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Research Article

Use and Management System of Large-scale Machinery and Equipment Based on Teaching Process of Colleges and Universities

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Abstract

Since the beginning of the new century, our country has made more efforts and attached increasing importance to colleges and universities. The number and scale of various large-scale equipment in the teaching process of colleges and universities are also growing rapidly and steadily. However, the management of these large-scale machinery and equipment is still dominated by traditional manual management mode, and there are practical problems existing in the use and management system such as low use efficiency, unreasonable purchase and obvious management loopholes. Based on these conditions, this paper takes the management system of large-scale machinery and equipment as the research direction, and proposes financial index, internal process index, scientific research development index and interest-related index to construct an index system structure, then it uses a combined algorithm which integrated the improved Analytic Hierarchy Process (AHP) with the entropy weight method to calculate the impact factors of each index, at last, this paper puts forward specific countermeasures and suggestions according to the size of the impact factors, in the hopes of providing support for the use and management of equipment in the teaching process of colleges and universities.

Keywords

Machinery and Equipment • Management Index • Analytic Hierarchy Process (AHP) • Entropy Weight Method • Impact Factor

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Since the new century, the state has implemented the goal of rejuvenating the country through science and education and scientific and technological innovation. To further promote the cultivation of talents, improve their scientific research skills and enhance the graduates' employment competence, the national education department's investment in large-scale machinery and equipment in university laboratories is growing steadily every year. Laboratory teaching is playing an increasingly important role in the cultivation of talents in colleges and universities, and large-scale machinery and equipment are also the core part of the hardware construction of colleges and universities and their fixed assets, it's an important resource for college talents to conduct skill training, scientific experiments, innovative integration, and basic teaching. Especially in recent years, the state's investment in Project 211 and Project 985 colleges and universities is huge, and at the same time, the teaching conditions of scientific research equipment in colleges and universities have been greatly improved (Galan, Muñoz & Viguri., 2016). From 2008 to 2017, the state's investment in large-scale machinery and equipment in colleges and universities increased from more than 40 billion yuan to more than 400 billion yuan, the investment has increased by 10 times. It can be seen that large-scale machinery and equipment are playing a more important role in the teaching of colleges and universities.

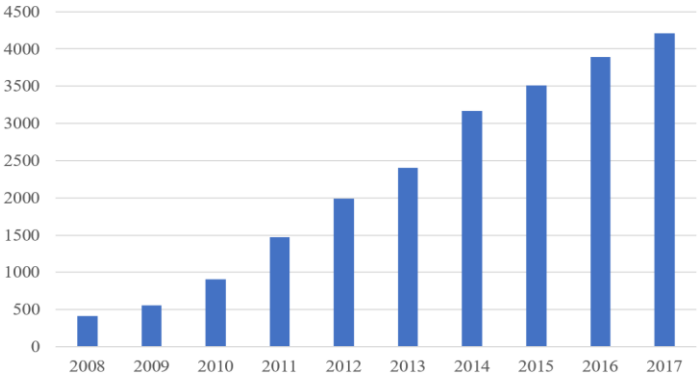

Figure 1. Annual change of large-scale machinery and equipment investment in colleges and universities

From Figure 1, we can intuitively see state's increasing investment in the laboratory equipment of colleges and universities in the past decade. The use and management of these large equipment in the teaching process is very different from the ordinary small instruments and devices. It has characteristics such as high operation and maintenance cost, many operation steps, great potential risks and high professional techniques, however, the management mode in colleges and universities hasn't advanced with the times and it is still based on the traditional manual management mode, in which there are problems such as low utilization rate of large equipment, incompetent equipment management staffs, unreasonable purchase plans, and insufficient use, etc., resulting in insufficient use of hardware equipment resources, research and teaching level and production funds in colleges and universities, and this outdated management mode and method fundamentally restrict the role of large-scale machinery and equipment in the teaching process.

Therefore, the increase in the utilization rate of large-scale machinery and equipment and the input-output ratio of scientific research results in colleges and universities are urgent problems need to be solved in the development of the information age. This paper makes a practical analysis of the background of the use and management of large-scale machinery and equipment in colleges and universities, and uses scientific research theories and analytical methods to study the specific indices in the management method of large-scale equipment in colleges and universities, it proposes the latest management index system to carry out reasonable analysis and calculation of various impact factors, so that the large-scale equipment in university laboratory can play its role to the greatest extent, this paper also puts forward a reasonable and effective management operation mechanism mode so that implementers of specific works can better serve the experimental education in colleges and universities (Sapunar, Grković, Lukšić & Marušić, 2016).

