A Study on Institution Improvement Plans for the National Supercomputing Joint Utilization System in South Korea

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***Abstract*—The purpose of this paper is to discover institutional gaps in the supercomputing joint utilization system that the government is actively promoting as an alternative to the problem of shortage of domestic supercomputing resources. The institutional gaps were discovered by examining the current status of laws, top-level plans, and operating guidelines related to the current joint utilization system and matching them with problems or issues that need to be resolved socially. The improvement plan for the institutional gaps was derived at a level that can be reflected in the operating guidelines of the Specialized Center and Unit Center so that the performing subject constituting the joint utilization system can directly participate and solve it. In the future, for the effective operation of the joint utilization system, we plan to promote the domestic market through the diffusion of research results and secure external technological competitiveness by reflecting the contents of institution improvement.**

Keywords*—Component; supercomputer; joint utilization system; institutional gap; national supercomputing center; specialized center

I. Introduction

Looking at major policies and technology development trends of major supercomputer countries, there is a tendency to integrate and link resources for efficient construction and utilization of computing resources. Leading countries such as XSEDE and ACCESS in the U.S., EuroHPC JU and PRACE in Europe, and Flagship 2020 strategy in Japan collect and intensively support supercomputer resources for key strategic areas at the national level, and also provide large-scale resources to various academic and industrial users as needed. In South Korea, as demand for AI-based supercomputer calculations is gradually increasing, the need and urgency for a joint utilization system for efficient use of resources has increased. Therefore, the government is making efforts to prepare a joint utilization system as an alternative to securing insufficient supercomputing resources. The joint utilization system refers to a system that is jointly utilized at the national level by linking domestic supercomputer resources, and converts from the existing governance system of a single national center to an ecosystem composed of national-specialized-unit centers. In 2021, with the designation of the 1st specialized center (7 fields, 7 institutions) and the beginning of the establishment of the joint utilization system in Korea, institutional support for smooth system establishment and non-discriminatory and fair participation of companies is essential. In particular, considering the nature of the structure of the supercomputer industry, where small and medium-sized venture companies participate and the number of experts is limited, influx of new companies and mid- to long-term development are important. Therefore, this paper analyzes the current status of the joint utilization system, support system that has been overhauled, focuses on participating organizations, discovers blank areas related to issues that are currently socially required to be resolved, and proposes institutional improvement measures [1-3].

This paper consists of a total of six sections. In the introduction of Section I, it was explained by presenting the background and necessity of the research, and the purpose. The Section II and III introduce the supercomputer joint utilization system, explain its functions and compositional system. Also, previous studies related to supercomputing joint utilization system are investigated, and academic values such as differentiation and novelty from this paper are reviewed. Section IV analyzes the current institutional status of the joint utilization system in Korea and discovers gaps. Section V analyzes the causes of the institutional vacuum and presents improvement plans. In the conclusion of Section VI, the analysis results were summarized and implications and future utilization plans were mentioned.

II. Theoretical Background

The supercomputing joint utilization system refers to a system in which the supercomputing resources installed in the domestic government, companies, research institutes, and schools in accordance with Article 17 of the (Supercomputer Act) is interlocked with joint utilization resources and used as needed at the national level. The main body of the joint utilization system is composed of a National Center, a Specialized Center, and a Unit Center according to the (Supercomputer Innovation Strategy) (referred to as Innovation Strategy). Currently, KISTI as the National Center and seven institutions, Korea Meteorological Administration, GIST (Gwangju Institute of Science and Technology) as the Specialized Center, has been selected. In the future, Specialized Centers and Unit Centers will continue to expand considering the needs of each field and computing demand. Jointly utilized resources are used for research areas where there is no Specialized Center or research that has a Specialized

Center but requires other types of resources, and there are plans to flexibly respond to various demands such as emergency demand support such as COVID-19. In the joint utilization system, resource linkage and service provision are made through the joint utilization platform. The platform closely links common resources with different resource characteristics and operating environments and improves user accessibility by providing cloud-based integrated services. Therefore, the following ripple effects can be obtained for users who use common resources [4-5].

- Establish a system that can integrate and utilize jointly utilized resources by National Center, Specialized Centers, Unit Centers to expand national supercomputing service resources and utilization base
- Improved scalability so that users can utilize resources as much as they need by integrating by applying cloud technology without being tied to physical environment of specific facilities and specific public institutions
- Improved user accessibility and convenience so that first-time users and advanced users who require various specialized languages and execution environments can use supercomputing services without restrictions and inconveniences.

