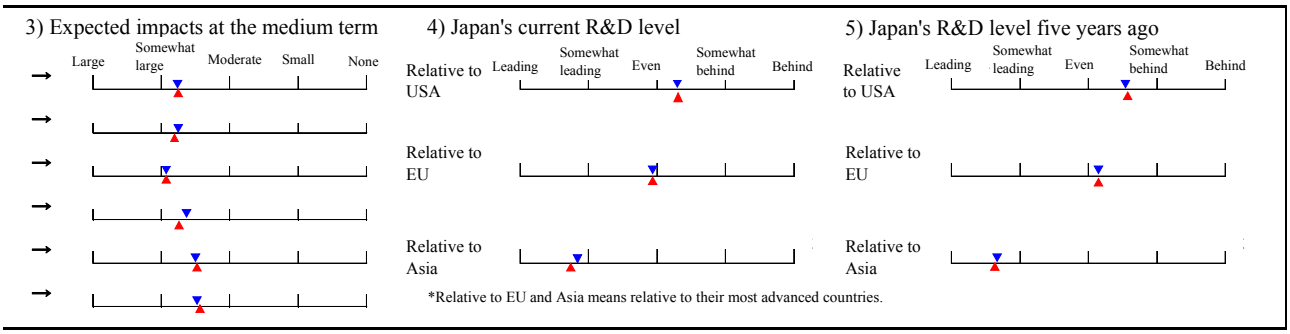
1) Degree of expertise in the area



2) Current impacts

2. Questions regarding toipcs

No	Topic	Questionnaire	Respondents (persons)	Degree of expertise (%)				Importance to Japan (%)					Time of technological realization							
				High	Moderate	Low	None	Index	High	Moderate	Low	None	Already realized	2006–2010	2011–2015	2016–2025	2026–2035	2036–	Will not be realized (%)	Do not know (%)
7	An advanced virtual manufacturing system and its operation system to support optimization, efficiency improvement, license application, and other processes of production activities such as design, development, manufacture, operation, maintenance, and disposal.	1	**133**	**23**	**33**	**44**	-	**76**	**56**	**36**	**8**	**0**							**1**	**4**
		2	**129**	**14**	**26**	**60**	-	**87**	**74**	**25**	**1**	**0**							**0**	**1**
		E	**18**	**100**	**0**	**0**	-	**97**	**94**	**6**	**0**	**0**							**0**	**0**
8	Digital mock-up technology with which, for the aim of shortening the design and R&D periods and reinforcing product competitiveness, all product evaluation parameters including strength, performance, reliability, environment-friendliness, and productivity can be assessed.	1	**145**	**19**	**35**	**46**	-	**78**	**58**	**38**	**4**	**0**							**2**	**2**
		2	**132**	**8**	**29**	**63**	-	**84**	**69**	**31**	**0**	**0**							**0**	**1**
		E	**11**	**100**	**0**	**0**	-	**95**	**91**	**9**	**0**	**0**							**0**	**0**
9	Construction of a life cycle assessment (LCA) database of the materials used for a product and technology for performing LCA of a designed product based on such a database.	1	**142**	**6**	**29**	**65**	-	**68**	**41**	**47**	**11**	**1**							**1**	**4**
		2	**132**	**1**	**20**	**79**	-	**66**	**33**	**65**	**2**	**0**							**0**	**2**
		E	**1**	**100**	**0**	**0**	-	**100**	**100**	**0**	**0**	**0**							**0**	**0**
10	A design/development support technology that can detect human brain waves to express thoughts of humans on a computer.	1	**87**	**6**	**16**	**78**	-	**47**	**16**	**45**	**34**	**5**							**21**	**12**
		2	**106**	**0**	**6**	**94**	-	**41**	**5**	**51**	**41**	**3**							**16**	**6**
		E																		
11	High-speed mold making technology for producing (and finishing) a prototype mold according to a 3D image within 10 minutes.	1	**136**	**17**	**33**	**50**	-	**73**	**50**	**41**	**9**	**0**							**1**	**4**
		2	**132**	**8**	**28**	**64**	-	**80**	**62**	**36**	**2**	**0**							**0**	**2**
		E	**11**	**100**	**0**	**0**	-	**95**	**91**	**9**	**0**	**0**							**0**	**0**

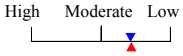


Countries at the leading edge					Regarding technological realization												Time of social application							Regarding social application													
					Necessity of gov't involvement				Effective measures that should be taken by gov't															Necessity of gov't involvement				Effective measures that should be taken by gov't									
Japan	USA	EU	Asia	Other	High	Moderate	Low	None	Human resources development	Strengthened industry-academic-government and interdisciplinary collaboration	Development of R&D infrastructure	Expansion of R&D funding	Internationalization of R&D activities	Relaxation or elimination of relevant regulations	Tightened or new regulations	Other	2006–2010	2011–2015	2016–2025	2026–2035	2036–	Will not be applied	Do not know	High	Moderate	Low	None	Human resources development	Strengthened industry-academic-government and interdisciplinary collaboration	Improvement of environment for business startups	Support through taxation, subsidies, and procurement	Relaxation or elimination of relevant regulations	Tightened or new regulations	Other
(%)					(%)				(%)													(%)		(%)				(%)							
19	70	9	0	2	17	46	29	8	36	56	34	49	11	13	3	0						1	5	15	35	37	13	32	46	25	41	21	6	1
6	94	0	0	0	6	70	22	2	26	73	18	56	4	5	2	0						0	2	3	53	41	3	25	71	16	43	11	3	0
17	83	0	0	0	18	64	18	0	41	76	24	65	6	6	0	0						0	0	6	50	44	0	38	69	31	31	13	0	0
26	65	7	1	1	15	39	35	11	31	55	35	53	6	4	0	1						2	2	12	34	37	17	30	55	27	41	9	1	3
11	88	1	0	0	3	64	28	5	25	74	22	52	5	2	1	0						0	1	2	47	45	6	26	79	15	42	4	1	0
27	73	0	0	0	18	55	27	0	64	91	45	55	9	0	0	0						0	0	9	73	18	0	45	91	36	36	0	0	0
26	27	45	0	2	23	56	17	4	27	52	24	43	15	9	15	2						1	4	26	44	23	7	24	48	14	42	15	27	2
11	15	74	0	0	10	80	8	2	15	80	17	47	6	2	9	0						0	2	16	70	12	2	13	80	7	48	9	21	0
0	0	100	0	0	100	0	0	0	0	100	0	100	0	0	100	0						0	0	0	100	0	0	0	100	0	100	0	0	0
6	88	0	0	6	21	32	30	17	39	36	43	47	6	6	0	4						24	9	18	30	28	24	48	44	22	38	8	9	5
0	98	0	0	2	7	42	42	9	24	40	43	48	2	2	0	1						20	6	4	40	46	10	52	62	8	30	3	2	2
72	22	4	0	2	16	32	40	12	29	43	34	69	3	3	1	0						1	5	17	25	41	17	28	51	31	51	7	2	0
91	8	1	0	0	5	36	53	6	20	48	17	75	1	1	0	0						0	2	6	25	64	5	19	66	15	57	4	0	0
100	0	0	0	0	27	46	27	0	45	27	18	64	0	0	0	0						0	0	27	18	55	0	18	64	36	36	0	0	0

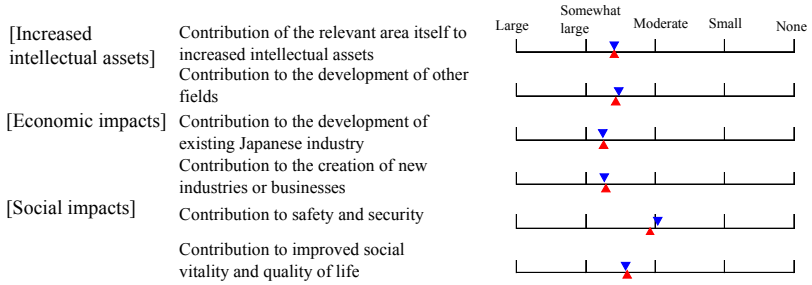
III. Manufacturing technology for high-value added products