Construction idea of management system for large-scale machinery and equipment

The research on the management system of large-scale machinery and equipment in the laboratory is a process starts from scratch, and it is a process of continuous improvement, revision and determination. Its research ideas and the conventional scientific research methods have similar processes, including important processes such as the collection of literature data, the decomposition of targets, and expert analysis and determination, etc. The specific construction ideas are shown in Figure 2.

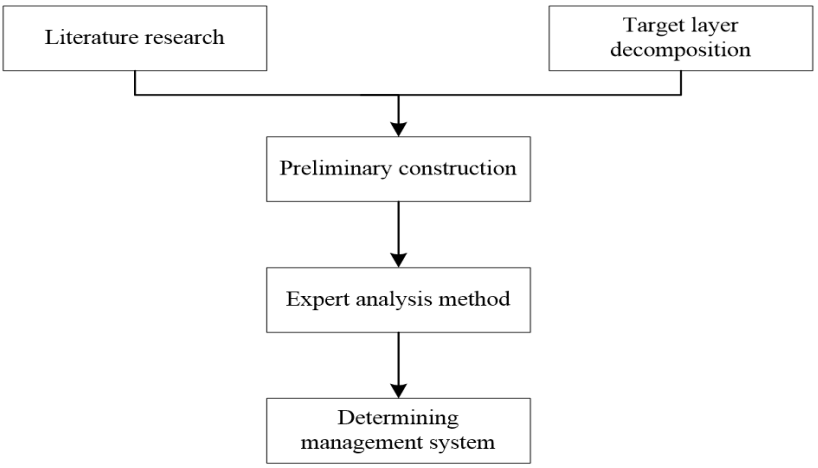

Figure 2. Construction of management system for large-scale machinery and equipment

The literature research method mainly takes the target of management system set by the target layer as the research objective, it collects the latest research results and methods from the most advanced literature materials worldwide, summarizes the technical characteristics of the target objects, and more clearly defines the nature of the research objects. It enhances our understanding of the questions, and preliminarily draws the basic structural characteristics of the management system for large-scale machinery and equipment (Wen, 2016).

The target decomposition method is to stratify the research objectives, with the target layer as the final research objective, it decomposes the target mode into specific criterion layers according to the strict research

mode, for the sub-targets in each criterion, they are broken down into independent index layers. The affiliation between layers must be maintained, and the correlation and independence between specific objects between each layer must be ensured. The specific process of the target decomposition method is shown in Figure 3.

