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Research paper

The optimization planning of research equipment operation through the efficient integration of research equipment and scientist

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Abstract

This paper provides a quantitative way of ensuring the placement and integration of research equipment and scientists. An attempt was made to develop methods of enhancing the research equipment efficiency by focusing on the research equipment utilization difficulty level and the research equipment utilization capability of scientists. Eight research equipment and five scientists were selected for the study. Methods and research results on how to deploy and integrate research equipment and manpower according to the ranks based on the research equipment utilization difficulty and the research capabilities of scientists are presented herein. It is believed that a systematic method of and an optimized plan for deploying and integrating research equipment and scientists, as opposed to the intuitive method, are necessary. That is, deploying and integrating research equipment and scientists according to the ranks based on the research equipment utilization difficulty level and the research equipment utilization capability of the scientists are effective. The authors are confident that an efficient and optimized deployment and integration study for research equipment and scientists will make a significant contribution to research efficiency and productivity improvement. It is hoped that the findings obtained from this study will prove to be very useful for professors, researchers, and policymakers at universities and research institutes around the world.

Keywords: *Research Equipment; Science and Technology; Scientist; Management; Optimization; Planning; Operation; Integration*

1. Introduction

The Ministry of Science, Technology, and Information (MoST) of South Korea has greatly expanded the creative and challenging basic research opportunities it is offering based on the ideas of the researcher, by preparing for the fourth industrial revolution with creative research and development (R&D) innovation. MoST has decided to expand its budget support for basic research projects by expanding its researcher open recruitment (2017, USD1.26 billion → 2018, USD1.42 billion → 2019, USD2.52 billion). The research support for new and post-doctoral researchers is being reinforced, and USD48 million was invested in 2018 for the establishment of the first innovation laboratory system. To strengthen the R&D technology scale, such scale is being expanded and specialized for universities and research institutes to induce disruptive innovations based on the technology scale (2017, USD1.26 billion → 2018, USD1.42 billion → 2019, USD2.52 billion). The government is endeavoring to expand the country's challenging research projects by actively pursuing the grand R&D system, which guarantees the maximum autonomy of researchers for small university projects worth less than USD92 million (2017, USD92 million → 2018, USD83 million). Further, support for outstanding research tasks is being extended to strengthen the country's long-term reliable research support program. About 30% of application tasks were provided 15-20% support, and the follow-up support count was abolished. The R&D process is highly reflective of the opinions of the researchers at research sites through innovation (planning, selection, assessment, and reward) [1]. The R&D leadership models of openness, cooperation, and competition are applied to strengthen the strategic investment in preparation for the fourth industrial revolution, and to promote the development of high-risk, high-value technologies and the creation of new markets. In addition, the government focuses on intelligent development in high-risk, uncertain areas as well as convergence-based technologies, considering the effects of the fourth industrial revolution and through role sharing with the private sector. For the current year (2018), it increased the investment in the next-generation Internet of Things (IoT) (USD4.3 million) and block chain (USD4.1 million). To secure innovation and growth engines through core source technology development, there is a need to develop new integrated biotechnologies such as global leadership and innovation, digital health care, and building mind maps, and to promote mid- to long-term economic development. The government has secured a response to climate change and to the need for new growth engines by developing innovation technologies for fostering the climate industry, enhancing carbon resources, and advancing support for entry into overseas markets for the introduction of new technologies. To secure technologies for the development of nanomaterials, the government is conducting research in tandem with the nano sector for the purpose of developing fast, large-scale, and low-power technologies, and of constructing an ecosystem for securing innovative raw material sources for materials and fusion research. The government is also continuously pushing for the development of information and communication technologies (ICTs) and core technologies such as 5G network convergence services, and beyond 5G, it is also emphasizing human-technology cooperation, artificial-intelligence-(AI)-based data analysis management, holo reality (HR), etc. It is likewise supporting the advance of outstanding technologies and companies into the global market by expanding the international cooperative research for global contribution to enhance the scientific and ICT global cooperation. To improve the special zone system for R&D, the test bed has been introduced with a negative regulatory method by switching the special zone designation and the operational model for excellent key institutions. To spread the participatory innovation system, the government is promoting living-level issues, nurturing R&D and ICT based on regional reform bodies and participating residents for Living Lab. Living Lab is a local-government-driven model in which the local members participate in problem-solving and demonstration by presenting ideas and providing feedback, and through prototyping. The voucher system was improved to enhance the competitiveness of small businesses. The AI open innovation hub is also being implemented to provide machine learning data, the open application programming interface (API), and computers essential for the development of AI-based products and services. To create a collaborative research environment, expensive research facilities and equipment needed at small business sites are deployed to enhance the ICT and software (SW) industry competitiveness. The government is also providing incentives to activate R&D using the existing research results. To expand the support for ICT research in the field of intelligent information core technologies, it has provided support to ICT Research Center and has demonstrated a strong demand for ICT based on the R&D-related business cluster. Optimization of research equipment operation is essential for the successful activation of basic research in the preparation for the fourth industrial revolution. This study was conducted with focus on the efficient placement and integration of research equipment and scientists. The research equipment utilization difficulty and the research capabilities of the scientists were set as the measurement indices for the efficient placement and integration of research equipment and scientists. In this paper, the efficient integration of research equipment and scientists was attempted for the optimization planning of research equipment operation. It is hoped that this study will make a significant contribution to professors, researchers, and policymakers at universities and research institutes around the world.

