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Application and Exploration of Early Warning Mechanism in Abnormal Use of Large Sharing Instruments

Longzhao Zhang [a], Xinyuan Rao[*,b]

Laboratory Equipment Management Section,Jinan University,Guangzhou ,China;

[a] tsimon@jnu.edu.cn, [b] raoxinyuan@jnu.edu.cn

Abstract. With the continuous investment of the national "Double First Class" universities, the financial investment of universities has increased year by year, and the purchased instruments have correspondingly grown rapidly. At the same time, the performance evaluation standards for large-scale shared instruments by national ministries and commissions are gradually improving, and higher requirements are being put forward for instrument sharing and management. In the process of large-scale instrument sharing in universities, there are common problems such as insufficient management personnel, inadequate management, and difficulty in implementing responsibilities. By utilizing the usage data in the shared platform data warehouse, analyzing relevant data such as usage time intervals, personal behavior, and user affiliation units, a preliminary evaluation of the reasonable usage interval is made. Combined with the use of early warning mechanisms, feedback from users is utilized to continuously optimize the usage warning values, This provides a solution for strengthening the digital management of large-scale instruments.

Keywords: Large instruments; Open sharing; Instrument warning; Rationalization; Digitization.

1. Introduction

Large instruments are playing an increasingly important role in today's scientific research. They are the technological foundation and important means to break through the forefront of science, solve economic and social development, achieve national high-level technological self-reliance and major scientific and technological issues of national security. The open sharing of large instruments has entered a new stage, and reform and innovation are imperative. We will promote the in-depth development of "high-end, intelligent, and green" instrument sharing, The strict requirements for inventory management and digital management of large instruments are currently an important issue in instrument management[1-2].In order to promote the open sharing of national major scientific research infrastructure and large-scale scientific research instruments, fully unleash service potential, accelerate the opening of scientific research facilities and instruments to society, and further improve the efficiency of scientific and technological resource utilization, The State Council has successively issued documents such as the "Opinions on the Opening of National Major Scientific Research Infrastructure and Large Scientific Research Instruments to the Society" (Guo Fa [2014] No. 70) and the "Management Measures for the Opening and Sharing of National Major Scientific Research Infrastructure and Large Scientific Research Instruments" (Guo Ke Fa Ji [2017] No. 289)[3].Since 2018, the Ministry of Science and Technology and the Ministry of Finance have carried out open sharing evaluation and assessment of major scientific research infrastructure and large-scale scientific research instruments in over 300 central level universities and research institutes. They require each unit to report annually on the organization and management, operation and use, and sharing service effectiveness of large-scale instruments, aiming to accurately grasp the stock of national large-scale instruments and the development status of basic scientific research conditions, Promote the exchange and sharing of national instrument data, and promote the comprehensive opening and sharing of large-scale instruments[4].

In addition, with the construction of the national "Double First Class" universities and high-level universities in Guangdong Province, the financial investment in scientific research in universities has increased sharply year by year, and the instruments purchased by various units have also significantly increased[5-6].This article takes Jinan University as an example, and the research object is the instrument with a unit price of more than 400000 yuan (hereinafter referred to as "large-scale instrument"). During the five years from 2018 to 2022, the number of large-scale instruments will increase from 445 to 835, with a five-year growth rate of 87.64%, of which the number of large-scale instruments will increase by 33.72% from 2019 to 2020. The rapid increase in the stock of large-scale instruments and insufficient supporting management personnel can easily lead to inadequate instrument management and difficulty in implementing

responsibilities. At the same time, the national management departments have increasingly standardized and detailed requirements for the assessment of large-scale instruments, which has put forward higher requirements for the digital and precise management of the usage data of large-scale instruments[7].