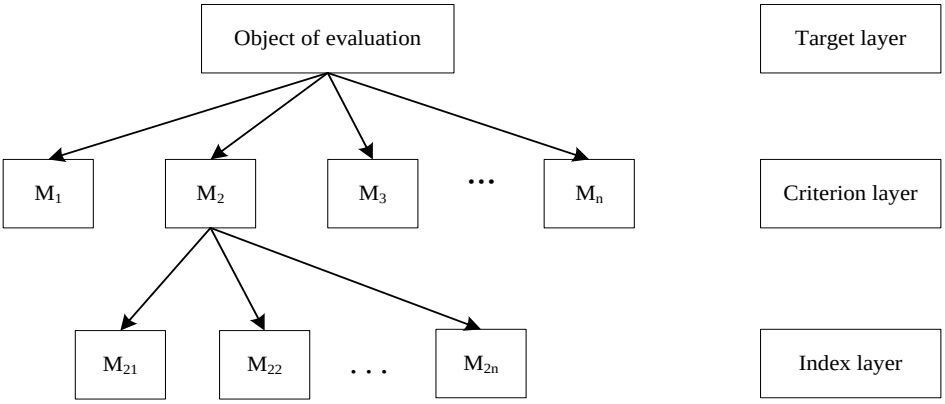

Figure 3. Target decomposition

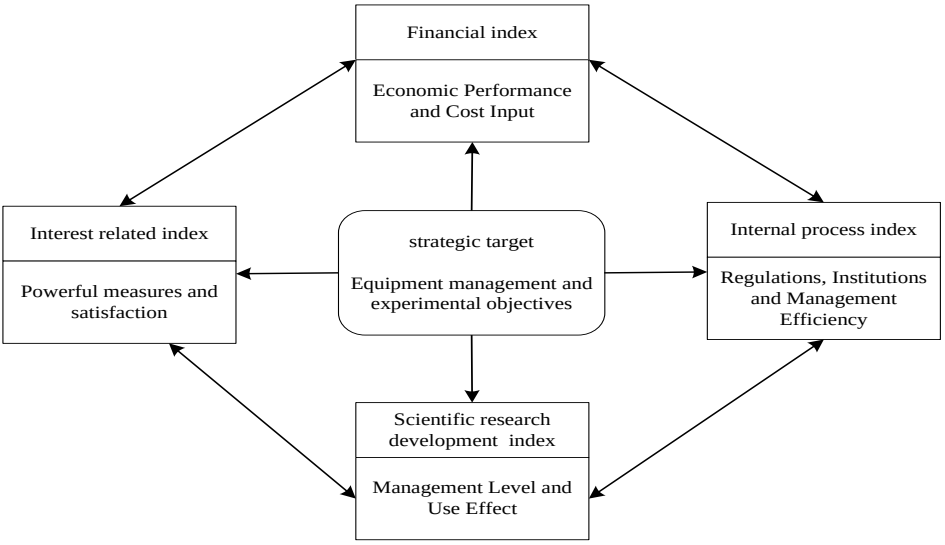

Figure 4. Logical framework of evaluation indices

The expert analysis method is to more accurately correct and determine the preliminary structural model that has been established. It hires well-known domestic and foreign industry experts to provide specific guidance on the research methods and results in a formal way, so as to construct the target system structure. In the construction of the use and management system structure for large-scale machinery and equipment, the

personnel from important departments of colleges and universities such as the asset management department, the experiment management department, the scientific research team, and the equipment purchase department are invited to conduct discussion and investigation for several times, and the system structure indices are verified and adjusted repeatedly, then the construction of the use and management system for large-scale machinery and equipment is finally completed (Özkan, Alpak & Var, 2017).

Determination of the evaluation indices

In the teaching of colleges and universities, the indices of the use and management system for large-scale machinery and equipment should be determined according to the theoretical basis of "strategy", "balance" and "coordination", the indices should be oriented to the output performance of laboratory instruments and the management direction of each coordination department, and are in accordance with the requirements of the school's basic experimental teaching, scientific research results, competition participation, etc., specific indices of laboratory large-scale machinery and equipment such as management mode, structure construction, operation and maintenance, should be enhanced. From a comprehensive perspective, in-depth analysis and research are conducted, under the guidance of strategic objectives, four criterion indices of financial index, scientific research development index, internal process index and interest-related index are summarized, each criterion index and specific implementation index can strategically improve the use and management system for laboratory large-scale machinery and equipment (Rodriguez, 2016). The status and logic of the four criterion indices in the system construction are shown in Figure 4.

Financial index

The use of large-scale machinery and equipment in university laboratories must not be measured by economic benefits, but it is closely related to the financial process in the specific use and management. A detailed analysis of financial index is carried out from aspects of the investment of instruments and devices in the purchase plan, their consumption during the use and maintenance, and the output performance of their experimental results, etc.

The first is the occupancy rate of large-scale machinery and equipment in teaching research instruments. From this specific index we can see the amount of investment in large-scale equipment from a macro perspective, it reflects the investment scale of scientific research in colleges and universities. And the size of occupancy rate directly indicates the importance attached to large-scale machinery and equipment in colleges and universities, its specific calculation formula is: total number of large-scale machinery and equipment ÷ total number of equipment ×100%.

The second is the annual operating and maintenance cost of large large-scale machinery and equipment. In the use and management of large-scale machinery and equipment, the loss of the equipment is inevitable, the maintenance and update are necessary, so the economic loss caused by these necessary losses is an important guarantee for the normal operation of large-scale machinery and equipment. The education department

stipulates that the annual invested maintenance cost shall not be less than 6% of the purchase cost, and must be earmarked. The specific calculation formula is: the annual maintenance cost of large-scale machinery and equipment ÷ the maintenance cost of all equipment × 100%.

