May 30, 2022 National Assembly Budget Office I NABO Briefing I Vol. 118
nabo briefing

Analysis of Large Accelerator Construction Projects and Operation System

Economic Industrial Program Evaluation Division, Budget Analysis Department

- Particle accelerators, as large-scale research facilities underpinning basic science, are increasing in scope in terms of industrial utilization. Their influence is also expanding across many areas including life sciences, medicine, nuclear engineering, materials engineering, nanotechnologies, and defense industries. As of 2022, Korea has invested 4.57 trillion won into building and operating six accelerator units. Even though extensive financial resources are poured into the construction and operation of these large-scale facilities, frequent delays occur in relevant construction projects, and an efficient operation scheme is lacking. Therefore, this report intends to analyze the current state of large-scale accelerator construction and operation projects, identify issues, and address each major issue found.
- First, this analysis identifies a need for building a systematic mid- to long-term roadmap for accelerator construction projects and improving the efficiency of relevant financial investments by implementing timely modifications to respond to future science and technology changes. Second, a technology prevalidation R&D phase must be introduced before launching projects to gauge the feasibility and risks involved in R&D efforts. Furthermore, before an actual project take-off, the risk of project delays should be minimized by conducting R&D and facility-building projects in a stepwise manner. Third, accelerator operation efficiency must be increased by fostering specialists and facilitating joint access to accelerator-related technologies, talent, and information. Lastly, efforts should be made towards strategic R&D investments for next-generation accelerators and localization of major equipment, as well as supporting the commercialization of industry players to help strengthen technological capabilities.

Budget Analyst
Byung-Chul Lee

This report examines the current state of large accelerator construction projects and operation systems and reviews effective improvement measures that address major issues.

I. The Concept of a Large Accelerator and the Construction and Operation Status

1. The Concept of a Large accelerator

A large accelerator is an extensive research facility that includes a particle accelerator*, research equipment, research facilities, and support facilities for utilization.

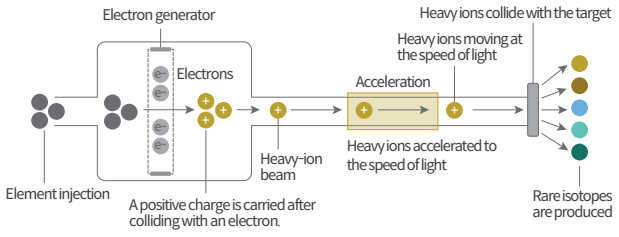
* A particle accelerator is a device that uses electric and magnetic fields to accelerate charged particles such as electrons, heavy ions, and protons to the speed of light.

Types of Large Accelerators

Type	Accelerated Particle	Usage
Synchrotron	Electrons	Structural analysis of materials and observation
Proton accelerator	Protons	Nuclear transmutation and neutron production
Heavy-ion accelerator	Heavy-ions	Rare isotope production and related research
Heavy-ion medical	Heavy-ions	Cancer treatment and related technology research

* Source: Rare Isotope Science Project

How a Heavy-Ion Accelerator Works (Example)



* Source: Rare Isotope Science Project

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2. Construction and Operation of Large Accelerators in Korea

There are six accelerator units in Korea, including three synchrotrons, one proton accelerator, one heavy-ion accelerator, and one heavy-ion medical accelerator.

Construction and Operation of Large Accelerators in Korea

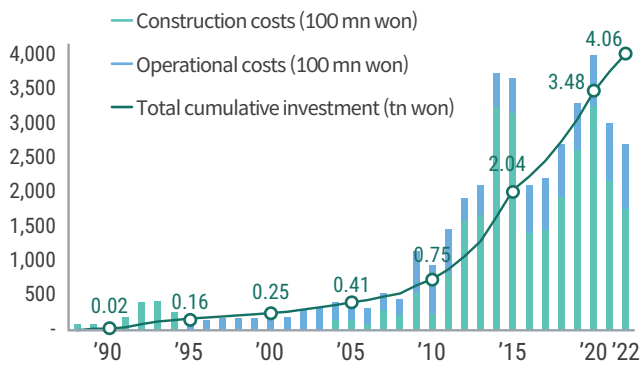
Type		Shape	Construction period (performance improvement)	Total investment (performance improvement)	Operating entity	Region	Note
Synchrotron	PLS-II	Circular	1991—1994 (2009—2011)	150 billion won (100 billion won)	Pohang Accelerator Laboratory	Pohang	In operation
	XFEL	Linear	2011—2015	429.8 billion won		Pohang	In operation
	Multipurpose	Circular	2021—2027	1.0454 trillion won	Korea Basic Science Institute	Cheongju	Under construction
Proton accelerator		Linear	2002—2012	314.3 billion won	Korea Atomic Energy Research Institute	Gyeongju	In operation
Heavy-ion accelerator		Linear	2011—2022 (Phase 1)	1.5183 trillion won	Institute for Basic Science	Daejeon	Under construction
Heavy-ion medical accelerator		Circular	2010—2024	259.61 billion won	Seoul National University Hospital	Busan	Under construction

* Source: Ministry of Science and ICT

3. The Current State of Financial Investment in Large Accelerators

Total investment from 1988 to 2022 stands at 4.057 trillion won (construction costs: 2.8702 trillion won, operational costs: 1.1869 trillion won).