2. Global government trend for science and technology

2.1. United states

In the United States, the private sector is leading the response to the fourth industrial revolution, and the government is focusing on creating an ecosystem [2], [3]. The private sector, with advanced technologies and financial strength, is leading the fourth industrial revolution while the government is pushing ahead with the preemptive system and with large-scale pilot projects [4], [5]. As global information technology (IT) companies (Google, Facebook, etc.) dominate the platform and merge with other industries, such as those producing manufacturing and cultural contents, they create additional value. This reaffirms the importance of basic research and emphasizes the need for effective investment. The importance of basic research and effective investment were described in the America COMPETES Re-authorization Act of 2015. The R&D budget for basic research support institutions was increased through a scientific and innovative plan (2006, USD9.7 billion → 2017, USD19.5 billion).

2.2. Japan

Japan strives to lead the economic and social transformation of its country based on strong areas, such as robots and AI, and is promoting national innovation projects based on these same original technologies, such as the 4th National Restructuring Project (2016.4) [6]. The Council for Future Investment (2016.9) of the Japanese Prime Minister is in charge of the readjustment of the national response system, and the 5th Science and Technology Basic Plan (2016-2020) focuses on three main areas and two policies for creating scientific innovation. The three main areas are the challenge of creating future industries and social transformation, the promotion of innovation in scientific technology to help revive the region, and the promotion of innovation for the 2020 Tokyo Olympics. The two policy areas are designed to improve the environment that creates an innovation chain, and to solve the existing economic and social challenges [7], [8]. Research Institute of Science and Technology for the Society (RISTEX) focuses on public R&D achievements and addresses specific social issues.

2.3. Germany

Germany is accelerating ICT convergence throughout its economy and society, and continues to be a manufacturing powerhouse [9], [10]. Six main tasks for growth and welfare have been presented: a digital economy and society, sustainable management and energy, an innovative labor world, healthy living, intelligent mobility, and civic safety [11]. To accelerate the shift to a digital society, Digital Strategy 2025 (2016.3) was presented, and 10 major initiatives were proposed, including creating a nationwide 1Gbyte broadband network, developing economic norms to promote corporate investment and consumer information protection, promoting digitalization investment and start-ups, and developing ICTs and SW systems. To spread Industry 4.0 to the small and medium-sized businesses, the private sector and the government formed Platform Industry 4.0 (2015), through which multi-faceted support is provided. The multi-governmental support includes support for IT investment policies, dispatching experts (transfer of technologies and know-how), and joint research and development.