1. Questions regarding the relevant area

1) Degree of expertise in the area

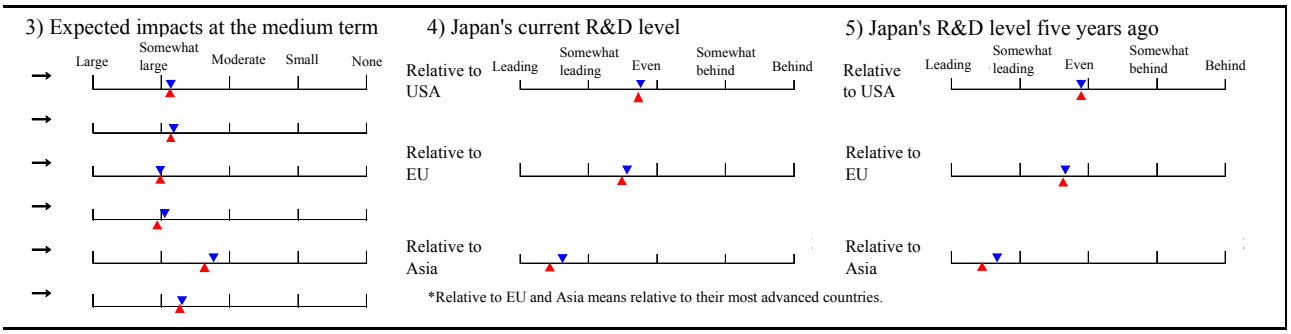


2) Current impacts



2. Questions regarding toipcs

No	Topic	Questionnaire	Respondents (persons)	Degree of expertise (%)				Importance to Japan					Time of technological realization							
				High	Moderate	Low	None	Index	High	Moderate	Low	None	Already realized	2006–2010	2011–2015	2016–2025	2026–2035	2036–	Will not be realized (%)	Do not know (%)
12	Technology for making customized products for which distinctive characteristics (e.g. physical constitution, sensibilities, five senses, stress, genetic information) of individuals are measured, analyzed and used for product design.	1	**99**	**3**	**26**	**71**	-	**56**	**26**	**46**	**27**	**1**							**3**	**9**
		2	**111**	**2**	**13**	**85**	-	**51**	**11**	**73**	**16**	**0**							**2**	**2**
		E	**2**	**100**	**0**	**0**	-	**75**	**50**	**50**	**0**	**0**							**0**	**0**
13	Simulation technology for detecting and embodying values in need among people before specific needs are formulated.	1	**97**	**2**	**20**	**78**	-	**51**	**23**	**36**	**39**	**2**							**9**	**15**
		2	**109**	**1**	**7**	**92**	-	**44**	**8**	**51**	**41**	**0**							**5**	**6**
		E	**1**	**100**	**0**	**0**	-	**100**	**100**	**0**	**0**	**0**							**0**	**0**
14	A reconfigurable manufacturing system in which production volume can be quickly and flexibly adjusted to each of many different products.	1	**130**	**18**	**34**	**48**	-	**74**	**52**	**39**	**8**	**1**							**0**	**2**
		2	**128**	**8**	**25**	**67**	-	**85**	**70**	**28**	**2**	**0**							**0**	**1**
		E	**10**	**100**	**0**	**0**	-	**100**	**100**	**0**	**0**	**0**							**0**	**0**
15	On-demand manufacturing technology for pharmaceutical drugs and chemicals based on microreactors.	1	**81**	**10**	**21**	**69**	-	**67**	**40**	**50**	**9**	**1**							**0**	**9**
		2	**99**	**1**	**13**	**86**	-	**61**	**24**	**73**	**3**	**0**							**0**	**3**
		E	**1**	**100**	**0**	**0**	-	**100**	**100**	**0**	**0**	**0**							**0**	**0**
16	Technology for forming and machining a one-off product without using a mold.	1	**145**	**18**	**32**	**50**	-	**65**	**38**	**45**	**16**	**1**							**1**	**8**
		2	**134**	**8**	**31**	**61**	-	**63**	**28**	**67**	**5**	**0**							**0**	**1**
		E	**11**	**100**	**0**	**0**	-	**91**	**82**	**18**	**0**	**0**							**0**	**0**

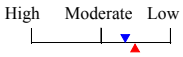


Countries at the leading edge					Regarding technological realization												Time of social application							Regarding social application											
					Necessity of gov't involvement				Effective measures that should be taken by gov't															Necessity of gov't involvement				Effective measures that should be taken by gov't							
Japan	USA	EU	Asia	Other	High	Moderate	Low	None	Human resources development	Strengthened industry-academic-government and interdisciplinary collaboration	Development of R&D infrastructure	Expansion of R&D funding	Internationalization of R&D activities	Relaxation or elimination of relevant regulations	Tightened or new regulations	Other	2006–2010	2011–2015	2016–2025	2026–2035	2036–	Will not be applied	Do not know	High	Moderate	Low	None	Human resources development	Strengthened industry-academic-government and interdisciplinary collaboration	Improvement of environment for business startups	Support through taxation, subsidies, and procurement	Relaxation or elimination of relevant regulations	Tightened or new regulations	Other
(%)					(%)				(%)													(%)		(%)				(%)							
24	61	8	0	7	16	41	32	11	25	47	44	45	8	7	7	1						4	12	14	36	36	14	31	45	27	37	18	14	0
8	91	1	0	0	5	55	36	4	17	63	37	52	3	3	2	0						2	4	5	41	49	5	22	74	16	40	12	7	0
100	0	0	0	0	0	0	100	0	50	100	0	0	0	0	0	0						0	0	0	0	100	0	50	100	0	0	0	0	0
8	78	6	0	8	8	33	44	15	37	41	37	36	4	4	3	3						5	19	9	24	47	20	30	48	19	29	10	7	3
2	97	0	0	1	4	29	60	7	29	60	37	42	2	2	0	0						8	7	3	23	64	10	37	73	11	32	4	2	0
0	100	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0						0	0	0	0	0	100	0	0	0	0	0	0	0
73	22	5	0	0	14	37	32	17	25	59	38	52	3	5	0	0						1	2	11	30	36	23	24	51	26	48	8	2	0
95	4	1	0	0	2	49	40	9	17	79	20	50	0	1	0	0						0	1	2	34	55	9	16	77	15	55	2	1	0
100	0	0	0	0	0	70	10	20	50	100	50	50	0	0	0	0						0	0	0	60	20	20	38	100	13	63	0	0	0
9	76	12	0	3	22	53	21	4	19	48	38	52	8	18	5	0						0	9	25	44	22	9	19	50	33	49	26	16	0
2	94	3	0	1	8	76	14	2	16	62	33	68	2	7	1	0						0	3	8	74	16	2	11	71	23	55	26	2	0
100	0	0	0	0	0	100	0	0	100	100	100	100	0	0	0	0						0	0	0	100	0	0	0	100	100	100	0	0	0
62	27	9	0	2	10	36	38	16	28	52	43	57	2	2	0	1						2	8	13	29	36	22	26	48	43	47	5	1	0
92	5	3	0	0	4	35	53	8	19	67	25	68	0	1	0	0						0	1	3	26	60	11	18	67	29	55	3	1	0
100	0	0	0	0	27	46	27	0	27	73	27	55	0	0	0	0						0	0	18	55	27	0	18	91	27	36	0	0	0

IV. Nano-machining/ micromachining technology

1. Questions regarding the relevant area

1) Degree of expertise in the area

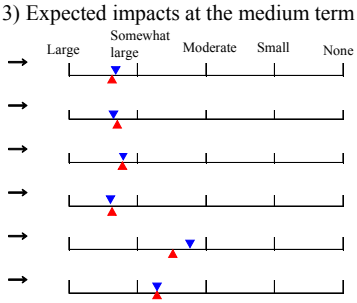


2) Current impacts

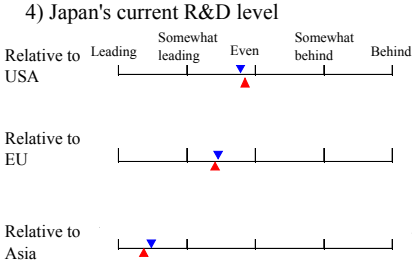
2. Questions regarding toipcs

No	Topic	Questionnaire	Respondents (persons)	Degree of expertise (%)				Importance to Japan					Time of technological realization							
				High	Moderate	Low	None	Index	High	Moderate	Low	None	Already realized	2006–2010	2011–2015	2016–2025	2026–2035	2036–	Will not be realized	Do not know
17	Super high precision process technology (for processing, analyzing, testing, and in-situ monitoring) at the angstrom level achieved through advances in beam technology (ion, electron, laser, etc.), machine control technology, and sensor technology.	1	**106**	**22**	**34**	**44**	-	**82**	**65**	**33**	**2**	**0**							**0**	**2**
		2	**114**	**11**	**17**	**72**	-	**91**	**82**	**18**	**0**	**0**							**0**	**1**
		E	**13**	**100**	**0**	**0**	-	**100**	**100**	**0**	**0**	**0**							**0**	**0**
18	Packaging technology at the few micron level for achieving super-small wearable equipment for use anywhere, anytime by a combination of optoelectronics, microelectronics, and micromachinery.	1	**100**	**12**	**30**	**58**	-	**76**	**56**	**37**	**7**	**0**							**0**	**2**
		2	**112**	**8**	**13**	**79**	-	**89**	**78**	**22**	**0**	**0**							**0**	**1**
		E	**9**	**100**	**0**	**0**	-	**94**	**89**	**11**	**0**	**0**							**0**	**0**
19	Technology for net shape forming with an accuracy of around ±1 μm through casting、sintering, and plastic working.	1	**113**	**29**	**31**	**40**	-	**72**	**48**	**47**	**5**	**0**							**1**	**4**
		2	**120**	**18**	**28**	**54**	-	**76**	**52**	**48**	**0**	**0**							**0**	**1**
		E	**22**	**100**	**0**	**0**	-	**93**	**86**	**14**	**0**	**0**							**0**	**0**
20	Technology for manufacturing high-value added products by using the bottom-up approach (self-organization) for supermolecular structure control at the nano level.	1	**96**	**16**	**27**	**57**	-	**75**	**54**	**39**	**7**	**0**							**1**	**4**
		2	**105**	**6**	**18**	**76**	-	**82**	**66**	**32**	**2**	**0**							**2**	**3**
		E	**6**	**100**	**0**	**0**	-	**92**	**83**	**17**	**0**	**0**							**0**	**0**
21	Technology that allows manufacturing processes to practically use the measurement of length, displacement, and surface roughness down to the angstrom level and the time measurement down to the femtosecond level.	1	**111**	**22**	**17**	**61**	-	**72**	**49**	**39**	**12**	**0**							**0**	**7**
		2	**115**	**7**	**19**	**74**	-	**82**	**64**	**34**	**2**	**0**							**1**	**2**
		E	**8**	**100**	**0**	**0**	-	**88**	**75**	**25**	**0**	**0**							**0**	**0**
22	Manufacturing technology for achieving innovative functions and properties through nanoscale manipulation and control of atoms and molecules or through control of materials structure or arrangement.	1	**102**	**15**	**25**	**60**	-	**77**	**58**	**35**	**7**	**0**							**0**	**5**
		2	**116**	**6**	**19**	**75**	-	**87**	**73**	**26**	**1**	**0**							**0**	**3**
		E	**7**	**100**	**0**	**0**	-	**93**	**86**	**14**	**0**	**0**							**0**	**0**