III. Literature Review

Lee (2018) performed an economic analysis on the effect of joint utilization of supercomputers. A cost-benefit analysis method was used as an economic feasibility analysis method, and the economic effect was analyzed by comparing the cost required for the establishment and operation of the existing centralized system. Economic effect means cost reduction effect. Hardware, software construction and purchase costs, operating manpower and maintenance costs were selected as cost reduction factors [6]. Kim (2015) analyzed trends on supercomputer innovation policies in the manufacturing sector and drew implications. Manufacturing innovation plans of advanced manufacturing powerhouses in the United States, Japan, and Germany were analyzed to investigate the use of supercomputers in manufacturing innovation plans and the promotion trends of related organizations and projects. In order to expand the use of supercomputers in the domestic manufacturing sector, it is concluded that participation of small and medium-sized venture companies is necessary, and efforts to prepare related policies are urged [7]. Nam (2016) introduces a plan to introduce and operate a supercomputer system led by a National Center and secure self-development capabilities as a way to secure national competitiveness of supercomputers. As the main contents, it describes the demand forecast of domestic resources, development goals and strategies for the introduction of supercomputers, and analyzes the operating environment for the establishment of a supercomputer ecosystem in the long term, and presents future plans and expected effects [8]. Huh (2021) suggested legal and institutional improvements to secure technological competitiveness in the future supercomputer market. Problems were identified through analysis of relevant legal systems and ecosystem conditions, and improvements were suggested, such as strengthening the role of the government, National Centers, and Specialized Centers, supporting industries, and promoting commercialization. As for the problems with the (supercomputer law), the highest law related to supercomputers, the factors that impede the linkage between national R&D achievements and industries, and the factors that are ineffective in enforcement were analyzed with an emphasis [9].

Summarizing the content of previous studies, it can be divided into studies that analyze economic effects on the subject of joint use of supercomputers, and studies that present legal and institutional improvements or plans for supercomputers. In the case of the supercomputer joint utilization system, since it is being promoted starting with the designation of a Specialized Center in 2021, there has been no research dealing with the legal and institutional aspects yet. Although many studies on supercomputers and related laws and top-level planning units have been published, there are no studies dealing with subsystems such as operating guidelines related to the joint utilization system. In addition, this paper derives legal and institutional improvements related to the joint utilization system, so it is novel compared to previous studies. As for the improvement plan, the status of problems and issues in the domestic supercomputer industry was investigated, and through the analysis of the OS matrix with the solution plan, inventiveness was secured and academic value was enhanced in presenting the improvement plan by focusing on the institutional gaps.

IV. Joint Utilization System Institutional Status Analysis

A. Identification of Problems and Issues

Institutional problems and issues of the joint utilization system were investigated through individual interviews with supercomputer forum members, etc., and a number of problems and issues presented were prioritized in order of frequency and selected. Problems and issues including the lack of supercomputer computational resources that can be used jointly, the absence of source technology related to supercomputer manufacturing, the insignificant participation of SMEs and the lack of professional manpower due to the ecosystem centered on government-funded research institutes, schools, and large corporations has been derived

B. Institutional Support Status

The status of institutional support for the derived problems and issues was derived based on the possibility of solving problems and issues and the level of association as an alternative, with reference to the legal system related to the joint utilization system. First, as a solution to the lack of infrastructure, two alternatives can be suggested: expansion of domestic supercomputer infrastructure and utilization of overseas infrastructure. The legal basis for the expansion of domestic infrastructure can be found in Articles 11 and 17 of the (Supercomputer Act), and it is stated that the government must provide support for infrastructure expansion. Second, as an alternative to the absence of source technology, direct technology development and introduction of foreign technology can be presented as alternatives, and institutional grounds exist for the expansion of investment in R&D projects

and technology exchange through international cooperation. There are two alternatives to the problem of insignificant private participation: inducing participation of private companies and direct promotion. By law, the government must provide preferential support to technology-intensive SMEs related to supercomputing and the establishment of a joint utilization system in which companies, institutions, organizations, and universities participate. Lastly, there are alternatives to the lack of professional manpower, such as fostering professional manpower, developing training programs, and utilizing overseas professional manpower. In accordance with Articles 9 and 12 of the (Supercomputer Act), the government and the National Center must establish a plan for fostering and supplying specialized manpower, and make efforts to introduce advanced technology through attracting excellent foreign manpower and international cooperation.

As a result of the current status analysis shown in Table I, it can be considered that the response to industrial issues related to the joint utilization system is institutionally prepared at a certain level or higher. However, most of the institutional support specified is centering on the government and National Centers, and there are relatively few details on Specialized Centers and Unit Centers. Therefore, it is necessary to look at the support institution for the sub-participating organizations based on the performance system of the joint utilization system.