2.4. China

China has announced seven major objectives for its economy's medium- to high-speed growth and for the improvement of its people's living standards and of its ecosystem, among others, through the 13th Five-Year Plan (2016-2020) for innovation. The seven major objectives are maintaining medium- to high-speed economic growth, visualization of the development effects of the country's innovation drive, increased cooperation for development, improvement of the people's living levels and quality, improvement of the level of its civilization, improvement of its ecosystem level, and maturity and stability of each system [12]-[14]. The top five strategies are innovation (upgrading the industrial structure), sharing (improving the people's welfare and quality of life), opening up (securing new growth engines), harmony (eliminating gaps), and eco-friendliness (promoting low-carbon-circulation development). China aims to become a manufacturing powerhouse through the Chinese Manufacturing 2025 Strategy (2015.5) and Internet Plus Strategy (2015.7). Towards this end, it has strengthened the collaboration between the private sector and the government.

3. Research mechanism design

The qualitative and quantitative research methods were used in this study to ensure the efficient placement and integration of research equipment and scientists in the country. Towards this end, the research capacities of the scientists and the required capabilities for research equipment utilization were quantified and examined. The research capabilities of scientists, the research equipment utilization difficulty level, and the difference between the capabilities required for research equipment utilization and the research capabilities of the scientists were measured quantitatively. Efficient placement and integration of research equipment and scientists was designed, and a model for the application of such was developed. The mechanism design process is shown in Figure 1.

The required capabilities for research equipment utilization vary widely from one type of research equipment to another, and each research equipment has a different utilization method. One can learn how to utilize small and simple research equipment from one to three months, but it may take longer than three to four years to learn how to use large and complex research equipment.

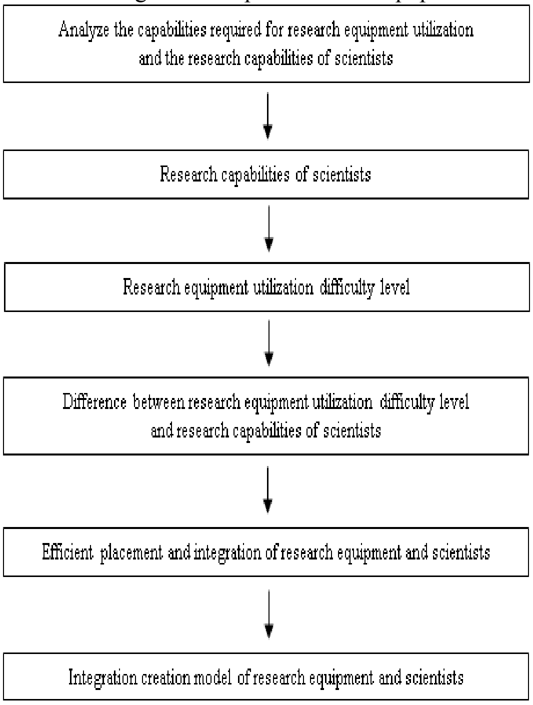

Fig. 1: Mechanism Design Process.

Accordingly, it is difficult to analyze and measure the capabilities required for scientists to be able to utilize research equipment. Thus, in this study, quantitative analysis methods were utilized, and the capabilities required to be able to utilize research equipment were expressed in a formula. If there are n tasks for utilizing research equipment, and k task capabilities for each of such tasks, it should be marked as matrix T. A 5-point-scale method was used to analyze the capabilities required for the research equipment utilization task. On the 5-point scale, the highest score was 5 points while the lowest was 1 point. Below is the detailed formula that was used.

$$T = \begin{bmatrix} t_{11} & \cdots & t_{1k} \\ \vdots & \ddots & \vdots \\ t_{n1} & \cdots & t_{nk} \end{bmatrix} \quad (1)$$

In this paper, the capability of a scientist to utilize research equipment is presented as matrix J. A 5-point-scale method was used to display the capability of a scientist to utilize research equipment. Matrix J shows such capability of a scientist based on a 5-point scale when the number of skills that the scientist has is l. Below is the detailed formula that was used.

$$J = \begin{bmatrix} j_{11} & \cdots & j_{1k} \\ \vdots & \ddots & \vdots \\ j_{m1} & \cdots & j_{mk} \end{bmatrix} \quad (2)$$