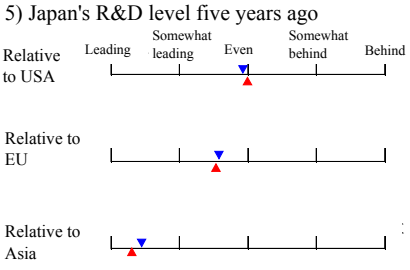
3) Expected impacts at the medium term



4) Japan's current R&D level



5) Japan's R&D level five years ago



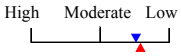
*Relative to EU and Asia means relative to their most advanced countries.

Countries at the leading edge					Regarding technological realization													Time of social application							Regarding social application													
					Necessity of gov't involvement				Effective measures that should be taken by gov't																	Necessity of gov't involvement				Effective measures that should be taken by gov't								
Japan	USA	EU	Asia	Other	High	Moderate	Low	None	Human resources development	Strengthened industry-academic-government and interdisciplinary collaboration	Development of R&D infrastructure	Expansion of R&D funding	Internationalization of R&D activities	Relaxation or elimination of relevant regulations	Tightened or new regulations	Improvement of environment for business startups	Support through taxation, subsidies, and procurement	Other	2006–2010	2011–2015	2016–2025	2026–2035	2036–	Will not be applied	Do not know	High	Moderate	Low	None	Human resources development	Strengthened industry-academic-government and interdisciplinary collaboration	Improvement of environment for business startups	Support through taxation, subsidies, and procurement	Relaxation or elimination of relevant regulations	Tightened or new regulations	Other
(%)					(%)				(%)															(%)					(%)								
50	37	11	1	1	33	46	17	4	27	62	37	61	3	1	0	0								0	3	24	44	21	11	21	64	24	39	5	4	0
73	26	1	0	0	15	73	11	1	15	74	25	62	1	0	0	0								0	1	11	66	21	2	16	83	15	46	4	1	0
67	33	0	0	0	54	46	0	0	15	77	54	69	0	0	0	0								0	0	38	54	8	0	23	85	23	69	0	0	0
45	50	5	0	0	31	48	19	2	32	59	41	61	5	2	0	0								0	3	24	43	26	7	25	63	28	44	9	6	0
26	74	0	0	0	9	81	10	0	17	74	25	67	2	0	0	0								0	1	5	72	22	1	17	83	13	47	1	1	0
25	75	0	0	0	50	50	0	0	38	63	63	63	13	0	0	0								0	0	33	56	11	0	22	67	44	78	0	0	0
76	10	12	0	2	18	47	27	8	33	60	37	63	3	1	0	0								1	6	19	36	29	16	30	60	24	48	3	2	0
91	3	6	0	0	9	71	17	3	25	73	23	68	1	1	0	0								0	2	5	64	25	6	22	78	13	53	1	1	0
91	0	9	0	0	24	71	0	5	45	70	30	70	0	0	0	0								0	0	18	54	23	5	24	90	5	43	5	5	0
34	56	9	0	1	26	53	16	5	40	59	36	68	5	2	0	0								2	6	26	40	18	16	34	68	25	51	1	0	0
10	89	1	0	0	9	79	10	2	30	74	28	68	3	1	0	0								2	4	8	70	18	4	27	84	16	52	0	0	0
0	83	17	0	0	50	50	0	0	33	83	50	50	0	0	0	0								0	0	50	33	17	0	17	100	17	33	0	0	0
44	39	17	0	0	23	44	24	9	28	58	44	54	4	2	0	0								0	8	21	38	21	20	28	65	22	45	6	1	0
60	38	2	0	0	11	74	11	4	16	84	31	62	0	0	0	0								1	3	4	67	25	4	18	84	14	48	1	1	0
87	13	0	0	0	62	38	0	0	50	88	75	50	0	0	0	0								0	0	50	25	25	0	38	75	13	38	13	13	0
31	62	6	0	1	34	50	13	3	32	63	46	58	4	1	0	0								1	7	32	40	16	12	31	71	22	49	5	1	0
8	91	1	0	0	18	75	6	1	22	75	39	69	0	0	0	0								0	3	13	72	12	3	27	78	18	59	0	0	0
50	33	17	0	0	100	0	0	0	29	57	29	86	0	0	0	0								0	0	86	0	14	0	29	57	29	71	0	0	0

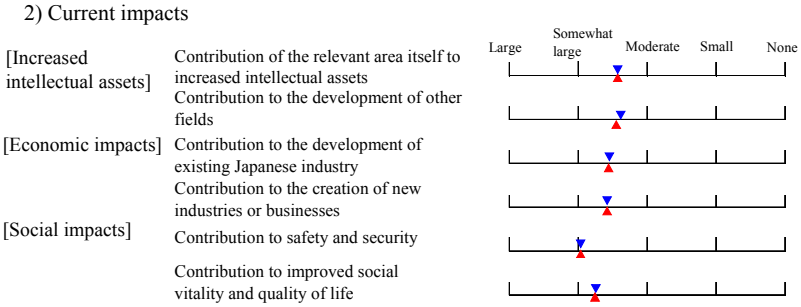
V. Recycling-oriented manufacturing technology with a low environmental load