In order to promote the shared use of large-scale instruments, accurately master the data collection and performance evaluation of the school in the use process, use the Internet, digital and Big data technology to build a large-scale instrument sharing service management platform (hereinafter referred to as "sharing platform"), and constantly improve the digital precision management level of the sharing platform. Provide data support by analyzing sharing platform data warehouses, evaluating rational intervals, optimizing digital management of large instruments, and promoting effective sharing of large instruments[8].

2. Use data to rationalize analysis

2.1 Data recording methods for large-scale instruments

The data recording methods used by large instruments are divided into traditional manual recording and electronic information recording. Traditional manual recording refers to registering relevant experimental information such as usage time, equipment, personnel, and testing content in an experimental notebook [9]. Electronic information recording refers to the instrument corresponding to the IoT controller terminal. Users scan the code to record, and the controller terminal uploads usage data to the system. The usage data will be stored, organized, and analyzed by the system [10].

2.2 Rationalization Analysis of Large Instrument Usage Data

Relying on a sharing platform to collect usage records, establish a usage record data warehouse, which not only saves and retrieves the generated usage data, but also analyzes and processes the operating status and future development trends of the instrument [13]. Due to significant differences in instrument usage time, testing methods, and testing methods among different types of instruments, further subdivision of large-scale instrument types is needed [14]. Instruments can be classified according to their subject of use, operational functions, test objects, and placement locations. As the classification becomes more accurate, the resulting judgment basis becomes more reasonable.

According to the usage time of instruments collected on the sharing platform, the usage time can be divided into reasonable usage intervals and unreasonable usage intervals. Those outside the reasonable usage interval are called unreasonable usage intervals.

Taking the NMR spectrometer of Jinan University as an example, the school currently has 9 NMR spectrometers with a total amount of 57037600 yuan. In the past decade, 7 NMR spectrometers have been purchased with a total amount of 52.774 million yuan. The sharing platform collected 7299 pieces of data from the 7 NMR spectrometers purchased in the past decade from January 1 to December 31, 2021, as shown in Table 1.

Table 1 Annual Usage of NMR Spectrometers in the Last Decade

number	Device Name	Original Value (10000 yuan)	Belonging unit	Number of uses	Machine usage hours (hours)	Average usage time per session (hours)
1#	300M NMR Spectrometer	139.90	college of Chemistry and Materials	2123	2139.67	1.01
2#	400M NMR Spectrometer	249.80	college of Chemistry and Materials	1918	2974.93	1.55
3#	400M NMR Spectrometer	207.70	college of pharmacy	2776	4440.09	1.60
4#	500M NMR Spectrometer	387.50	Analysis and Testing Center	161	1356.11	8.42

5#	600MNMR Spectrometer	529.80	Analysis and Testing Center	165	1468.22	8.90
6#	600M NMR Spectrometer	763.80	college of pharmacy	158	4846.39	30.67
7#	9.4T Small Animal NMR Imaging System	2998.90	First Clinical Medical College	159	432.56	2.72

According to the usage frequency and usage time in Table 1, the average usage time of the instrument for each time the user uses it (average usage time=usage time/usage time) can be obtained, as shown in Figure 1.

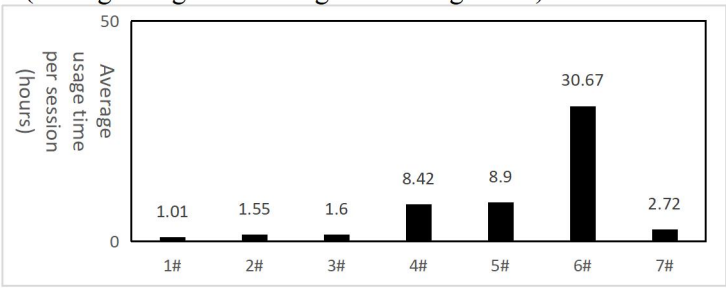

Figure 1 Average usage time of NMR spectrometer in the past decade

From Figure 1, it can be seen that the average operating time of the nuclear magnetic resonance spectrometer is 7.84 hours, among which the average operating time of the 600 MHz nuclear magnetic resonance spectrometer (No. 6) is 30.67 hours, significantly higher than the average operating time of other similar instruments. The reason may be due to users' non-standard recording behavior, significant differences in testing methods or scope compared to other instruments, and the large research volume of the research team to which the instrument belongs.