TABLE I. INSTITUTIONAL SUPPORT STATUS ANALYSIS RESULT

Problems and issues	Alternative solution	Relevant basis(Supercomputer Act)
Lack of infrastructure	Infrastructure expansion	Articles 11 and 17 of the Act
	Utilization of overseas infrastructure	-
Absence of source technology	Core/original technology development	Articles 10 and 16 of the Act
	Introduction of overseas core/original technology	Article 19 of the Act
Lack of private participation	Encourage participation of participating private companies (provision of incentives)	Article 17 of the Act
	Nurturing private companies	Article 18 of the Act, Enforcement decree of the Act 15-2
Lack of professional manpower	Enforcement Decree Establishment of curriculum (graduate school)	Article 12 of the Act, Enforcement decree of the Act 13
	Utilization of overseas experts	Article 19 of the Act
	Education training and program development	Article 9 of the Act

C. Discover Institutional Gaps

The analysis of the current status of institutional support in the joint utilization system was conducted targeting the Specialized Centers currently. As for the analysis method, a 2 by 2 matrix analysis method was used for the function of the Specialized Centers and the support for function execution. The function of the Specialized Center targets the main functions specified in the (Supercomputer Act). The contents of the support matched the contents of the "Innovation Strategy" the top-level supercomputer plan, and the "Operation Guidelines" of the Specialized Center, the subsystem, for budget, technology, and network, which are essential factors of the joint utilization system. First, the support contents of the "Innovation Strategy" and the joint utilization system of the "Operation Guidelines" were coded as Table II. In the "Innovation Strategy", related institution specify services including service providers and users, educational programs, data management systems, etc., and "Operation Guidelines" support costs, technologies, and domestic and international networks for service operation and management.

TABLE II. CODING RESULT

[Innovation Strategy]	[Specialized Center Operation Guidelines]
AA - Designation and development of 10 Specialized Centers for 30 years AB - Training and dispatch to Specialized Centers, provision of technical education programs(strengthening manpower capacity) AC - Operation of a joint utilization consultative body(Establishment of resource distribution standards and establishment of an operating system) AD - Provides cloud-based platform service to link common resources and improve user accessibility AE - Establishment of Data Hub - Establishment of integrated data storage and preparation of data standard system AF - Expand integrated sharing of data in connection with domestic and foreign data centers (data dam: bio, material, transportation, disaster, environment, etc.) and platforms	BA - Linked technology support BB - Resource building budget BC - Providing opportunities to participate in R&D projects BD - Training and technical exchange support BE - Operating expenses BF - Network BG - International cooperation, technology exchange, etc.

The matrix analysis results are shown in Table III. In the function of the Specialized Center for building resources, institutional support was established in all factors of budget, technology, and network. The contents of support for operation and service provision and basic adaptation research are also presented in the "Innovation Strategy" and "Operation Guidelines". In terms of data management and operation support and manpower training, the grounds for support are meticulously prepared without institutional gaps. On the other hand, in the part related to the dissemination of research results, the budget part belongs to the realm of the institutional gap. Dissemination of research results refers to all cases in which research results related to the joint utilization system are transferred to the private sector, schools, research institutes, etc. Support for the dissemination of research results refers to technology value evaluation costs, patent-related costs, standards-related costs, etc. under the "Act on Performance Evaluation and Performance Management of National R&D Projects". In the case of other technology fields, various government-led financial support is provided. Therefore, although the current support institution for the joint utilization

system is prepared at a compliant level, it can be analyzed as a situation where the financial support system is insufficient in terms of performance utilization.

TABLE III. MATRIX ANALYSIS

Specialized Center Functions	Support content		
	Budget	Technology	Network
Building resources	BB, AA	BA	AC
Operation and service provision	BE	BA	AC, AD
Basic and applied research	BC	BA, BC	BG
Dissemination of research results	-	BG	BD, BF
Data management and operation support	BE, AE	BA, AE, AF	AD, AF
manpower training	BD AB	BD, AB	BG

V. INSTITUTIONAL IMPROVEMENT PLAN

A. Cause Analysis

In order to prepare improvement plans for the joint utilization system support institution, it is necessary to analyze the cause of the gaps. For the analysis of causes, recent domestic supercomputer-related statistical data and reports were referred to, and the following four causes were derived by comprehensively considering the influence and solution potential among various causes.