1. Questions regarding the relevant area

1) Degree of expertise in the area

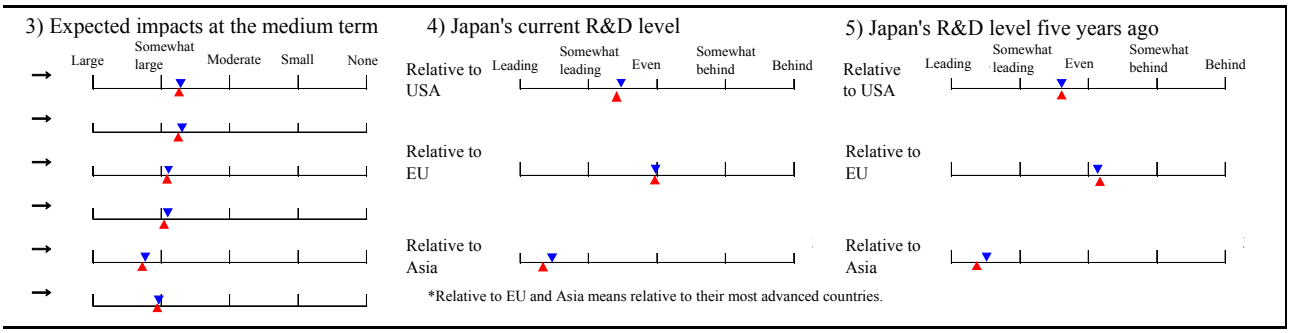


2) Current impacts



2. Questions regarding toipcs

No	Topic	Questionnaire	Respondents (persons)	Degree of expertise (%)				Importance to Japan					Time of technological realization							
				High	Moderate	Low	None	Index	High	Moderate	Low	None	Already realized	2006–2010	2011–2015	2016–2025	2026–2035	2036–	Will not be realized	Do not know
23	Optimizing technology on energy usage in a production process by means of large-scale energy storage system (superconductivity technology, a flywheel, a capacitor, etc.).	1	102	3	25	72	-	70	46	40	14	0							2	7
		2	108	3	10	87	-	75	52	42	6	0							0	5
		E	3	100	0	0	-	100	100	0	0	0							0	0
24	A low-entropy eco-factory taking everything into consideration of impacts on ecosystems including whole product life from birth to disposal.	1	110	3	17	80	-	70	46	44	10	0							0	7
		2	114	2	10	88	-	75	51	48	1	0							0	2
		E	2	100	0	0	-	100	100	0	0	0							0	0
25	An "inverse" manufacturing system that combines "arterial" (production) and "venous" (disposal) activities in which the production system (design→produce→use→scrap) and the resources recycling system	1	132	7	36	57	-	79	61	35	4	0							1	4
		2	133	3	29	68	-	90	81	19	0	0							0	2
		E	4	100	0	0	-	100	100	0	0	0							0	0
26	Assessment technology on the potential damage and risk associated with industrial parks and individual companies and production facilities, even assuming local impacts of chain-reaction and/or complex accidents.	1	81	2	22	76	-	58	25	60	14	1							0	5
		2	94	0	7	93	-	56	14	83	3	0							0	3
		E																		
27	Widespread use of production processes using low CO2 emitting energy sources such as non-fossil energy (wind, geothermal, photovoltaic, solar heat, waste heat, etc.), cogeneration systems, stationary fuel-cell systems etc..	1	128	8	27	65	-	85	71	25	4	0							3	4
		2	128	3	20	77	-	95	89	10	1	0							1	1
		E	4	100	0	0	-	100	100	0	0	0							0	0
28	Manufacturers' responsibility for collecting and disposing of discarded products is defined by law, and recycling systems in which more than 90% of used material is thermal- or material-recycled become widespread. Design for recycle/disassemble technology, easy assemble & disassemble production technology , selective collection system technology etc. enable it to achieve.	1	128	5	27	68	-	78	58	38	4	0							0	2
		2	123	5	18	77	-	91	83	17	0	0							0	1
		E	6	100	0	0	-	92	83	17	0	0							0	0
29	Product/material manufacturing technology and system technology that achieve safety, cleanness, high energy efficiency, and high cost effectiveness based on natural and biological mechanisms.	1	115	7	23	70	-	71	45	47	8	0							0	6
		2	119	3	14	83	-	67	35	64	1	0							0	5
		E	3	100	0	0	-	83	67	33	0	0							0	0
30	Technology that achieves energy and space savings through a major plant downsizing (1/2 to 1/10 of current size) or a dramatic improvement in plant serviceability by introducing modules in workflows, recombining modules, and constructing module-to-module communications systems.	1	120	9	31	60	-	71	47	45	8	0							0	1
		2	122	4	31	65	-	75	50	49	1	0							0	1
		E	5	100	0	0	-	90	80	20	0	0							0	0

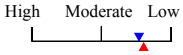


Countries at the leading edge					Regarding technological realization													Time of social application							Regarding social application													
					Necessity of gov't involvement				Effective measures that should be taken by gov't																	Necessity of gov't involvement				Effective measures that should be taken by gov't								
Japan	USA	EU	Asia	Other	High	Moderate	Low	None	Human resources development	Strengthened industry-academic-government and interdisciplinary collaboration	Development of R&D infrastructure	Expansion of R&D funding	Internationalization of R&D activities	Relaxation or elimination of relevant regulations	Tightened or new regulations	Other	2006–2010	2011–2015	2016–2025	2026–2035	2036–	Will not be applied	Do not know	High	Moderate	Low	None	Human resources development	Strengthened industry-academic-government and interdisciplinary collaboration	Improvement of environment for business startups	Support through taxation, subsidies, and procurement	Relaxation or elimination of relevant regulations	Tightened or new regulations	Other
(%)					(%)				(%)													(%)		(%)				(%)							
47	30	22	0	1	44	39	14	3	21	42	44	58	7	14	5	1						2	9	32	46	18	4	22	41	18	52	32	13	2
75	17	8	0	0	60	33	6	1	10	46	43	76	0	7	4	0						1	4	27	65	7	1	12	55	11	75	22	7	0
67	33	0	0	0	100	0	0	0	33	100	67	67	0	0	0	0						0	0	33	67	0	0	33	100	0	33	33	0	0
31	14	54	0	1	44	43	12	1	21	42	44	44	9	10	23	1						1	7	37	50	11	2	21	50	13	47	21	34	1
12	0	88	0	0	45	52	3	0	11	53	50	70	3	3	13	0						0	1	18	81	1	0	11	66	4	63	9	30	0
100	0	0	0	0	100	0	0	0	50	100	50	50	0	0	0	0						0	0	50	50	0	0	50	100	0	0	0	0	0
47	7	46	0	0	43	45	9	3	15	46	44	48	10	18	26	1						0	5	41	47	9	3	17	44	16	48	25	43	0
43	0	57	0	0	43	52	4	1	9	59	34	67	2	9	20	0						0	1	38	60	1	1	10	58	3	70	14	40	0
75	0	25	0	0	75	0	0	25	33	67	33	100	0	0	0	0						0	0	75	0	0	25	33	67	0	67	0	0	0
18	44	37	0	1	48	37	11	4	19	49	45	38	8	14	14	1						0	4	36	51	10	3	27	42	16	35	22	35	1
2	61	37	0	0	60	40	0	0	11	70	48	37	1	3	16	0						0	2	27	72	1	0	16	79	2	45	8	36	0
46	14	40	0	0	63	30	3	4	20	53	39	62	10	24	16	0						2	4	54	36	5	5	18	35	19	65	39	32	0
61	2	37	0	0	88	9	1	2	10	67	25	73	5	19	10	0						0	2	81	17	0	2	10	43	6	81	40	23	0
75	0	25	0	0	100	0	0	0	25	50	50	100	25	25	0	0						0	0	100	0	0	0	25	50	0	100	50	25	0
35	5	60	0	0	59	31	7	3	20	47	33	48	13	20	41	1						0	3	60	32	6	2	16	38	15	49	26	58	2
13	0	87	0	0	85	12	3	0	10	61	23	67	5	11	28	0						0	1	86	13	1	0	9	46	4	65	19	62	1
33	0	67	0	0	83	0	17	0	33	67	33	33	17	17	33	0						0	0	83	0	17	0	33	50	17	67	50	50	0
26	36	35	0	3	22	56	18	4	35	50	44	55	11	5	5	2						1	9	23	52	18	7	35	51	17	52	18	15	0
17	46	36	0	1	8	86	3	3	25	69	30	70	2	1	3	0						0	5	9	80	8	3	25	68	4	66	9	6	0
67	33	0	0	0	67	33	0	0	33	100	67	33	0	0	0	0						0	0	67	0	33	0	67	67	0	0	0	0	0
72	17	9	0	2	13	50	27	10	23	52	36	49	8	9	4	2						0	3	14	43	30	13	29	50	18	49	19	11	1
96	2	1	0	1	4	76	15	5	15	74	19	65	1	4	0	0						0	2	5	70	18	7	16	71	6	66	5	3	0
100	0	0	0	0	50	50	0	0	25	100	50	50	25	0	0	0						0	0	40	40	20	0	20	100	20	40	0	0	0