The following analyzes the rationality and related reasons of using a NMR spectrometer from three aspects: time interval, personal behavior, and unit of use.

2.2.1 Use interval analysis

By sorting out and analyzing the detailed usage records of each instrument, the specific usage time interval of that instrument can be obtained, which can further understand, analyze, and grasp the usage status of each instrument. Below, three cases of NMR spectrometers will be used to analyze the median usage time, average usage time, and abnormal usage time. The median of usage refers to the usage time of the machine in the middle of a set of data arranged in sequence during the use of the machine, while abnormal usage time refers to the usage time collected by non-standard instruments.

Figure 2 shows the usage of the 600M NMR spectrometer (5 #), Figure 3 shows the usage of the 600M NMR spectrometer (6 #), and Figure 4 shows the usage of the 9.4T small animal NMR imaging system (7 #).

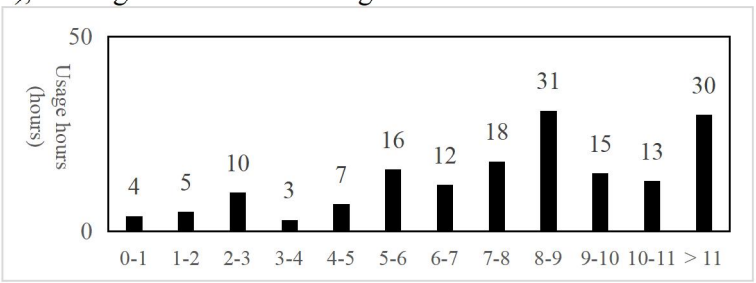

Figure 2 Usage of 600M NMR Spectrometer (5 #)

According to Figure 2 and the specific usage information collected by the system, the median usage time of the 600M NMR spectrometer (5 #) is 8.08 hours, with an average usage time of 9.53 hours. This instrument belongs to the management of the experimental technology center of the school level public platform, and the unit is equipped with full-time experimental technicians responsible for the operation, maintenance, and repair of the instrument. The recording method of the instrument's usage time is that the experimental technicians uniformly record the usage time of the day, which is approximately 8 to 9 hours per day, consistent with the system records.

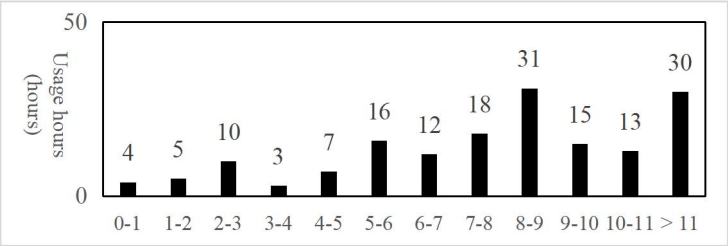

Figure 3 Usage of 600M NMR Spectrometer (5 #)

According to Figure 3 and the specific usage information collected on the sharing platform, the median usage time of the 600 MHz NMR spectrometer (6 #) is 0.41 hours, with an average usage time of 30.67 hours. Among the usage records of this instrument, there are 44 records of less than 10 minutes, accounting for 28.76%, and 13 records of single use exceeding 100 hours, accounting for 8.49%. Through comparison with similar instruments, it is determined that there are obvious unreasonable phenomena in most of the machine time intervals used by the instrument. It can be preliminarily determined that there is non-standard registration of this instrument, resulting in unreasonable usage intervals in the system's recorded instrument usage time.