To deploy the most appropriate scientists for utilizing research equipment, the prioritization order was determined using matrix T of the required capabilities to be able to utilize research equipment and matrix J of the capability of a scientist to utilize research equipment. In this study, the functional deployment matrix (FDM) was used. FDM is a method of prioritization using the relationship between input variable X and output variable Y. FDM is utilized for m scientists and n tasks. In the formula, f=fdm and F=FDM. Below is the detailed formula that was used.

$$f_{ig} = \sum_{e=1}^{k} (t_{ie} \times j_{eg}) \quad (3)$$

$$F = \begin{bmatrix} f_{11} & \cdots & f_{1k} \\ \vdots & \ddots & \vdots \\ f_{n1} & \cdots & f_{nk} \end{bmatrix} \quad (4)$$

The capabilities of scientists that are required for them to be able to utilize research equipment were ranked through the matrix of the research capabilities of scientists and the FDM matrix of scientists. The method of ranking was to set the highest calculated no. 1 at fdm. Below is the detailed formula that was used.

$$Rank\ f_{ig} = Rank\ of\ \ f_{ig}\ \ in\ raw\ i \quad (5)$$

The prioritization numbers were the same for the same calculation. Below is the detailed formula that was used.

$$Rank\ F = \begin{bmatrix} Rank\ \ f_{11} & \cdots & Rank\ \ f_{1k} \\ \vdots & \ddots & \vdots \\ Rank\ \ f_{n1} & \cdots & Rank\ \ f_{nk} \end{bmatrix} \quad (6)$$

The average fdm of the scientists were calculated through the rank FDM matrix. The combined capabilities of the scientists were measured against the average fdm. Below is the detailed formula that was used.

$$Average\ \ f_g = \frac{\sum_{e=1}^{n} Rank\ of\ \ f_{ig}}{n} \quad (7)$$

The research utilization capabilities of the scientists and their and priority order were calculated using the formula below. A higher priority in the use of the research equipment indicates the greater difficulty of utilizing such research equipment compared to the others.

$$\begin{aligned} Rank\ of\ \ SA = {} & SA\ with\ Top\ Rank\ of\ \ Average\ f\ , \\ & Second\ \ Rank\ of\ \ Average\ f\ , \ldots, \\ & Last\ \ Rank\ of\ \ Average\ f \end{aligned} \quad (8)$$

It is necessary to allocate scientists of reasonable capability according to the research equipment utilization difficulty level, which requires designing methods of calculating such level. In this study, the sum of capabilities required to be able to utilize research equipment was used as the research equipment utilization difficulty level. Below is the detailed formula that was used (D=difficulty).

$$D = \left(\sum_{g=1}^{k} t_{1g} \cdots \sum_{g=1}^{k} t_{ng} \right) \quad (9)$$

There is a need to determine the difference between the capabilities required to be able to utilize research equipment and the research capabilities of scientists. In addition, there is a need to transfer to other research sites the excess high-quality research equipment or the personnel who are too incompetent in terms of utilizing research equipment, and this will enable efficient placement and integration. Below is the detailed formula that was used (d=difficulty; D=difficulty).

$$d_{ig} = \sum_{e=1}^{k} (t_{ei} - j_{ge}) \quad (10)$$

Table 1: Research Capabilities Required for Research Equipment Utilization

Classification	Research equipment operation capability	Research equipment analysis handling	Research result production	Research result interpretation	Research equipment safety management
Research equipment 1	1	3	5	3	3
Research equipment 2	2	5	4	3	2
Research equipment 3	4	2	1	4	2
Research equipment 4	1	3	3	1	4
Research equipment 5	3	1	2	3	3
Research equipment 6	5	3	3	4	3
Research equipment 7	3	4	5	1	4
Research equipment 8	4	1	4	2	3

$$D = \begin{bmatrix} d_{11} & \cdots & d_{1n} \\ \vdots & \ddots & \vdots \\ d_{k1} & \cdots & d_{kn} \end{bmatrix} \tag{11}$$