VI. Human and robot participation in manufacturing

1. Questions regarding the relevant area

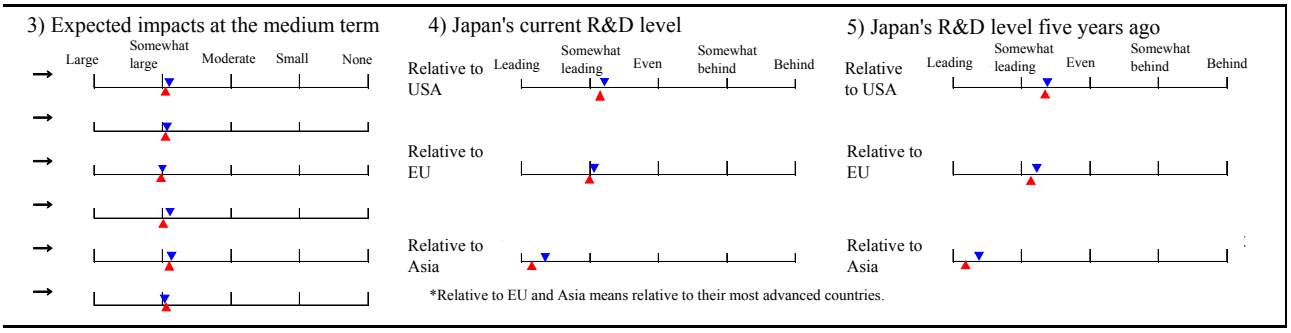
1) Degree of expertise in the area



2) Current impacts

2. Questions regarding toipcs

No	Topic	Questionnaire	Respondents (persons)	Degree of expertise (%)				Importance to Japan					Time of technological realization (%)							
				High	Moderate	Low	None	Index	High	Moderate	Low	None	Already realized	2006–2010	2011–2015	2016–2025	2026–2035	2036–	Will not be realized	Do not know
31	Digitization and advanced industrial robots reshape the job market and the employment practices in the manufacturing sector.	1	**136**	**8**	**32**	**60**	-	**65**	**39**	**47**	**13**	**1**							**2**	**7**
		2	**131**	**5**	**23**	**72**	-	**64**	**30**	**65**	**5**	**0**							**0**	**2**
		E	**6**	**100**	**0**	**0**	-	**92**	**83**	**17**	**0**	**0**							**0**	**0**
32	Technology for using robots in dangerous or hazardous work in manufacturing processes to ensure human operators' safety.	1	**142**	**8**	**26**	**66**	-	**67**	**40**	**50**	**9**	**1**							**1**	**4**
		2	**130**	**5**	**22**	**73**	-	**63**	**27**	**70**	**3**	**0**							**0**	**1**
		E	**6**	**100**	**0**	**0**	-	**79**	**66**	**17**	**17**	**0**							**0**	**0**
33	A system that issues an alert when a possibility of human error is detected through real-time analysis of human behavior across the shop floor.	1	**124**	**7**	**29**	**64**	-	**56**	**24**	**53**	**23**	**0**							**1**	**7**
		2	**122**	**2**	**23**	**75**	-	**55**	**11**	**86**	**3**	**0**							**0**	**1**
		E	**3**	**100**	**0**	**0**	-	**83**	**67**	**33**	**0**	**0**							**0**	**0**
34	In the manufacturing sector, women account for 50% of researchers and engineers.	1	**112**	**3**	**19**	**78**	-	**54**	**22**	**53**	**23**	**2**								
		2	**123**	**1**	**10**	**89**	-	**52**	**11**	**74**	**15**	**0**								
		E	**1**	**100**	**0**	**0**	-	**100**	**100**	**0**	**0**	**0**								
35	A common global language (including software) to express manufacturing information and knowledge is established, resulting in an interface technology through which communications (including intentions) between humans, machines, and information systems can be conducted accurately across different cultures and languages.	1	**107**	**8**	**17**	**75**	-	**59**	**29**	**53**	**14**	**4**							**8**	**10**
		2	**117**	**3**	**8**	**89**	-	**52**	**6**	**88**	**6**	**0**							**5**	**5**
		E	**4**	**100**	**0**	**0**	-	**63**	**25**	**75**	**0**	**0**							**0**	**0**
36	Manufacturing and process design technologies resulting from the discovery of new laws based on life science.	1	**90**	**4**	**22**	**74**	-	**55**	**23**	**53**	**21**	**3**							**6**	**16**
		2	**109**	**1**	**8**	**91**	-	**53**	**11**	**80**	**9**	**0**							**0**	**6**
		E	**1**	**100**	**0**	**0**	-	**100**	**100**	**0**	**0**	**0**							**0**	**0**
37	An operator support system that creates work environments friendly to all workers including women, the elderly, and the disabled.	1	**111**	**5**	**25**	**70**	-	**68**	**41**	**50**	**9**	**0**							**0**	**2**
		2	**119**	**3**	**9**	**88**	-	**66**	**33**	**66**	**1**	**0**							**0**	**2**
		E	**3**	**100**	**0**	**0**	-	**100**	**100**	**0**	**0**	**0**							**0**	**0**
38	Production system technology based on robots with s elf-repair capability.	1	**113**	**8**	**25**	**67**	-	**56**	**24**	**54**	**21**	**1**							**3**	**9**
		2	**108**	**4**	**19**	**77**	-	**53**	**8**	**87**	**5**	**0**							**1**	**1**
		E	**4**	**100**	**0**	**0**	-	**63**	**25**	**75**	**0**	**0**							**0**	**0**



*Relative to EU and Asia means relative to their most advanced countries.

Countries at the leading edge					Regarding technological realization												Time of social application							Regarding social application											
					Necessity of gov't involvement				Effective measures that should be taken by gov't															Necessity of gov't involvement				Effective measures that should be taken by gov't							
Japan	USA	EU	Asia	Other	High	Moderate	Low	None	Human resources development	Strengthened industry-academic-government and interdisciplinary collaboration	Development of R&D infrastructure	Expansion of R&D funding	Internationalization of R&D activities	Relaxation or elimination of relevant regulations	Tightened or new regulations	Other	2006–2010	2011–2015	2016–2025	2026–2035	2036–	Will not be applied	Do not know	High	Moderate	Low	None	Human resources development	Strengthened industry-academic-government and interdisciplinary collaboration	Improvement of environment for business startups	Support through taxation, subsidies, and procurement	Relaxation or elimination of relevant regulations	Tightened or new regulations	Other
(%)					(%)				(%)													(%)		(%)				(%)						
80	19	1	0	0	18	39	27	16	25	58	27	39	9	20	11	4						4	8	15	44	24	17	30	47	17	44	30	17	2
97	3	0	0	0	6	61	28	5	15	79	16	52	0	15	4	0						0	3	6	68	21	5	20	66	7	54	23	6	0
100	0	0	0	0	17	33	33	17	20	80	20	60	0	0	0	0						0	0	17	50	33	0	33	83	33	33	0	0	0
70	24	5	0	1	14	52	20	14	22	57	30	56	7	13	13	1						0	6	16	45	25	14	21	51	18	58	24	21	1
90	9	1	0	0	6	76	16	2	14	75	19	60	0	12	10	0						0	2	9	72	17	2	13	66	6	68	18	10	0
67	33	0	0	0	17	33	33	17	0	100	40	40	0	20	0	0						0	0	33	33	17	17	0	80	20	20	20	20	0
50	37	11	0	2	9	43	34	14	29	48	39	53	6	7	8	2						2	7	12	39	31	18	26	52	13	47	14	13	2
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100	0	0	0	0	0	33	67	0	0	100	33	67	0	0	0	0						0	0	0	67	33	0	33	67	0	33	0	33	0
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																						12	8	20	66	5	9	80	5	1	21	56	19	0
																						0	0	0	100	0	0	0	0	0	0	100	0	0
15	66	15	0	4	23	42	22	13	34	47	43	37	34	8	1	2						9	12	17	51	19	13	40	51	23	47	17	6	3
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10	75	11	0	4	23	45	19	13	43	49	47	49	16	7	7	1						10	17	22	53	12	13	47	54	24	39	12	15	0
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0	100	0	0	0	0	100	0	0	0	100	100	100	0	0	0	0						0	0	0	100	0	0	100	100	100	100	0	0	0
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67	33	0	0	0	67	33	0	0	33	67	33	33	0	33	33	0						0	0	67	33	0	0	33	33	33	67	0	0	0
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84	16	0	0	0	2	74	20	4	15	69	25	72	2	2	0	0						1	4	2	71	23	4	18	82	10	51	6	2	0
75	25	0	0	0	25	50	25	0	50	50	50	50	0	0	0	0						0	0	25	50	25	0	75	50	50	25	0	0	0

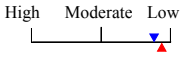
No	Topic	Questionnaire	Respondents (persons)	Degree of expertise (%)				Importance to Japan (%)					Time of technological realization							
				High	Moderate	Low	None	Index	High	Moderate	Low	None	Already realized	2006–2010	2011–2015	2016–2025	2026–2035	2036–	Will not be realized	Do not know
39	Manufacturing technology based on robots that can adapt to change in the operational environment with real-time 3D image processing and force control functions.	1	**114**	**12**	**21**	**67**	**-**	**61**	**31**	**54**	**13**	**2**							**3**	**5**
		2	**110**	**5**	**12**	**83**	**-**	**54**	**9**	**87**	**4**	**0**							**1**	**2**
		E	**6**	**100**	**0**	**0**	**-**	**92**	**83**	**17**	**0**	**0**							**0**	**0**
40	Technology for controlling robots in human-robot cooperative tasks using high-accuracy detection of human brain waves.	1	**90**	**8**	**13**	**79**	**-**	**53**	**24**	**43**	**28**	**5**							**13**	**7**
		2	**99**	**0**	**7**	**93**	**-**	**46**	**3**	**78**	**17**	**2**							**14**	**6**
		E																		

Countries at the leading edge					Regarding technological realization												Time of social application							Regarding social application													
					Necessity of gov't involvement				Effective measures that should be taken by gov't															Necessity of gov't involvement				Effective measures that should be taken by gov't								
Japan	USA	EU	Asia	Other	High	Moderate	Low	None	Human resources development	Strengthened industry-academic-government and interdisciplinary collaboration	Development of R&D infrastructure	Expansion of R&D funding	Internationalization of R&D activities	Relaxation or elimination of relevant regulations	Tightened or new regulations	Other	2006–2010	2011–2015	2016–2025	2026–2035	2036–	Will not be applied	Do not know	High	Moderate	Low	None	Human resources development	Strengthened industry-academic-government and interdisciplinary collaboration	Improvement of environment for business startups	Support through taxation, subsidies, and procurement	Relaxation or elimination of relevant regulations	Tightened or new regulations	Other
(%)					(%)				(%)													(%)		(%)				(%)							
60	33	4	0	3	11	55	26	8	24	54	36	68	4	7	1	1						5	5	14	46	26	14	24	59	29	43	9	2	0
85	15	0	0	0	3	74	18	5	16	70	21	73	1	1	0	0						1	3	4	72	18	6	21	79	12	58	2	0	0
100	0	0	0	0	17	49	17	17	40	80	40	40	0	0	0	0						0	0	33	17	33	17	80	60	20	20	0	0	0
28	64	5	0	3	14	43	33	10	30	43	46	48	4	8	4	4						14	10	14	38	33	15	40	58	19	37	10	7	1
4	96	0	0	0	2	69	23	6	24	50	47	73	1	3	0	0						19	6	3	63	28	6	38	76	8	37	8	4	1

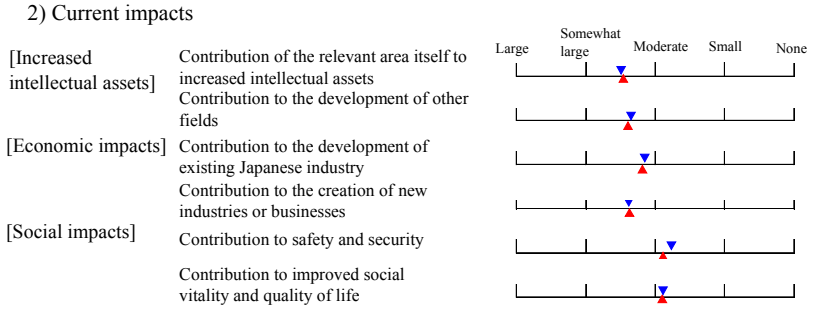
VII. Manufacturing technology in special environments