The third is the annual renewal rate. Large-scale machinery and equipment will be updated in a timely manner according to the actual situation in the purchase plan every year. Similarly, it can also reflect the technical requirements of hardware investment of scientific research and construction work in colleges and universities. The specific calculation formula is: (total purchase of large-scale machinery and equipment this year - total purchase of large-scale machinery and equipment last year) ÷total purchase of large-scale machinery and equipment last year × 100%.

The fourth is the budget level. According to the relevant regulations, the procurement of large-scale machinery and equipment must be basically consistent with the purchase plan of the project, whether the use of the cost is consistent with the budget, and the completion of these budgets are also important support points for the financial index (Boniwell, Osin & Martinez, 2016).

The fifth is the internal and external rate of return. In addition to completing the internal basic teaching and research experiments in colleges and universities, large-scale machinery and equipment can also cooperate with other off campus units to achieve win-win cooperation through other means, and a certain amount of fee can be charged, which would increase income while improving the utilization rate of the machine, the specific calculation formula is: off-campus service income ÷ the original value of large-scale machinery and equipment × 100%.

The sixth is the actual utilization rate. It is used to reflect the operation time of the large-scale instruments and equipment within a year, its specific calculation formula is: actual utilization rate = effective utilization time ÷timed utilization time × 100%. For example, the calculation formulas of utilization rate of instruments, equipment and mechanical machinery are:

General instruments: 1600 hours / year 8 hours × 20 days × 10 months = 1600 hours

Special equipment: 800 hours / year 4 hours × 20 days × 10 months = 800 hours

Mechanical machinery: 600 hours / year 3 hours × 20 days × 10 months = 600 hours

Internal process index

In the operation of large-scale machinery and equipment, it's necessary to use scientific business process methods as guidance, and management should be carried out on time according to daily work specifications, which provides more favorable guarantee for the scientific use of large-scale machinery and equipment and its perfection of measures and methods (Bandara & Ouyang, 2012).

The first is the establishment of management institutions. The purpose is whether the equipment management department of the university is complete and effective, whether the division of labor is clear and reliable, and whether the main leaders attach importance to the use and management of the equipment.

The second is the utilization rate of all equipment. This index mainly reflects the utilization condition of important equipment and instruments in the laboratory, the specific calculation formula is: utilization rate = the number of equipment used ÷ the number of all equipment × 100%.

The third is the sharing rate. For the cooperation units and industry units inside and outside the school, reasonable equipment sharing can be carried out to maximize the utilization of the equipment. The specific calculation formula is: sharing rate = the number of equipment shared by the external development ÷ the number of numbered equipment × 100%.

The fourth is the level of purchase management. It is mainly used to regulate the norm and process of large-scale equipment in setting budgets, executing purchases and using processes (Chaves *et al*., 2015).

The fifth is the robustness of management system. A perfect and sound management system can better exert the functions of the equipment to ensure its good operation. The specific robustness index indicates whether the management system is perfect and whether the laboratory management personnel's operational skills are excellent.

The sixth is the intact rate. Damage to the equipment is inevitable during use. Timely maintenance and protection can prolong the life of the equipment. Random inspection can be conducted to test the intact condition of the equipment in the laboratory, the specific calculation formula is: intact rate = the number of equipment that are inspected and intact ÷ the number of equipment that are inspected × 100%.

The seventh is whether the management business is sound. Whether the cleaning and maintenance work of large-scale machinery and equipment in daily management is complete, and whether its utilization condition is recorded normatively, etc.

Scientific research development index

From a long-term perspective, the use of large-scale machinery and equipment is mainly reflected in the basic experimental teaching work, professional scientific experiments, instruments and equipment management mode and the skill level of laboratory operators in the scientific research direction, it is an important index for the result direction in management system indices.

The first is operational use and development. It mainly reflects condition of service, technical transformation, improvement in scientific research and development of the large-scale machinery and equipment.

The second is the achievements in scientific research. It reflects the basic teaching and the output of scientific research results at the national and provincial levels carried out in this category of equipment, it can reflect the contribution of these instruments and equipment to the achievements of the colleges and universities.

The third is personnel training. The operation of large-scale machinery and equipment by teachers, students and laboratory staff in colleges and universities is the best way to improve the hands-on operation ability. In the use of experimental instruments, strengthen the training and guidance for all kinds of personnel, and cultivate

more talents.