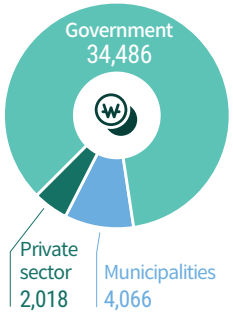
Total Investment by Year



* Source: Ministry of Science and ICT

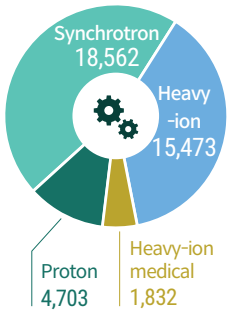
Total Investment by Financial Source

(cumulative, 100 mn won)



Total Investment by Accelerator

(cumulative, 100 mn won)



※ Including construction and operational costs

Operational Costs Versus Construction Costs

(Unit: 100 mn won)

Accelerators	In operation since	Total construction cost	Total operational cost	Average annual operational cost
PLS-II	1995	1,500	8,543	305
XFEL	2016	4,298	1,326	190
Proton accelerator	2002	3,143	1,560	156
Total		8,941	11,429	651

* Source: Ministry of Science and ICT

Ⅱ. Analysis of Key Issues

1. Large Accelerator Construction Project System

Since establishing the Second National Large Research Facilities Roadmap in 2012, the government has not developed a mid- to long-term roadmap.

National Large Research Facilities Roadmaps

	First (2010)	Second (2012)
No. of proposed facilities	69 facilities in 5 major investment areas	13 facilities requiring more than 50 bn won for construction
Evaluation criteria	Scientific and technological importance, national applicability, economic and social impact	
Feasibility study	Researcher demand survey	Demand survey, investigation, performance analysis
Review cycle	Every two years (irregular)	Every three years (regular)
Investment timing	By priority (groups S, A, B) until 2025	By period (short-term, medium-term, long-term) until 2030

* Source: National Science and Technology Committee

The government should establish a systematic mid- to long-term national roadmap and continuously revise and supplement it to reflect future environmental changes and research demands.

The heavy-ion accelerator construction projects have been frequently delayed and require more investment than originally planned.

National Large Research Facilities Roadmaps

		Original	Current	Increase
Heavy-ion accelerator	Project period	2011—2017	2011—2022	+5 years
	Total cost	1,444.5 bn won	1,518.3 bn won	73.8 bn won
Heavy-ion medical accelerator	Project period	2010—2015	2010—2024	+9 years
	Total cost	195 bn won	259.61 bn won	+64.61 bn won

* Source: Ministry of Science and ICT

The construction of large research facilities requires developing advanced technologies. The project plan acknowledges the high uncertainty of the project, but the plan is insufficient, and the project management is not systematic.

The government should build an effective project management system considering the characteristics of large research facility construction projects.

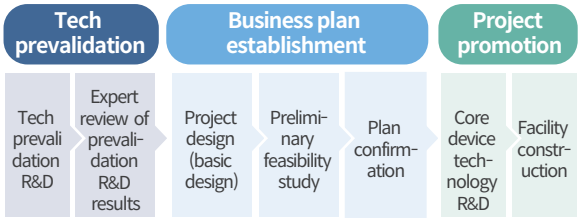
Large research facility construction projects generally have two sub-projects: large-scale R&D and extensive facility/equipment construction. However, the projects lack a thorough R&D validation process and need a step-by-step approach.

Heavy-Ion Accelerator Construction Progress

Accelerators	R&D	Equipment and facility construction
Heavy-ion accelerator	Accelerator, infrastructure, RI generator, and experimental devices under development	Heavy-ion accelerator and research facility construction (completed in May 2021)
Heavy-ion medical accelerator	The project changed from medical baryon accelerator development to equipment introduction.	Baryon accelerator treatment center construction (completed in May 2016)

* Source: Ministry of Science and ICT

The Improved Project Process for Large Research Facility Construction (Draft)