1. Questions regarding the relevant area

1) Degree of expertise in the area

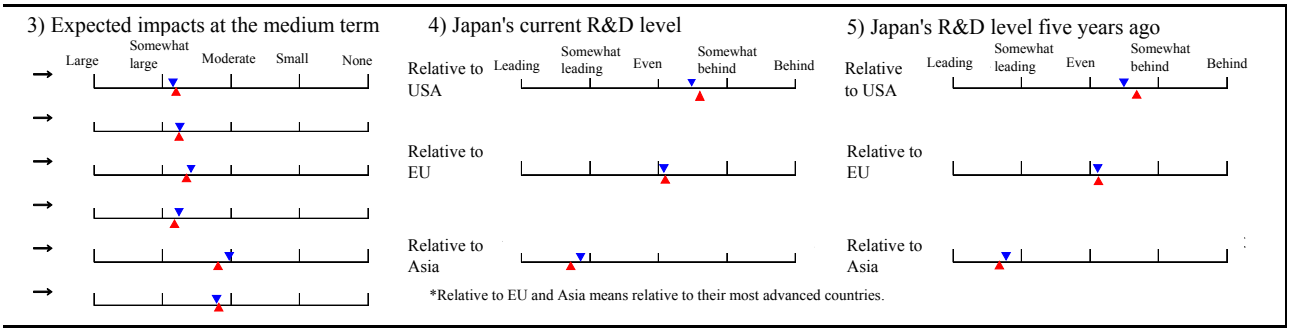


2) Current impacts



2. Questions regarding toipcs

No	Topic	Questionnaire	Respondents (persons)	Degree of expertise (%)				Importance to Japan					Time of technological realization							
				High	Moderate	Low	None	Index	High	Moderate	Low	None	Already realized	2006–2010	2011–2015	2016–2025	2026–2035	2036–	Will not be realized (%)	Do not know (%)
41	Manufacturing process technology that utilizes functions of microorganisms inhabiting ultrahigh pressure, high pH, or other extreme environments.	1	52	6	19	75	-	50	12	67	19	2							2	19
		2	82	0	5	95	-	47	1	86	11	2							0	5
		E		100	0	0	-	0	100	0	0	0							0	0
42	Manufacturing process technology that utilizes gravity-free, minimal gravity, or other special environments.	1	80	1	11	88	-	49	15	53	29	3							3	10
		2	97	0	5	95	-	43	3	68	26	3							5	4
		E																		
43	An efficient manufacturing process that uses or mimics microorganism functions.	1	63	8	17	75	-	59	27	55	16	2							2	13
		2	96	0	6	94	-	50	7	81	10	2							0	4
		E		100	0	0	-	0	100	0	0	0							0	0

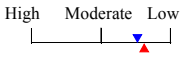


Countries at the leading edge					Regarding technological realization													Time of social application							Regarding social application													
					Necessity of gov't involvement				Effective measures that should be taken by gov't																	Necessity of gov't involvement				Effective measures that should be taken by gov't								
Japan	USA	EU	Asia	Other	High	Moderate	Low	None	Human resources development	Strengthened industry-academic-government and interdisciplinary collaboration	Development of R&D infrastructure	Expansion of R&D funding	Internationalization of R&D activities	Relaxation or elimination of relevant regulations	Tightened or new regulations	Other	2006–2010	2011–2015	2016–2025	2026–2035	2036–	Will not be applied	Do not know	High	Moderate	Low	None	Human resources development	Strengthened industry-academic-government and interdisciplinary collaboration	Improvement of environment for business startups	Support through taxation, subsidies, and procurement	Relaxation or elimination of relevant regulations	Tightened or new regulations	Other
(%)					(%)				(%)													(%)		(%)				(%)							
19	71	6	0	4	21	44	25	10	33	37	52	43	2	4	4	0						2	19	15	49	23	13	32	59	20	50	14	9	0
3	97	0	0	0	4	74	19	3	29	38	71	45	3	0	0	0						0	6	3	75	17	5	27	77	9	53	1	0	0
100	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0						0	0	100	0	0	0	0	0	0	0	0	0	0
8	87	4	0	1	24	52	20	4	29	47	51	53	21	3	4	1						3	16	18	45	29	8	30	70	26	48	4	4	0
0	99	1	0	0	13	73	12	2	16	38	64	60	11	0	0	0						4	10	6	71	20	3	23	77	9	48	1	0	1
30	57	9	0	4	19	50	21	10	27	47	51	51	7	11	4	0						3	13	15	49	20	16	28	56	26	52	18	10	0
7	92	0	0	1	5	82	12	1	25	46	70	57	3	2	0	0						1	6	2	81	14	3	25	75	11	52	8	2	0
100	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0						0	0	100	0	0	0	0	0	0	0	0	0	0

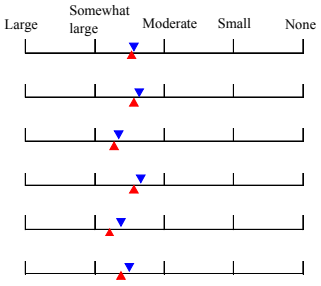
VIII. Advanced manufacturing technology for social infrastructure

1. Questions regarding the relevant area

1) Degree of expertise in the area



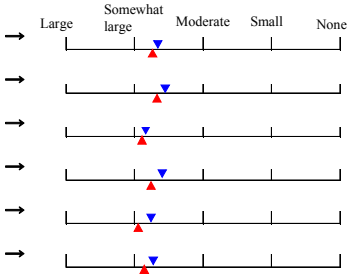
2) Current impacts



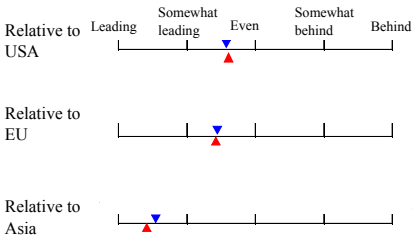
2. Questions regarding toipcs

No	Topic	Questionnaire	Respondents (persons)	Degree of expertise (%)				Importance to Japan					Time of technological realization								
				High	Moderate	Low	None	Index	High	Moderate	Low	None	Already realized	2006–2010	2011–2015	2016–2025	2026–2035	2036–	Will not be realized	Do not know
																			(%)		
44	Technology for manufacturing heavy structures such as large equipment, buildings, and vessels by using light-weight, high-strength composite materials instead of conventional steel materials.	1	**104**	**17**	**30**	**53**	**-**	**65**	**36**	**55**	**8**	**1**							**5**	**8**
		2	**106**	**8**	**28**	**64**	**-**	**60**	**21**	**75**	**4**	**0**							**2**	**1**
		E	**9**	**100**	**0**	**0**	**-**	**89**	**78**	**22**	**0**	**0**							**0**	**0**
45	High-strength, high-durability bonding technologies, such as plastic bonding, that can substitute for welding in heavy structures.	1	**97**	**16**	**27**	**57**	**-**	**55**	**20**	**61**	**18**	**1**							**4**	**6**
		2	**104**	**8**	**21**	**71**	**-**	**54**	**11**	**83**	**6**	**0**							**0**	**1**
		E	**8**	**100**	**0**	**0**	**-**	**79**	**57**	**43**	**0**	**0**							**0**	**0**
46	Technology for bonding dissimilar materials (e.g., composite material and steel) in heavy structures.	1	**96**	**18**	**27**	**55**	**-**	**59**	**27**	**57**	**15**	**1**							**2**	**6**
		2	**103**	**9**	**18**	**73**	**-**	**56**	**14**	**81**	**5**	**0**							**1**	**1**
		E	**9**	**100**	**0**	**0**	**-**	**89**	**78**	**22**	**0**	**0**							**0**	**0**
47	Low-deformation/-distortion (1/1000 of conventional level) bonding technology based on liquid-phase or solid-state diffusion that can substitute for conventional hot-melt bonding in heavy structures.	1	**80**	**18**	**34**	**48**	**-**	**59**	**25**	**61**	**13**	**1**							**1**	**9**
		2	**95**	**8**	**17**	**75**	**-**	**53**	**9**	**86**	**5**	**0**							**0**	**2**
		E	**8**	**100**	**0**	**0**	**-**	**69**	**38**	**62**	**0**	**0**							**0**	**14**
48	Technology for construction of vessels, bridges, thermal power plants and other large structures with no need for modification and maintenance, by simulating and accurately predicting deformations by gravity, temperature, heat input in bonding, and residual stress in steel, and incorporating the results into the initial design.	1	**87**	**17**	**23**	**60**	**-**	**60**	**29**	**52**	**18**	**1**							**1**	**8**
		2	**97**	**6**	**14**	**80**	**-**	**56**	**13**	**86**	**1**	**0**							**0**	**1**
		E	**6**	**100**	**0**	**0**	**-**	**75**	**50**	**50**	**0**	**0**							**0**	**0**
49	Technology for desert revegetation and food production in desert areas to help avoid food crises resulting from population growth.	1	**63**	**5**	**11**	**84**	**-**	**60**	**33**	**45**	**17**	**5**							**0**	**10**
		2	**88**	**1**	**0**	**99**	**-**	**53**	**11**	**78**	**11**	**0**							**0**	**1**
		E	**1**	**100**	**0**	**0**	**-**	**50**	**0**	**100**	**0**	**0**							**0**	**0**

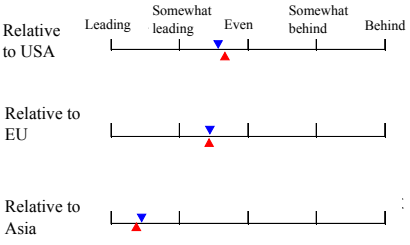
3) Expected impacts at the medium term



4) Japan's current R&D level



5) Japan's R&D level five years ago



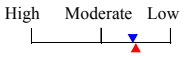
*Relative to EU and Asia means relative to their most advanced countries.