The fourth is information construction. In the management system, whether the information construction has been enriched by advanced scientific method to improve the transparency and openness of the management mode.

The fifth is manager configuration. Instruments and equipment must be managed by a complete, responsible and high-quality team during use, the management personnel should be trained and guided annually, and updated in a timely manner.

Interest-related index

Teachers and students in colleges and universities are the main users of large-scale machinery and equipment, and priorities should be given to those crowds to guarantee their normal needs, so as to effectively exert the cooperation effect between people and machines.

The first is the satisfaction degree of the instruments and equipment. It represents the satisfaction degree of college teachers and students about their experience feelings during the use of the large-scale machinery and equipment planned to be purchased.

Table 1
Management Indices of Large-Scale Machinery and Equipment

Target	First level target	Second level target
Instrument management system of large-scale machinery and equipment (A)	Financial index (B_1)	Occupancy rate (B_{11})
		Annual operating and maintenance costs (B_{12})
		Annual renewal rate (B_{13})
		Budget level (B_{14})
		Rate of return (B_{15})
		Actual utilization rate (B_{16})
	Internal process index (B_2)	Establishment of Management Institutions(B_{21})
		Utilization rate (B_{22})
		Sharing rate (B_{23})
		Purchase management level (B_{24})
		Robustness of management system (B_{25})
		Intact rate (B_{26})
		Management business (B_{27})
	Scientific research development index (B_3)	Operational Use and Development (B_{31})
		Achievements in scientific research (B_{32})
		Personnel training (B_{33})
		Information construction (B_{34})
		Manager Configuration (B_{35})
	Interest related index(B_4)	Satisfaction degree(B_{41})
		Per capita occupancy (B_{42})
		Establishment of Open Bonus (B_{43})
		Laboratory environment (B_{44})

The second is the per capita occupancy. In colleges and universities, higher occupancy of students to the equipment indicates the students occupy more hardware resources in this college or university, which means the quality and ability of the school can be more secure. The specific calculation formula is: the per capita

occupancy = the total number of large-scale equipment ÷ conversion ratio of user number (Sembiring, Sembiring, Tarigan & Sembiring, 2017).

The third is the establishment of open bonus. According to the specific conditions of each year, colleges and universities will reward certain bonus to laboratories that well managed the experimental equipment, so as to show that the school attaches importance to the instruments and equipment. (Thanassoulis, Dey, Petridis, Goniadis & Georgiou, 2017)

The fourth is the laboratory environment. The clean and safe environment of the laboratory plays an important role in the protection of experimental instruments. Regularly organize special personnel to carry out the necessary organization and implementation of the establishment of a safe environment (Roth & Roychoudhury, 2010).

Through the determination and analysis of the above four criterion indices, the specific connotation of the implementation indices is further divided, and the system structure shown in Table 1 is established according to the management construction idea of large-scale machinery and equipment.

Impact factor calculation

Improved AHP

AHP generally calculates the eigenvalues and eigenvectors, and completes important processes such as the consistency check of the impact factors by constructing comparison judgment matrix. The improved AHP is mainly to modify the problem of recalculating the judgment matrix when there is an inconsistency in the stratification operation. Its main idea is to use 1 to represent the importance of the two established standards U and V, assume the importance of U is higher or lower than V, then use 2 or 0 to represent it. According to the calculation steps of the judgment matrix, we can get the expression of the element as $r_i=\sum_a^0 a_{ij}$, then complete the establishment of the judgment matrix $A=(a_{ij})_{n\times n}$:

$$\begin{cases} a_{ij} = r_i - r_j + 1, r_i \geq r_j \\ a_{ij} = (r_j - r_i + 1)^{-1}, r_i \leq r_j \end{cases} \tag{1}$$

According to the nature of the matrix, calculate the impact factor of the index:

$$w_i = \frac{\overline{w_i}}{\sum_{i-1}^{n} \overline{w_i}} \tag{2}$$

Entropy weight method

The entropy weight method is an important calculation method proposed in the field of thermodynamics, however, it can reflect the degree of variation of information quantity and corresponding change in system engineering, and the size of the impact factor of the index can reflect the importance degree of the impact factor. The calculation steps for the impact factors in the use and management of large-scale machinery and equipment in colleges and universities are:

The first step is to use the improved AHP to standardize the established judgment matrix to obtain the standard matrix:

$$P = (p_{ij})_{n\times n}, where\ p_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \tag{3}$$