In this study, as a way to locate the scientists who are necessary for research equipment utilization, the research equipment that is easiest to utilize was identified through the ranking based on the research equipment utilization difficulty, and the weakest scientist based on the ranking of the research capabilities of scientists was assigned to utilize such research equipment. The best scientist was assigned to utilize the research equipment that was most difficult to utilize. The remaining placement was arranged through the overall rankings based on the research equipment utilization difficulty and the research capabilities of the scientists. It was necessary to verify the validity of the initial research equipment utilization assignment results of the scientists. For this, the difference calculation values were used. If the difference calculation results were zero or higher, the scientists assigned to utilize the research equipment could not complete their research on their own and had to obtain help from other scientists. These scientists needed to conduct their research through collaboration with capable scientists. If the research capabilities of the scientists differed greatly from those required for the utilization of the research equipment, such research equipment had to be replaced with another one that was easier to utilize. If the research capabilities of the scientists differed significantly from those required for the utilization of the research equipment, the said scientists had to be replaced by other scientists.

Communication is very important for collaborative research activities. What is communicated can be interpreted differently depending on the situation or target. This paper analyzes the network of relationships among scientists using research equipment for research collaboration. A network of relationships is described as that in which the scientist is a node and the relationship of the scientist is an edge. The relationship forming model of scientists goes through the following process. First, the R&D project leader, the main node of the relationship model, is selected using FDM, which can select the most capable scientist. The selected R&D project leader plays an important role in facilitating collaboration among scientists through the relational model. The R&D project leader in the relationship model among scientists is a central node that connects edges to other scientists. Then a link is established between scientists, except for the central node. The table of differences in the research equipment utilization difficulty level and the research capabilities of scientists was utilized to establish relationships. Below is the detailed formula that was used to determine the reference value.

$$Reference\ \ Value = \frac{\sum_{e=1}^{k} d_{eg}}{n} - 1 \tag{12}$$

In this paper, the level of conflict was calculated through the relationship model of scientists for the edge numbers. Below is the detailed formula that was used.

$$\left(\frac{\frac{m \times (m-1)}{2}}{2} \right) \pm \left(\frac{m}{2} \right) \tag{13}$$

If the number of main lines was within the range of the formula, the level of conflict was normal. If it was large or small, the level of conflict was high.

4. Research results analysis

In this paper, eight research equipment were analyzed for the optimization planning of research equipment operation through the efficient integration of research equipment and scientists. There were five items on the research capabilities of the scientists, one each on the research equipment operation capability, research equipment analysis handling, research result production, research result interpretation, and research equipment safety management. The scores for the research capabilities needed to be able to utilize the research equipment were calculated using a 5-point scale (5: very good; 4: good; 3: neither good nor bad; 2: bad; 1: very bad). The capabilities required to be able to utilize research equipment are presented in Table 1. A total of five scientists in this study were using research equipment. The research capabilities of these scientists were calculated using a 5-point scale (5: very good; 4: good; 3: neither good nor bad; 2: bad; 1: very bad). The research capabilities of the scientists are presented in Table 2. FDM was used to calculate the scientists' ranks based on their research capabilities. Below is the detailed formula that was used.

$$f_{ig} = \sum_{e=1}^{k} (t_{ie} \times j_{eg}) \tag{14}$$

Scientists 1 and 2 were determined to match research equipment 1 through the formula.

$$FDM\ \ Research\ \ Equipment\ 1 \otimes Scientist\ 1 = (1\times5+3\times3+5\times2+3\times1+3\times3) = 37 \tag{15}$$

$$FDM\ \ Research\ \ Equipment\ 1 \otimes Scientist\ 2 = (1\times4+3\times3+5\times3+3\times3+3\times4) = 49 \tag{16}$$

FDM 2 was determined to match research equipment 1 and 2 through the formula.

$$FDM\ \ Research\ \ Equipment\ 1 \quad (37, 49, 54, 26, 42) \tag{17}$$

$$FDM\ \ Research\ \ Equipment\ 2 \quad (42, 52, 58, 29, 45) \tag{18}$$

The FDM for research utilization is presented in Table 3. Below is the detailed formula that was used to determine the research capability ranks of the scientists using FDM.

$$Rank\ \ f_{ig} = Rank\ of\ \ f_{ig}\ \ in\ raw\ i \quad (19)$$

The research capability ranks of the scientist are presented in Table 4. The total research capacities of the scientists were calculated based on the foregoing.