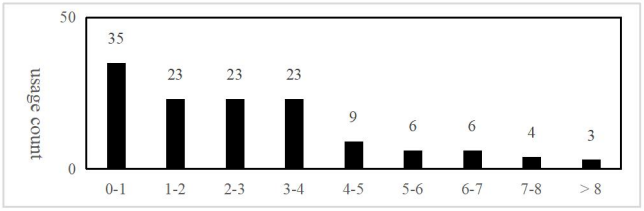

Figure 4 Usage of 9.4T Small Animal NMR Imaging System (7 #)

From Figure 4 and the specific usage information collected by the system, it can be seen that the median usage time of the 9.4T small animal NMR imaging system (7 #) is 2.92 hours, with an average usage time of 3.23 hours. The distribution of machine hours is uniform and reasonable, and there are no cases of non-standard registration. Among them, three records greater than 8 hours were registered during administrator maintenance, which were 18.26 hours, 24.53 hours, and 46.95 hours, respectively.

2.2.2 Personal Behavior Analysis

By sorting and analyzing the usage habits of individual users and their records, it is possible to determine whether the user's single use is abnormal. Table 2 shows the average usage time, median usage time, and abnormal usage time of the 400MHz NMR spectrometer (2 #), and lists three users who frequently use the instrument for data analysis.

Table 2 Usage of 400M NMR Spectrometer (2 #)

classification	Average machine usage time(hours)	Median usage time （hours）	Abnormal machine usage frequency	Total sampling frequency	Proportion of abnormal machine usage
User A	0.83	0.45	58	285	20.35%
User B	1.43	0.65	7	239	2.93%
User C	1.24	0.74	16	135	11.85%
All users	1.55	0.54	314	1918	16.37%

According to the actual use of the instrument, using the machine for less than 10 minutes is considered an abnormal use of the machine, which is an unreasonable use interval. User A has the highest frequency of usage, but their average usage time is significantly lower than the average usage time of the user. According to system record data, the frequency of abnormal usage of the machine by User A (less than 10 minutes or more than 10 hours each time) is 58 times, with 56 times using the machine less than 10 minutes each time. It can be preliminarily determined that user A's non-standard registration resulted in a high proportion of abnormal machine usage frequency. The frequency of abnormal use of the machine by user B is 5 times, with 2 times using the machine for more than 10 hours, 15.31 hours and 21.64 hours respectively. Other use of the machine is within the normal range, indicating good user behavior. The frequency of abnormal machine usage by user C is 16 times, with 15 times using the machine for less than 10 minutes each time. The frequency of abnormal machine usage belongs to the average level of similar users.

2.2.3 Analysis of user affiliation units

By organizing and analyzing the user's affiliation unit and its related usage time, it is possible to determine whether the device is saturated during operation and assist in determining the scientific research status of the user unit. Figure 5 shows the usage of the user affiliation unit of the 400MHz NMR spectrometer (2 #).