Countries at the leading edge					Regarding technological realization													Time of social application							Regarding social application													
					Necessity of gov't involvement				Effective measures that should be taken by gov't																	Necessity of gov't involvement				Effective measures that should be taken by gov't								
Japan	USA	EU	Asia	Other	High	Moderate	Low	None	Human resources development	Strengthened industry-academic-government and interdisciplinary collaboration	Development of R&D infrastructure	Expansion of R&D funding	Internationalization of R&D activities	Relaxation or elimination of relevant regulations	Tightened or new regulations	Other	2006–2010	2011–2015	2016–2025	2026–2035	2036–	Will not be applied	Do not know	High	Moderate	Low	None	Human resources development	Strengthened industry-academic-government and interdisciplinary collaboration	Improvement of environment for business startups	Support through taxation, subsidies, and procurement	Relaxation or elimination of relevant regulations	Tightened or new regulations	Other
(%)					(%)				(%)													(%)		(%)				(%)							
65	29	5	0	1	16	50	27	7	22	54	33	65	6	16	6	2						4	9	16	47	29	8	23	51	14	49	34	11	3
92	7	1	0	0	8	73	17	2	15	67	17	72	2	4	0	0						2	1	5	71	22	2	16	71	3	53	16	5	0
87	13	0	0	0	45	44	11	0	33	78	33	67	0	0	0	0						0	0	22	67	0	11	38	75	0	50	25	0	0
48	28	23	0	1	13	42	34	11	29	56	30	67	4	11	2	0						3	7	11	38	38	13	19	59	16	51	21	6	1
87	8	5	0	0	4	77	17	2	20	72	17	72	1	0	0	0						0	1	3	66	28	3	13	74	2	57	7	0	0
100	0	0	0	0	13	62	25	0	50	100	0	63	0	0	0	0						0	0	14	58	14	14	33	83	0	33	0	0	0
44	38	17	0	1	13	42	35	10	31	61	30	66	4	7	2	0						1	8	11	40	34	15	22	61	21	48	18	6	0
78	20	2	0	0	5	75	18	2	20	71	17	73	1	0	0	0						1	1	5	66	26	3	19	71	3	60	7	0	0
87	13	0	0	0	22	67	11	0	44	78	0	67	0	0	0	0						0	0	33	56	0	11	38	63	0	50	0	0	0
54	24	19	0	3	13	48	33	6	30	58	36	62	3	4	3	0						1	8	13	44	31	12	22	60	21	47	18	9	0
89	10	1	0	0	4	78	17	1	17	70	22	66	1	0	0	0						0	2	3	75	20	2	15	81	3	54	4	1	0
100	0	0	0	0	13	62	25	0	13	88	25	63	0	0	0	0						0	14	13	61	13	13	43	86	0	43	0	0	0
50	42	7	0	1	16	41	33	10	32	53	34	64	8	5	4	3						1	8	16	38	31	15	28	59	23	46	13	8	0
76	23	1	0	0	5	79	15	1	16	67	20	74	1	1	0	0						0	1	3	75	19	3	16	81	8	56	4	1	0
100	0	0	0	0	33	50	17	0	33	83	50	67	0	0	0	0						0	0	17	66	0	17	40	80	20	60	0	0	0
27	43	18	7	5	39	43	10	8	40	33	33	56	46	9	4	0						0	10	33	51	9	7	43	55	19	58	13	8	4
16	81	3	0	0	22	75	1	2	49	27	16	80	37	0	0	0						0	1	18	78	3	1	44	59	5	76	3	0	0
100	0	0	0	0	0	100	0	0	100	100	0	100	100	0	0	0						0	0	0	100	0	0	100	100	0	100	0	0	0

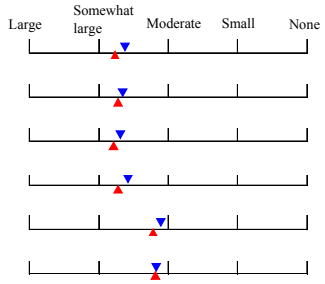
IX. Surface modification and interface control technology

1. Questions regarding the relevant area

1) Degree of expertise in the area



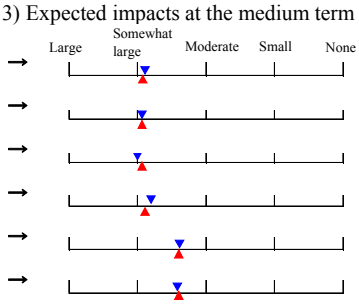
2) Current impacts



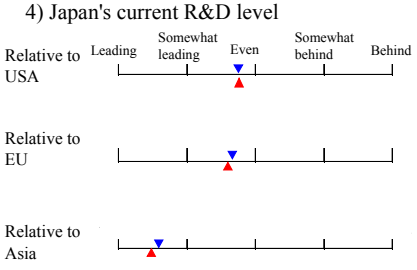
2. Questions regarding toipcs

No	Topic	Questionnaire	Respondents (persons)	Degree of expertise (%)				Importance to Japan					Time of technological realization								
				High	Moderate	Low	None	Index	High	Moderate	Low	None	Already realized	2006–2010	2011–2015	2016–2025	2026–2035	2036–	Will not be realized	Do not know
																			(%)		
50	Technology for dramatically (three or more times longer than current level) extending the life of production facilities through innovations in material surface properties.	1	**114**	**17**	**28**	**55**	**-**	**61**	**29**	**59**	**12**	**0**							**3**	**6**
		2	**121**	**8**	**22**	**70**	**-**	**55**	**13**	**82**	**5**	**0**							**0**	**2**
		E	**10**	**100**	**0**	**0**	**-**	**75**	**50**	**50**	**0**	**0**							**0**	**0**
51	Technology for forming super-hard thin film (e.g. diamond thin film) on a complex surface to be applied to the sliding surface of bearings and special tools.	1	**116**	**16**	**29**	**55**	**-**	**60**	**28**	**58**	**14**	**0**							**0**	**3**
		2	**121**	**9**	**19**	**72**	**-**	**56**	**14**	**83**	**3**	**0**							**0**	**1**
		E	**11**	**100**	**0**	**0**	**-**	**73**	**45**	**55**	**0**	**0**							**0**	**0**
52	Self-lubricating machine elements become commercially available, widely eliminating the need for lubricating the processing machines.	1	**111**	**14**	**30**	**56**	**-**	**59**	**28**	**52**	**20**	**0**							**7**	**6**
		2	**120**	**7**	**23**	**70**	**-**	**54**	**12**	**82**	**6**	**0**							**2**	**3**
		E	**8**	**100**	**0**	**0**	**-**	**75**	**50**	**50**	**0**	**0**							**13**	**0**
53	Proliferation of dry processing technology with which no lubricant or processing fluid is necessary for machining and plastic working.	1	**115**	**29**	**23**	**48**	**-**	**60**	**28**	**53**	**19**	**0**							**4**	**4**
		2	**120**	**17**	**26**	**58**	**-**	**59**	**21**	**73**	**6**	**0**							**3**	**3**
		E	**20**	**100**	**0**	**0**	**-**	**73**	**45**	**55**	**0**	**0**							**10**	**0**
54	Machine element technology that allows significant regulation of holding stiffness and damping properties through the use of functional materials such as electroviscous fluid.	1	**91**	**10**	**31**	**59**	**-**	**50**	**14**	**59**	**26**	**1**							**0**	**1**
		2	**104**	**7**	**20**	**73**	**-**	**51**	**6**	**85**	**9**	**0**							**0**	**2**
		E	**7**	**100**	**0**	**0**	**-**	**64**	**29**	**71**	**0**	**0**							**0**	**0**
55	Micromachining/ultra micromachining technology that can change material's surface properties, such as wettability and optical quality, according to the aim of the machine element.	1	**91**	**22**	**30**	**48**	**-**	**65**	**33**	**59**	**8**	**0**							**0**	**4**
		2	**109**	**12**	**21**	**67**	**-**	**56**	**15**	**81**	**3**	**1**							**0**	**2**
		E	**13**	**100**	**0**	**0**	**-**	**69**	**38**	**62**	**0**	**0**							**0**	**0**

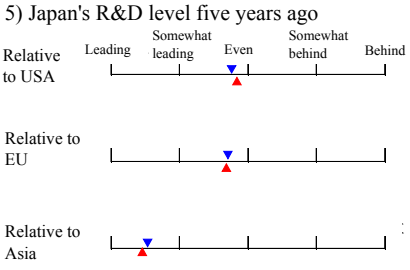
3) Expected impacts at the medium term



4) Japan's current R&D level



5) Japan's R&D level five years ago



*Relative to EU and Asia means relative to their most advanced countries.