1) Low participation of private enterprises: The budget for dissemination of research achievements is targeted at institutions that have research achievements. According to the National Center statistics, the utilization rate of national supercomputers by private companies in 2022 is very low at about 3.9% of the total. Given the computational capacity of the National Center, which supports about 140 institutions for a year, the number of private companies that commercialize research results is very small, considering the number of participating private companies. The participation of SMEs in the private sector is also very small. Even at KSC (Korea Supercomputing Conference), the largest conference in Korea, the committee is mostly composed of personnel from government-funded research institutes and schools, except for some employees of large foreign companies. Even in the case of representative research achievements of National Centers, all 26 are owned by schools or government-funded research institutes. Therefore, it is difficult to efficiently execute the budget as there is no beneficiary to support the spread of performance. The reasons for the limited participation of SMEs can be attributed to the investment cost and lack of professional manpower. Since supercomputers have high initial investment costs, SMEs have limitations in building and operating their own infrastructure. This is why the National Center is currently building infrastructure and providing services to SMEs. However, participation in services provided by National Centers is also limited. It is difficult to secure supercomputer experts, who are classified as relatively high-level workers, for the use of supercomputers, and there is a burden of labor costs for the experts.

2) Limitation of small market size: The global HPC market size is about $32 billion by 2021. However, in the case of South Korea, it is less than 980 million dollars, so effective economies of scale do not apply, and it is an unstable market in which some foreign companies may monopolize due to the absence of competitive domestic companies. Even if domestic companies commercialize technology, technical competition is impossible due to the technological gap with leading companies such as Intel, AMD, and NVIDIA, and it is difficult to respond in terms of price. In cases where institutions with excellent technologies, such as domestic conglomerates and government-funded research institutes, transfer technology and try to commercialize it, the results are sold back to large corporations and government-funded research institutes.

3) Inadequate start-up support system: In the field of supercomputers, there are few achievements in commercialization technology development for the dissemination of research achievements. In the statistical data of the National Center, more than 60% of creative research (usage, as of 2022), which is in the basic source stage, is higher than research related to application, development, and commercialization for start-ups. In other words, there are few research projects and achievements in the commercialization stage where start-ups can generate sales and invest in technology development and manpower recruitment. In addition, in the case of other fields, programs such as technology exchange, financial support, and environment creation are being prepared for corporate support. However, in the case of the supercomputer field, there is no program to support the growth and development of start-up companies, and there is a shortage of dedicated departments and manpower in charge of the government.

4) Few institutions that possess source technology and transfer cases: In the case of source technology related to supercomputers, major companies in some countries, such as the United States, China, and Japan, preoccupy it. As a result of a survey on the status of patent index by country for US registered patents, in South Korea, the patent impact index was 0.05, lower than that of the US (1.06), and the market security index was 1.75, lower than the US (2.63), leaving behind a lot in both technological competitiveness and quality. The lack of source technology and the need to promote commercialization and commercialization limited to applied technology also become an economic barrier for companies. In addition, because of few cases of technology transfer and success, it makes difficult for start-ups to enter the market.

B. Suggestions for Improvement

In order to prepare an effective and efficient budget support institution for the dissemination of research results, the following institutional improvement plans are proposed.

1) Establishment of a national center performance management organization utilizing the execution system and legal functions: First, the current National Center is designated as the KISTI, and the KISTI is designated as an institution dedicated to R&D performance management and distribution according to Article 33 of the Enforcement Decree of the (National R&D Innovation Act)". Based on the (Act on Performance Evaluation and Performance Management of National R&D Projects), etc., KISTI can receive support for all or part of the expenses necessary for the operation as a dedicated agency, and the dedicated agency can receive papers and patents from a number of research institutes to promote joint utilization by registering and depositing research results. Therefore, the National Center will be able to benchmark the existing research performance utilization and management system as a dedicated agency, establish its own research performance utilization and management system, and effectively operate the organizational system and professional manpower. Even in the transfer of achievements, the KISTI, in accordance with Article 11 of the (Act on the Promotion of Technology Transfer and Commercialization), transfers technology developed in public research institutes to the private sector. Since an organization dedicated to commercialization must be established, it is possible to quickly form an organization. In addition, since the NTIS (National Science & Technology Information Service) platform, which is a performance information integration service that enables performance status, statistical data, and performance search, is established, accessibility and diversity of performance information can be increased by providing services related to this platform. Therefore, it is possible to establish efficient governance for performance utilization through functional convergence and linkage with the organization of the National Center and the dedicated agency, and through this, it will be possible to lower the entry barrier for private companies and continuously secure excellence and transfer cases.