* Source: National Assembly Budget Office

<Other examples>

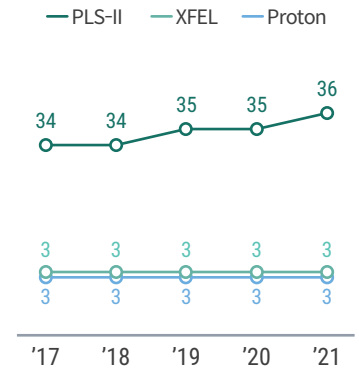
1. **The US Department of Energy's Critical Decision (CD) system:** a decision-making system to complete the CDs of a specific stage to allow the project to proceed to the next stage or CD. This is mandatory for DOE projects with a total cost of over $50M.
2. **Korea's Technology Readiness Assessment system (a defense R&D program):** This system quantitatively evaluates the technological readiness of critical technology elements (CTE)* before launching a weapon system development project and determines whether to proceed with the project according to the evaluation result. *CTE refers to elements that are technically essential for completing a project.

The government should minimize the risk of R&D causing delays in projects by adding a prevalidation R&D stage before proceeding with a large research facility construction project, including large accelerator constructions, and carrying out the sub-projects separately.

2. Large Accelerator Operating System and Performance

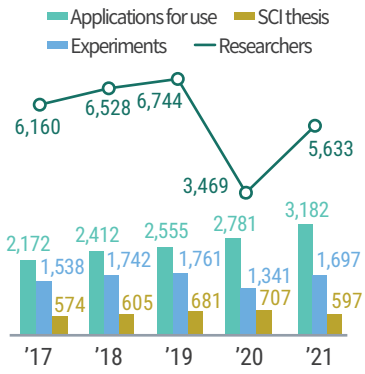
The demand for large accelerators has increased significantly, but the project support rate has decreased or stagnated due to a limited number of beamlines along with others.

Large Accelerator Beamlines in Operation



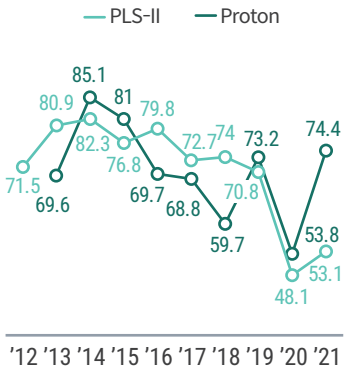
* Source: Ministry of Science and ICT

Large Accelerator Beamlines in Operation



* Source: Ministry of Science and ICT

Project Support Rate for Accelerators (%)

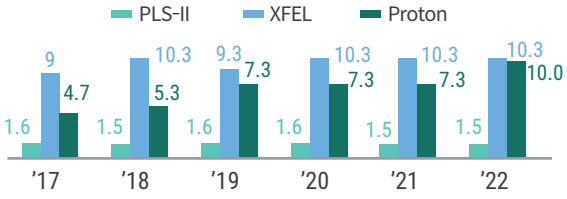


* Source: Ministry of Science and ICT

The government must build effective operating systems, such as remodeling unpopular beamlines, improving researcher support systems, and establishing systems for the joint utilization of technical workforce information.

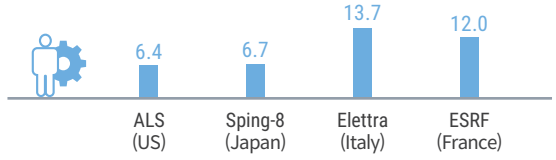
Large accelerator facilities are understaffed, leading to ineffective beamline operation and a lack of researcher support.

No. of Staff per Beamline in Korea



* Source: Ministry of Science and ICT

No. of Staff per Beamline in Major Countries

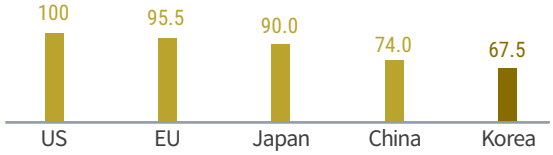


*Source: National Science and Technology Committee (2017)

To prepare for the expansion of large accelerator operations, the government should foster experts and utilize professionals from universities, government-funded research institutes, and corporations.

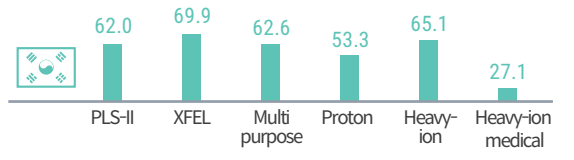
Korea's technology level for building and operating large accelerators is less than that of other major countries, and the localization rate is low for major equipment and parts.

Next-Generation Accelerator Technology Level in Major Countries (%)



* Source: Ministry of Science and ICT

Large Accelerator Construction Localization Rate (%)



* Source: Ministry of Science and ICT

Strategic R&D investment, reinforcement of related industries' technical capabilities, and commercialization support are necessary to improve the technology level of next-generation accelerators.

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Produced by | Economic Industrial Program Evaluation Division, Budget Analysis Department **Contact** | +82-2-6788-3777

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