Countries at the leading edge					Regarding technological realization													Time of social application							Regarding social application													
					Necessity of gov't involvement				Effective measures that should be taken by gov't																	Necessity of gov't involvement				Effective measures that should be taken by gov't								
Japan	USA	EU	Asia	Other	High	Moderate	Low	None	Human resources development	Strengthened industry-academic-government and interdisciplinary collaboration	Development of R&D infrastructure	Expansion of R&D funding	Internationalization of R&D activities	Relaxation or elimination of relevant regulations	Tightened or new regulations	Other	2006–2010	2011–2015	2016–2025	2026–2035	2036–	Will not be applied	Do not know	High	Moderate	Low	None	Human resources development	Strengthened industry-academic-government and interdisciplinary collaboration	Improvement of environment for business startups	Support through taxation, subsidies, and procurement	Relaxation or elimination of relevant regulations	Tightened or new regulations	Other
(%)					(%)				(%)													(%)		(%)				(%)							
54	36	10	0	0	16	43	24	17	24	59	37	56	5	2	1	0						2	7	11	42	24	23	20	64	22	47	5	1	0
90	8	2	0	0	3	74	17	6	12	75	20	71	0	2	1	0						0	3	3	70	18	9	10	86	6	52	4	1	0
70	10	20	0	0	20	80	0	0	20	50	40	90	0	0	0	0						0	0	30	50	20	0	30	80	10	30	0	0	0
62	25	12	1	0	15	35	32	18	21	55	32	60	5	2	1	0						0	4	10	38	25	27	24	60	23	48	4	2	1
92	6	2	0	0	4	65	26	5	11	66	17	79	0	3	1	0						0	1	3	62	25	10	9	85	9	52	3	1	0
91	0	9	0	0	27	73	0	0	18	36	27	100	0	0	0	0						0	0	27	55	18	0	27	91	0	18	0	0	0
62	25	13	0	0	13	38	30	19	24	56	34	51	3	3	2	1						8	7	10	36	29	25	27	54	19	46	6	4	1
91	6	3	0	0	3	62	30	5	9	71	17	68	0	2	1	0						3	4	3	59	29	9	10	78	4	56	2	2	0
74	13	13	0	0	13	61	13	13	14	43	29	100	0	0	0	0						13	0	25	37	25	13	29	100	0	29	0	0	0
57	17	25	0	1	11	40	30	19	29	52	32	52	9	4	5	1						4	4	11	39	27	23	27	53	18	48	7	9	0
90	2	8	0	0	4	65	27	4	15	73	18	71	2	2	2	0						3	3	3	61	29	7	13	79	2	55	3	5	0
75	0	25	0	0	16	63	16	5	22	67	17	89	11	0	6	0						11	0	11	63	21	5	17	83	0	44	0	0	0
50	36	14	0	0	10	41	30	19	22	51	33	56	8	1	1	1						1	2	7	44	27	22	24	72	16	40	3	1	0
80	17	3	0	0	2	69	26	3	9	67	20	74	0	1	0	0						1	2	2	67	25	6	12	82	4	55	1	0	0
86	0	14	0	0	0	57	43	0	14	57	29	71	0	0	0	0						0	0	0	33	50	17	20	80	0	40	0	0	0
50	36	14	0	0	20	44	19	17	24	55	36	67	3	1	1	0						0	3	16	44	17	23	29	66	24	43	4	1	1
82	13	5	0	0	5	77	14	4	12	72	23	75	0	1	0	0						1	3	5	76	12	7	13	88	10	54	1	0	0
77	23	0	0	0	23	77	0	0	31	62	46	85	0	0	0	0						0	0	23	69	8	0	38	92	23	54	0	0	0

Questions regardig other topics

No	Topic	Questionnaire	Respondents (persons)	Degree of expertise (%)				Importance to Japan (%)					Time of technological realization									
				High	Moderate	Low	None	Index	High	Moderate	Low	None	Already realized	2006–2010	2011–2015	2016–2025	2026–2035	2036–	Will not be realized	Do not know
56	A technical education program that ensures the handing down of expertise and craftsmanship by establishing technology for converting implicit knowledge on manufacturing and manufacturing technique (e.g. basic techniques and skills, know-how, experience) into explicit knowledge.	1	**157**	**17**	**36**	**47**	**-**	**81**	**65**	**29**	**6**	**0**								**5**	**8**
		2	**141**	**10**	**33**	**57**	**-**	**94**	**87**	**13**	**0**	**0**								**2**	**2**
		E	**14**	**100**	**0**	**0**	**-**	**96**	**93**	**7**	**0**	**0**								**7**	**0**
57	University and higher-education systems in which students can choose freely from broad production-related technical fields (materials, design, information, electronics, mechanical, and analysis/assessment technologies, quality engineering, business administration, etc.) and earn credits.	1	**139**	**20**	**30**	**50**	**-**	**72**	**49**	**44**	**6**	**1**									
		2	**136**	**12**	**24**	**64**	**-**	**82**	**65**	**33**	**2**	**0**									
		E	**16**	**100**	**0**	**0**	**-**	**91**	**81**	**19**	**0**	**0**									
58	Promotion of human resources mobility that is promoted across industry, academia, and government, leading to a greater number of joint or collaboration projects, and consequently bringing about innovations in manufacturing technology.	1	**156**	**15**	**38**	**47**	**-**	**81**	**63**	**32**	**5**	**0**									
		2	**139**	**9**	**35**	**56**	**-**	**93**	**86**	**14**	**0**	**0**									
		E	**12**	**100**	**0**	**0**	**-**	**100**	**100**	**0**	**0**	**0**									
59	Implementation of a new elementary and secondary education scheme that emphasizes science and mathematics to make Japan a world leader in science and technology.	1	**150**	**16**	**23**	**61**	**-**	**88**	**77**	**19**	**4**	**0**									
		2	**142**	**6**	**22**	**72**	**-**	**95**	**89**	**9**	**1**	**1**									
		E	**9**	**100**	**0**	**0**	**-**	**100**	**100**	**0**	**0**	**0**									

Countries at the leading edge					Regarding technological realization												Time of social application							Regarding social application															
					Necessity of gov't involvement				Effective measures that should be taken by gov't																Necessity of gov't involvement				Effective measures that should be taken by gov't											
Japan	USA	EU	Asia	Other	High	Moderate	Low	None	Human resources development	Strengthened industry-academic-government and interdisciplinary collaboration	Development of R&D infrastructure	Expansion of R&D funding	Internationalization of R&D activities	Relaxation or elimination of relevant regulations	Tightened or new regulations	Other	2006–2010	2011–2015	2016–2025	2026–2035	2036–	Will not be applied	Do not know	High	Moderate	Low	None	Human resources development	Strengthened industry-academic-government and interdisciplinary collaboration	Improvement of environment for business startups	Support through taxation, subsidies, and procurement	Relaxation or elimination of relevant regulations	Tightened or new regulations	Other				
(%)					(%)				(%)													(%)		(%)				(%)											
60	**22**	**18**	**0**	**0**	**37**	**37**	**18**	**8**	**64**	**55**	**36**	**40**	**5**	**4**	**1**	**0**						**3**	**7**	**37**	**36**	**18**	**9**	**67**	**60**	**12**	**39**	**10**	**5**	**1**				
87	**8**	**5**	**0**	**0**	**39**	**50**	**7**	**4**	**79**	**57**	**24**	**44**	**1**	**0**	**1**	**0**						**2**	**4**	**43**	**45**	**6**	**6**	**81**	**68**	**2**	**38**	**2**	**1**	**0**				
79	**21**	**0**	**0**	**0**	**54**	**23**	**23**	**0**	**54**	**62**	**31**	**46**	**0**	**0**	**0**	**0**						**7**	**0**	**57**	**14**	**29**	**0**	**93**	**71**	**0**	**50**	**0**	**0**	**0**				
																						2	**8**	**50**	**37**	**10**	**3**	**56**	**51**	**6**	**20**	**38**	**17**	**3**				
																						0	**1**	**81**	**13**	**5**	**1**	**76**	**63**	**0**	**14**	**31**	**3**	**1**				
																						0	**0**	**68**	**19**	**13**	**0**	**75**	**69**	**0**	**25**	**25**	**0**	**0**				
																						0	**7**	**61**	**30**	**7**	**2**	**57**	**75**	**8**	**27**	**42**	**14**	**1**				
																						0	**1**	**83**	**12**	**4**	**1**	**66**	**81**	**0**	**18**	**36**	**2**	**1**				
																						0	**0**	**84**	**0**	**8**	**8**	**82**	**91**	**0**	**18**	**73**	**0**	**0**				
																						1	**7**	**78**	**17**	**3**	**2**	**76**	**42**	**4**	**25**	**35**	**19**	**4**				
																						0	**1**	**94**	**4**	**1**	**1**	**91**	**44**	**0**	**20**	**28**	**4**	**1**				
																						0	**0**	**89**	**11**	**0**	**0**	**89**	**44**	**0**	**11**	**56**	**0**	**0**				