The second step calculates the entropy weight of the index. Assume that the entropy weight corresponding to each index is $e_j(0\leq e_j\leq 1)$, and its corresponding coefficient is $1/\ln n$, so when $p_{ij}=0$, $p_{ij}\ln p_{ij}=0$, then the value of e_j should be:

$$e_j = -\frac{1}{ln\, n}\sum_{i=1}^{n\Sigma_{ij}} p_{ij} ln \tag{4}$$

The third step is to calculate the impact factor of the index:

$$u_j = \frac{1-e_j}{\sum_{j=1}^{n}(1-e_j)} = \frac{1-e_j}{n-\sum_{j=1}^{n} e_j}, \sum_{j=1}^{n} u_j = 1 \tag{5}$$

Finally, in the use and management of large-scale machinery and equipment in college teaching, carry out index replication operation, conduct the final calculation according to the improved AHP and the entropy weight method, the multiplier synthesis normalization method is used to combine the two algorithms, so that the results of the implementation indices are more in line with the actual situation, the specific calculation formula is:

$$d_j = \frac{u_j w_j}{\sum_{j=1}^{n} u_j w_j} \tag{6}$$

Table 2
Judgment Matrix and Impact Factor of Criterion Layer to Target Layer

A	B_1	B_2	B_3	B_4	W_i	u_i
B_1	1	0.333	0.2	3	0.118	0.263
	0.107	0.073	0.119	0.188		
B_2	3	1	0.333	5	0.263	0.362
	0.321	0.221	0.199	0.313		
B_3	5	3	1	7	0.56	0.236
	0.536	0.662	0.597	0.438		
B_4	0.333	0.2	0.143	1	0.055	0.139
	0.036	0.044	0.085	0.063		

Table 3
Judgment Matrix and Impact Factor of Sub-indices Under Financial Index

B_1	B_{11}	B_{12}	B_{13}	B_{14}	B_{15}	B_{16}	W_i	u_i
B_{11}	1	0.111	0.333	0.167	0.167	0.091	0.04	0.14
	0.028	0.023	0.013	0.013	0.013	0.049		
B_{12}	9	1	7	4	4	0.333	0.31	0.2
	0.25	0.21	0.276	0.322	0.322	0.178		
B_{13}	3	0.143	1	0.25	0.25	0.111	0.47	0.219
	0.083	0.03	0.039	0.02	0.02	0.059		
B_{14}	6	0.25	4	1	1	0.167	0.12	0.16
	0.167	0.053	0.158	0.081	0.081	0.089		
B_{15}	6	0.25	4	1	1	0.167	0.12	0.16
	0.167	0.053	0.158	0.081	0.081	0.089		
B_{16}	11	3	9	6	6	1	0.35	0.12
	0.305	0.631	0.355	0.483	0.483	0.535		

Calculation of index impact factors

The paper uses improved AHP to test the importance of the indices in pairs, we interviewed and investigated 11 experts in the field, including 3 scientific research teachers, 4 student representatives, and 4 laboratory administrators in the school. According to the questionnaire survey and individual interviews, feedbacks of each person are collected multiple times, and the values of indices are determined via the investigation method, then use improved AHP and entropy weight method to process the data, calculate the corresponding impact factors from the preliminary matrix obtained, at last, calculate the judgment matrix and impact factors of the criterion layer to the target layer, and calculate the judgment matrix and impact factors of the financial index, internal process index, scientific research development index and interest-related index in the criterion layer. The specific calculation results are shown in Tables 2-6.

Table 4
Judgment Matrix and Impact Factor of Sub-indices Under Internal Process Index

B_2	B_{21}	B_{22}	B_{23}	B_{24}	B_{25}	B_{26}	B_{27}	W_i	u_i
B_{21}	1	0.167	0.167	0.1	1	1	0.1	0.03	0.1
	0.03	0.013	0.013	0.037	0.03	0.03	0.03		
B_{22}	6	1	1	0.2	6	6	0.2	0.11	0.2
	0.17	0.08	0.08	0.08	0.17	0.17	0.08		
B_{23}	6	1	1	0.2	6	6	0.2	0.11	0.2
	0.17	0.08	0.08	0.08	0.17	0.17	0.08		
B_{24}	10	5	5	1	10	10	1	0.34	0.14
	0.286	0.4	0.4	0.37	0.286	0.286	0.37		
B_{25}	1	0.167	0.167	0.1	1	1	0.1	0.03	0.1
	0.03	0.013	0.013	0.037	0.03	0.03	0.03		
B_{26}	1	0.167	0.167	0.1	1	1	0.1	0.03	0.1
	0.03	0.013	0.013	0.037	0.03	0.03	0.03		
B_{27}	10	5	5	1	10	10	1	0.34	0.14
	0.286	0.4	0.4	0.37	0.286	0.286	0.37		