2) Support for the whole cycle of commercialization of SMEs using the venture center: One of the ways to grow the market is to nurture companies that directly participate in the market. Although costly, it is the most effective way to rapidly nurture companies and expand the market. In South Korea, there are excellent benchmarking cases. In the case of the green technology industry, a number of start-ups and SMEs are being introduced by setting up an Environmental Venture Center in an environmental research complex composed of a number of related government departments, research and policy institutions. Economic and technical support is provided to resident companies at a relatively low cost. It is supported with full-cycle demonstration facilities for commercialization, such as inspection and certification for sales, expert mentoring for technology transfer items from public institutions related to R&D, testing and analysis, and certification, performance test. To date, the Environmental Venture Center has generated about four trillion won in economic effects and created about 9,400 jobs for 15 years.

In the field of supercomputers, it is possible to build an efficient venture center through a joint utilization system. First, companies participating in the joint utilization system can be institutionally introduced by designating them as Specialized Centers and Unit Centers. In the case of Unit Centers, they will be expanded step by step after the designation of Specialized Centers, so relevant contents can be reflected when establishing guidelines for the operation of Unit Centers. In addition, Specialized Centers and Unit Centers are supported with all expenses necessary for infrastructure construction and operation. Therefore, when a Specialized Center and a Unit Center are integrated into a venture center, it is possible to effectively reduce infrastructure construction space and common operating costs. It is possible to develop various convergence technologies by physically gathering supercomputer companies by field, and companies, not the government, can discover jobs for future with high added value. Due to the nature of supercomputers, face-to-face training and mentoring are possible even for small businesses that have difficulties in accessing and using services, so the use of services in the private sector is expected to increase significantly. However, in the case of supercomputers, research results and technology transfer items are lacking. Unlike environmental venture centers, Specialized Centers and Unit Centers should prioritize technology development and self-implementation, and induce exchange of research results between centers.

3) Establishment of unit center certification system reflecting preferential treatment for small and medium-sized enterprises: The Specialized Center is currently designated by the Ministry of Science and ICT. Currently, seven institutions in seven fields have been designated, and there are plans to continuously expand Specialized Centers for each field through the development of supercomputer-related fields in the future. However, in the case of the Unit Center, the relevant information for designation is not institutionally prepared. Unit Centers are classified and designated by sector like Specialized Centers, and operation plans such as infrastructure establishment and technology development linked to Specialized Centers must be established in the form of sub-organizations of Specialized Centers. Therefore, the budget size and payment method should be specified institutionally so that the budgetary part can be considered in the operation plan establishment stage. In addition, it is necessary to determine the appropriate size of the Unit Center through a demand survey by field so that many start-ups and small and medium-sized enterprises can participate. Also regulations to receive preferential treatment in the designation examination must be prepared. There is a need for a recovery support system to alleviate the burden of failure. Considering the market environment where the commercialization success rate of SMEs does not exceed 21%, it is necessary to prepare a safety device that can continue the benefits as a Unit Center [10].

4) Support lowering the threshold for commercialization through the introduction of the preferential purchase institution: The institution that preferentially purchases the research results of companies participating in the joint utilization system, such as the public institution preferential purchase institution, is essential for startups and SMEs to cross the threshold of commercialization. In the case of related companies in the supercomputer field, the initial threshold is even higher. Based on the supercomputers built in South Korea, the domestic market share is very low. Therefore, voluntary market entry by domestic companies should be pursued from a long-term perspective, and the government should provide sufficient time and resources for companies to grow by first raising the total purchase ratio in consideration of the characteristics of the sector.

VI. CONCLUSION

At the beginning of the establishment of the supercomputer joint utilization system, institutional gaps were discovered and improvement plans were drawn. In order to effectively perform the functions of the Specialized Centers constituting the joint utilization system, most of the support items are included through government laws and plans, such as the (Supercomputer Law), "Innovation Strategy" and "Operation Guidelines", etc. However, it was confirmed that the support system for securing a budget for the dissemination of research results was insufficient. As improvement plans for this, establishment of a National Center performance management organization using the execution system and legal functions of an institution dedicated to research achievements, support for the entire life cycle of commercialization of SMEs using venture centers, and establishment of a Unit Center certification institution that reflects preferential treatment for SMEs. Finally, support for lowering the threshold for commercialization through the introduction of a preferential purchase institution was proposed.

The government plans to designate a total of 60 Unit Centers by 2030 and prepare "Operating Guidelines" within this year. Using the results of this study, a specific support plan will be prepared so that a number of private companies can participate in the competition for designating Unit Centers, and preferential treatment for SMEs to participate will be reflected in the evaluation plan. In addition, in consultation with related ministries, the plan for the preliminary feasibility study project will be promptly promoted so that sufficient budget can be secured in advance.

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