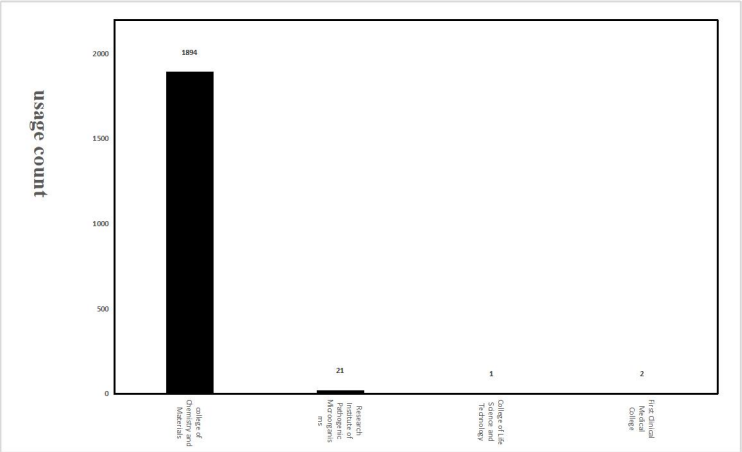

Figure 5 Usage of 400M NMR Spectrometer (2 #) by User's Home Unit

It can be seen from Figure 5 and the specific use conditions collected by the system that the Institute of Supramolecular coordination chemistry has used the instrument for 1894 times, accounting for 98.74% of the total use frequency. It is mainly the users of the unit who use the instrument. Three other units have used this instrument, accounting for 1.26%. According to the management regulations of the Ministry of Education on the use of universal instruments and the open sharing management regulations of Jinan University, the use of such instruments meets the standards and should be implemented for open sharing when idle.

By analyzing the range of instrument usage, individual usage behavior, and unit usage, it is possible to preliminarily determine whether user record lines are standardized and whether instrument testing methods are standardized, providing corresponding data support for the research volume of each team.

3. Exploring the Use of Early Warning

3.1 Definition and classification of usage warnings

Instrument usage warning refers to the act of sending warning signals to relevant instrument administrators or management units based on past patterns when there is suspicion of improper operation or abnormal use of the instrument, pushing reports on abnormal situations, and avoiding harm from happening without knowledge or insufficient preparation, in order to minimize harm or loss to the greatest extent possible. Apply Big data technology to the instrument use early warning mechanism, improve the accuracy of early warning system judgment, and realize the management of large-scale instrument use status and monitoring user behavior.

Usually divided into three types. One is that it has not been used for a long time, and the system records have not been able to collect valid machine hours; Secondly, it is used irregularly for a long time, with the system recording time exceeding the reasonable usage interval; The third reason is that the usage is abnormally frequent, and the system records a time that is less than the reasonable usage interval. Abnormal use of the machine is called when the usage time is within an unreasonable range.

3.2 Design of warning mechanism for use

The instrument usage warning mechanism includes data collection, data storage, data processing, data push, and warning processing.Data collection refers to the recording of usage data by users through scanning the QR code of the IoT controller terminal of the instrument. Data storage means that the IoT controller terminal pushes user use data to be stored in the data center of the sharing platform. From 2021 to 2022, the sharing platform of Jinan University will store about 160000 instrument use records every year. Data processing refers to the administrator setting warning values for machine usage, and the shared platform determines whether the collected usage records are abnormal based on the warning values. Data push refers to the sharing platform pushing abnormal warning information to administrators and management units

through PC, mobile, or email. Alert processing refers to that the administrator and management unit remind the user to handle the abnormal situation in time according to the abnormal alert information fed back by the platform.

3.3 Exploration of using early warning mechanisms

The instrument administrator pre-sets the unreasonable usage interval and warning conditions for each instrument. Based on the unreasonable usage interval of each instrument, the sharing platform data center analyzes and processes the collected usage data according to the pre-set warning conditions, determines whether it is abnormal usage information, and generates warning information. Subsequently, the warning information will be pushed to users and administrators. The administrator will provide feedback to the sharing platform data center based on the received warning information and the actual situation, and adjust and optimize the abnormal usage warning information.

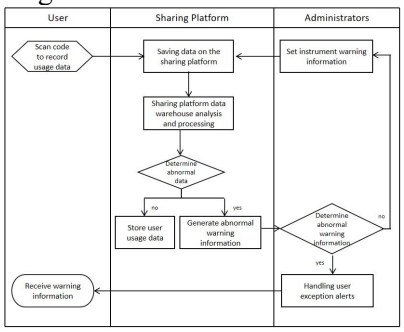

Figure 6 Instrument Usage Warning Mechanism

The data warehouse will utilize usage data and optimize instrument warning values through rational interval analysis. At the same time, detailed information such as organizational structure, user units, and user identities will also be compared to refine the warning information for different conditions and units, effectively achieving the management of instrument usage status and monitoring of user behavior.