$$Average\ \ f_g = \frac{\sum_{e=1}^{n} Rank\ \ of\ \ f_{ig}}{n} \quad (20)$$

Table 2: Research Capabilities of the Scientists

Classification	Scientist 1	Scientist 2	Scientist 3	Scientist 4	Scientist 5
Research equipment operation capability	5	4	4	3	2
Research equipment analysis handling	3	3	3	2	3
Research result production	2	3	4	1	2
Research result interpretation	1	3	5	1	3
Research equipment safety management	3	4	2	3	4

Table 3: FDM for Research Utilization

Classification	Scientist 1	Scientist 2	Scientist 3	Scientist 4	Scientist 5
Research equipment 1	37	49	54	26	42
Research equipment 2	42	52	58	29	45
Research equipment 3	38	45	50	27	36
Research equipment 4	33	41	38	25	36
Research equipment 5	34	42	44	25	34
Research equipment 6	53	62	67	37	49
Research equipment 7	50	58	57	35	47
Research equipment 8	42	49	51	29	37

Table 4: Research Capability Ranks of the Scientists

Classification	Scientist 1	Scientist 2	Scientist 3	Scientist 4	Scientist 5
Research equipment 1	4	2	1	5	3
Research equipment 2	4	2	1	5	3
Research equipment 3	3	2	1	5	4
Research equipment 4	4	1	2	5	3
Research equipment 5	3	2	1	5	3
Research equipment 6	3	2	1	5	4
Research equipment 7	3	1	2	5	4
Research equipment 8	3	2	1	5	4

Below is the detailed formula that was used to determine the total research capability of scientist 1.

$$\begin{aligned} Scientist\ \ 1 &= \frac{4+4+3+4+3+3+3+3}{8} \\ &= 3.4 \end{aligned} \quad (21)$$

The total research capabilities of the scientists are presented in Table 5. The total research capabilities ranks of the scientists can be known based on the research results (scientist 4 > scientist 5 > scientist 1 > scientist 2 > scientist 3). Below is the detailed formula that was used to determine the research equipment utilization difficulty level.

$$D = \left(\sum_{g=1}^{k} t_{1g} \cdots \sum_{g=1}^{k} t_{ng} \right) \quad (22)$$

The research equipment utilization difficulty levels are presented in Table 6. The research equipment utilization difficulty levels can be known based on the research results (research equipment 6 > research equipment 7 > research equipment 2 > research equipment 1 > research equipment 8 > research equipment 3 > research equipment 4 = research equipment 5). Below is the detailed formula that was used to determine the difference between the capabilities required for research equipment utilization and the research capabilities of the scientists.

$$d_{ig} = \sum_{e=1}^{k} (t_{ei} - j_{ge}) \quad (23)$$

Below is the detailed formula that was used to determine the difference between the capabilities required for research equipment utilization 1 and the research capabilities of scientists 1.

$$\begin{aligned} & Scientist\ \ 1 \otimes Research\ \ Equipment\ \ 1 \\ & = (5-1)+(3-3)+(2-5)+(1-3)+(3-3) \\ & = -1 \end{aligned} \quad (24)$$

The difference between the capabilities required for research equipment utilization and the research capabilities of the scientists is presented in Table 7.

If the capability required for research equipment utilization is high, scientists with excellent research capabilities are placed. If the capability required for research equipment utilization is low, scientists with low research capabilities are placed. Table 5 and 6 show the integration and placement of research equipment and scientists considering the capabilities required for research equipment utilization and the research capabilities of the scientists. The integration and placement of research equipment and scientists are presented in Table 8. Scientist 3 has the highest research capability. The selected R&D project leader is the main node and is connected to the other scientists through the main line. Below is the detailed formula that was used to determine the main line.

$$Reference\ \ Value = \frac{\sum_{e=1}^{k} d_{eg}}{n} - 1 \quad (25)$$

Below is the detailed formula that was used.

$$\begin{aligned} Reference\ Value &= \left[\frac{3+2+5+6+6+1+4}{8} \right] - 1 \\ &= 2.13 \end{aligned} \quad (26)$$