Table 5
Judgment Matrix and Impact Factor of Sub-indices Under Scientific Research Development Index

B_3	B_{31}	B_{32}	B_{33}	B_{34}	B_{35}	W_i	u_i
B_{31}	1	0.25	0.25	4	4	0.137	0.283
	0.105	0.099	0.099	0.2	0.2		
B_{32}	4	1	1	7	7	0.38	0.2
	0.421	0.394	0.394	0.35	0.35		
B_{33}	4	1	1	7	7	0.38	0.2
	0.421	0.394	0.394	0.35	0.35		
B_{34}	0.25	0.143	0.143	1	1	0.048	0.157
	0.026	0.056	0.056	0.05	0.05		
B_{35}	0.25	0.143	0.143	1	1	0.048	0.157
	0.026	0.056	0.056	0.05	0.05		

Through the calculation of the judgment matrix and the impact factors of the indices in each criterion layer, the influence of each index on the large-scale machinery and equipment in college teaching is integrated, and the impact factors of each index layer are finally calculated. The specific result values are shown in Table 7.

Table 6
Judgment Matrix and Impact Factor of Sub-indices Under Interest-related Index

B_4	B_{41}	B_{42}	B_{43}	B_{44}	W_i	u_i
B_{41}	1	0.2	0.2	1	0.084	0.25
	0.083	0.083	0.083	0.083		
B_{42}	5	1	1	5	0.417	0.25
	0.417	0.417	0.417	0.417		
B_{43}	5	1	1	5	0.417	0.25
	0.417	0.417	0.417	0.417		
B_{44}	1	0.2	0.2	1	0.084	0.25
	0.083	0.083	0.083	0.083		

Table 7
Final Impact Factors of Indices at All Levels

Target	First level target	Factor	Second level target	Factor
Instrument management system of large machinery equipment (A)	Financial index (B_1)	0.117	Occupancy rate (B_{11})	0.04
			Annual operating and maintenance costs (B_{12})	0.38
			Annual renewal rate (B_{13})	0.06
			Budget level (B_{14})	0.12
			Rate of return (B_{15})	0.12
			Actual utilization rate (B_{16})	0.28
	Internal process index (B_2)	0.347	Establishment of Management Institutions(B_{21})	0.02
			Utilization rate (B_{22})	0.148
			Sharing rate (B_{23})	0.148
			Purchase management level (B_{24})	0.32
			Robustness of management system (B_{25})	0.02
			Intact rate (B_{26})	0.02
			the management business (B_{27})	0.32
	Scientific Research development index(B_3)	0.487	Intact rate (B_{26})	0.18
			Management business (B_{27})	0.37
			Operational Use and Development (B_{31})	0.37
			Achievements in scientific research (B_{32})	0.05
			Personnel training (B_{33})	0.05
	Interest related index (B_4)	0.05	Information construction (B_{34})	0.084
			Manager Configuration (B_{35})	0.417
			Satisfaction degree(B_{41})	0.417
			Per capita occupancy (B_{42})	0.084

Conclusion

Along with the huge investment of the national education department in college education, the number and scale of large-scale machinery and equipment in colleges and universities are expanding year by year. In order

to solve the problems of the utilization rate of large-scale machinery and equipment in colleges and universities and the input-output ratio of scientific research results, this paper makes a practical analysis of the background of the use and management of large-scale machinery and equipment in colleges and universities, uses scientific research theories and analytical methods to study the specific indices in the management method of large-scale equipment in colleges and universities, and proposes the latest management index system to carry out reasonable analysis and calculation of various impact factors, so that the large-scale machinery and equipment in the university laboratory can play its greatest role, this paper also proposes a reasonable and effective management operation mechanism mode, so that the specific work implementers can better serve the experimental education of colleges and universities.

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