4. Effectiveness of using early warning applications

Build a sharing platform for instrument usage warning management module, and develop a mobile WeChat terminal warning reminder function to achieve real-time usage warning push effect. Remind users, administrators, laboratory directors, colleges, and equipment management personnel in a timely and hierarchical manner based on the severity of the warning, as shown in Figure 7.

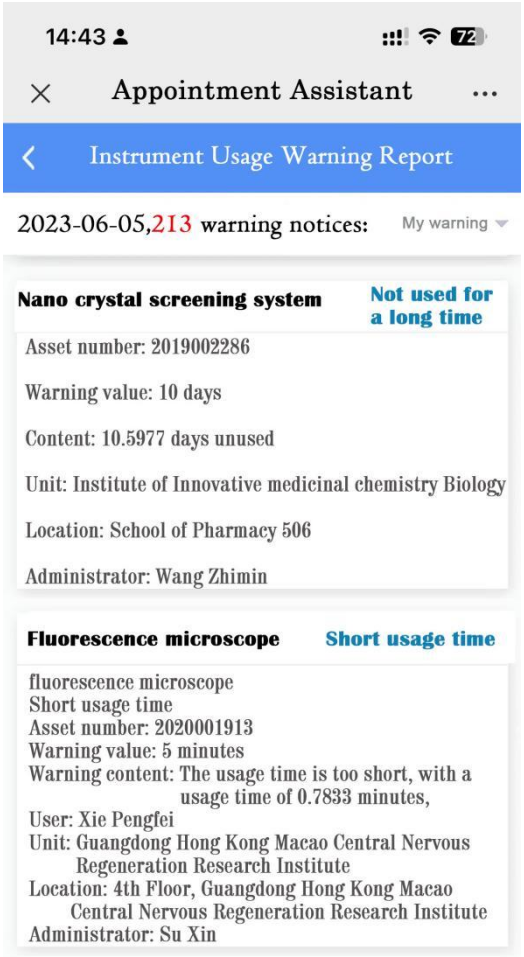

Figure 7 Warning content for instrument usage by university administrators

4.1 Improving instrument sharing efficiency

Timely detect instruments that have not been used for a long time, and the administrator determines which instruments are not commonly used based on the instrument usage warning data. Utilize idle or infrequently used instruments through free allocation, increased openness, and other channels to revitalize resources, such as opening them up to off campus units, hospitals, and other personnel for appointment use, or providing effective shared services through sample testing methods; Maximize the utilization of idle instruments and provide an effective decision-making reference for the school when coordinating the purchase of instruments.

4.2 Implement shared management responsibilities

Administrators can customize the multi-level warning management mode and implement instrument sharing responsibilities. Each instrument is assigned a dedicated person to manage it. Once the warning mechanism is triggered, the instrument administrator is notified first. When the instrument administrator mishandles or delays processing, a second level warning is triggered, and the system will send the warning information to the higher-level administrator. If the second level warning cannot be processed, the system will trigger a third level warning and push the event to the school level administrator until the final completion of event processing; Implement multi-level early warning, step by step, correct shortcomings, and implement responsibility to individuals

5. Conclusion

This article is based on the research of large-scale instrument inventory management and digital precision management, proposing a rational analysis method for large-scale instrument usage data. By utilizing digital

technology to mine and utilize sharing platform data warehouses, the reasonable usage range of data is preliminarily evaluated, providing data support for digital precision management of large-scale instruments and providing real-time basis for monitoring instrument usage status. Integrate the rational analysis of usage data with the early warning management system, gradually explore the rational use range of instruments, determine abnormal use of machines, grasp the real-time usage status of instruments, and implement digital and precise management of large-scale instruments. This article explores the application and exploration of early warning mechanisms in the abnormal use of large-scale shared instruments, with the aim of helping universities effectively manage large-scale instruments and equipment, and even providing reference for the management of large-scale instruments in China, helping to promote the high-quality development of large-scale shared instruments, and promoting national technology integration and innovation driven strategies

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