In this study, the main line of the relationship model of scientists was utilized to calculate the conflict level. The relationship model of scientists can have a maximum of 10 main lines. Below is the detailed formula.

$$\frac{m\times(m-1)}{2}=\frac{5\times(5-1)}{2}=10 \quad (27)$$

Below is the detailed formula that was used to determine the conflict level.

$$\left(\frac{\frac{m\times(m-1)}{2}}{2}\right)\pm\left(\frac{m}{2}\right)=\frac{\frac{5\times(5-1)}{2}}{2}\pm\frac{5}{2} \quad (28)$$

Table 5: Total Research Capabilities of the Scientists

Classification	Scientist 1	Scientist 2	Scientist 3	Scientist 4	Scientist 5
Average FDM	3.4	1.8	1.3	5.0	3.5

Table 6: Research Equipment Utilization Difficulty Level

Classification	Research equipment 1	Research equipment 2	Research equipment 3	Research equipment 4	Research equipment 5	Research equipment 6	Research equipment 7	Research equipment 8
Difficulty level	15	16	13	12	12	18	17	14

Table 7: Difference between the Capabilities Required for Research Equipment Utilization and the Research Capabilities of the Scientists

Classification	Scientist 1	Scientist 2	Scientist 3	Scientist 4	Scientist 5
Research equipment 1	-1	2	3	-5	-1
Research equipment 2	-2	1	2	-6	-2
Research equipment 3	1	4	5	-3	1
Research equipment 4	2	5	6	-2	2
Research equipment 5	2	5	6	-2	2
Research equipment 6	-4	-1	0	-8	-4
Research equipment 7	-3	0	1	-7	-3
Research equipment 8	0	3	4	-4	0

Table 8: Integration and Placement of Research Equipment and Scientists

Classification	Scientist 1	Scientist 2	Scientist 3	Scientist 4	Scientist 5
Average FDM	Research equipment 3 or 8	Research equipment 7	Research equipment 6	Research equipment 4 or 5	Research equipment 1 or 2

If the number of main lines fell within the range of 3-7, it was adjudged to be very efficient and to have shown very high performance from the perspective of the R&D project team. Therefore, the main lines of the R&D project team had to fall within the range of 3-7.

5. Conclusions and implications

In this paper, a quantitative way of ensuring the correct placement and integration of research equipment and scientists is proposed. The research process that was used was based on the matrix for the data calculation. The efficient integration of research equipment and scientists was attempted for the optimization planning of research equipment operation. An attempt was made to develop methods of enhancing research equipment efficiency by focusing on the research equipment utilization difficulty level and the research capabilities of scientists.

Eight research equipment and five scientists were selected for the study. A 5-point-scale method was used to display the research capabilities of scientists using research equipment. First, there were five items on the required capabilities of scientists for research equipment utilization. A 5-point-scale method was used to analyze the capabilities required for each task in research equipment utilization. Then another 5-point-scale method was used to display the research capabilities of the scientists using research equipment. The functional deployment matrix (FDM) was used for the calculation of the ranks based on the research capabilities of the scientists. Then the ranks for the research equipment utilization difficulty level were calculated. The remaining placement was arranged through the overall rankings based on the research equipment utilization difficulty level and the research capabilities of the scientists. It was necessary to verify the validity of the initial research equipment utilization assignment results of the scientists. This study calculated the difference between the capabilities required for research equipment utilization and the research capabilities of the scientists for validity verification. Based on the results, the integration and the placement of the research equipment and the scientists could be performed by considering the capabilities required for research equipment utilization and the research capabilities of the scientists. This paper proposed that the R&D project leader in the relationship model between scientists is a central node that connects the edges to other scientists for the efficient R&D project team operation. It is believed that a systematic method of and an optimized plan for deploying and integrating research equipment and scientists, as opposed to the intuitive method, are necessary. Therefore, the results of this study are necessary for the efficient integration of research equipment and scientists. The authors are confident that an efficient and optimized deployment and integration study for research equipment and scientists will make a significant contribution to research efficiency and productivity improvement. It is hoped that the findings obtained from this study will prove to be very useful for professors, researchers, and policymakers at universities and research institutes around the world.

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