The Contrast of the Two Evaluation Systems of the Development of Popularization of Science and Technology Infrastructures

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Abstract--**The primary purpose of this paper is to analyze how the Evaluation System of the Development of Popularization of Science and Technology Infrastructure was built in 2008 and why and how it was improved in 2012. The method used in our study is documentation, quantitative analysis, expert interview and summarization. The analysis strongly suggests that in today China, it is quite necessary to build an evaluation system to measure the development of popularization of science and technology infrastructures, enabling the researchers afford good advices to the government in policy-making in the science popularization field. It is concluded that the Evaluation System has its academic value and works quite well. Furthermore, it would develop in accordance with the changing of the social environment.**

I. INTRODUCTION

The Popularization of Science and Technology Infrastructure (PSTI) is the important part and main carrier of the Science and Technology Communication and Popularization (STCP) . The definition of PSTI is somehow ambiguous. Researchers have various ideas, and first of all, I'll show some of them.

In *Development Plan of Popularization of Science and Technology Infrastructures (2008-2010-2015)* (hereinafter referred to as the *Development Plan*) , PSTI include Museum of Science and Technology Category, Grass-root Science Facilities, Digital Science and Technology Museums and other venues which have the exhibition and education function of the popularization of science and technology[3]. The co-senior author of the paper Prof. LI Zhaohui from China Research Institute for Science Popularization (CRISP) thinks that the PSTI also include Science Education Bases [4]. Professor ZHAI Jiequan from Beijing Institute of Technology thinks that Mobile science Popularization (SP) Facilities (science wagon) should also be included [10].

Considering the regulations and the views of experts, in this paper, 4 items are included in PSTI: Museum of Science and Technology Category, Grass-root Science Facility, Mobile SP Facility and SP Media. And the Museum of Science and Technology Category includes the Science and Technology Museum and Science and the Nature Museum. The Museums of Science and Technology Category are normally built in the urban area with plenty of residents and are at relatively large scale. They have ambulant SP resources and are playing the leading role among all sorts of PSTI [2]. .

The level of PSTI determines the effect of SP. The *Development Plan* promulgated in March 2009 is a milestone after the promulgation of The *Law of the People's Republic of China on Popularization of Science and Technology* (hereinafter referred to as the *Law*) in June 2002 and *The Outline of National Scheme for Scientific Literacy (2006-2010-2020)* (hereinafter referred to as the *Outline*) in March 2006. It is a new start for China PSTI, from that time onward, PSTI begins to gain more and more attention and support of all levels of government and the quantitative evaluation of the development becomes imperative.

As the only national-class research institute engaged in the theory and practice of STCP, CRISP is chosen to complete this task by China Association for Science and Technology (CAST) . In early 2009, the Research Team of the Development of China PSTI (hereinafter referred to as the Research Team) is formed in CRISP. After a nationwide survey and detailed discussions, the Evaluation System of the Development of Popularization of Science and Technology Infrastructures (ESDPSTI 2009) is set up [14]. 3 years later, the Evaluation System is improved from the trial version to a comparatively steady one, ESDPSTI 2012 appears.

In this paper, the comparison of the two versions is made and the superiority of the latter is presented, the necessity and significance of the improvement of the Evaluation System is concluded.

II. ESDPSTI 2009

In 2009, after the careful study of the *Outline* and the *Development Plan*, the Research Team summarizes the essential attributes and characteristics of different PSTI. In line with the SMART principle[1], 3 items of the indicators are proposed: the scale indicator (SI) , the structure indicator (SI$_2$) and the effect indicator (EI) . The indicators are shown in the table below:

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[1] The SMART principle: S means Specific; M means Measurable; A means Achievable; R means Realistic; T means Timed.

TABLE1: THE EVALUATION SYSTEM OF DEVELOPMENT OF PSTI (2008) [12]

First Class Indicator	Second Class Indicator	A Brief Description	Third Class Indicator	Unit of Measurement
Scale Indicator	Main Types and Magnitude	Including 3 Elements: Human, Finance and Material	Exhibition Area Construction Area (CA) CA per Million People Average Length of Single Outdoor Facility Average Travelled Distance of Single Mobile Facility Average Information of SP Website Facility	m^2 % m^2/million m km kb
	Property		Asset Value of Facility per Million People Asset Value of Facility Exhibition Resource per Million People	Yuan/Million People Yuan/Million People
	Staff		Number of Full-time SP Staff per Million People Number of SP Staff with a Bachelor Degree or Above per Million People Number of SP Volunteer per Million People	Person Person Person
Structure Indicator	Fund and Expenditure	Reflect the operation of the facility and the development potential	Investment/GDP Financial Investment/Total fund Social Capital/Total Fund Construction Expenditure/Total Expenditure SP Expenditure Growth Rate Exhibition R&D Expenditure Growth Rate	% % % % % %
	Exhibition Resources and Activities		Exhibition Update Ratio Exhibition Developing Ratio Temporary Exhibition Growth Rate	% % %
Effect Indicator	Social Effect	Reflect the social effect and the citizen's benefit	The Total Number of Media Report Average Single SP Website Visitors	Number Person
	Citizens Benefit Rate		Number of Benefit Person per 100 Yuan SP Expenditure Number of Visitors per 1 m^2 Exhibition Area	Person/100Yuan Person/m^2

The first class indicator of the ESDPSTI reflect the amount, scale and quality of the PSTI on the whole and also evaluate the development capacity and the service effectiveness (from the aspect of visitor, coverage, the public benefit, etc.) to fully know the development of PSTI on a nation scale. The second class indicator carries on the elaboration from seven aspects: main types and magnitude, property, staff, annual funding and expenditure, exhibition resources and activities, social effect and citizen's benefit rate. And the ESDPSTI is further more refined from 23 aspects by the third class indicator.

In the survey procedure, the Research Team designs 5 different questionnaires to Museum of Science and Technology Category, Science Education Base, Grass-root Science Facility, Mobile SP Facility and SP Website. By using the organizational advantages of CAST, a nation-wide survey (Hong Kong, Macao and Taiwan excluded) is conducted, lasting from January 1, 2008 to December 31, 2008. 5377 effective feedbacks are collected: Museums of Science and Technology Category: 618 (including Science and Technology Museums and Science Center: 240, Science and Nature Museums: 378) , Science Education Bases: 3468, Grass-root Science Facilities: 440, Mobile SP Facilities: 250 and SP Websites: 601 [15].

The Research Team chooses "Delphi Method (also known as Expert Opinions) " [1] to confer the index weights. The panel members of the invited experts (including researchers and government officers in PSTI field,) would not be allowed to discuss with each other, but to communicate with the Research Team when complicated issues are involved. The method eliminates the authority figures' overwhelming superiority. A final consensus of the index weights is reached: the scale indicator weights 30%, the structure indicator weights 30% and the effect indicator weights 40%. And the formula calculating the Infrastructure Development Index (IDI) is also conducted:

$$IDI=SI\times30\%+ SI_2\times30\%+EI\times40\% \quad (1) [5]$$

In the Evaluation System, each index represents different physical meaning and has its own unit, so standardized treatment methods are applied on the data dimensionless process to make the comparison of different units possible, the calculating formula is shown as the following:

$$x_{ij}{}^*=\frac{x_{ij}-\overline{X_j}}{s_j} \quad (2) [12]$$

Here $x_{ij}{}^*$ was the standard value of the object i to be evaluated on the j indicator, X_{ij} was the actual value of the object i on the j indicator, $\overline{X_j}$ was the average value on the j indicator, and s_j was the standard deviation [12].

After the System construction, the feedback analysis and data calculation, the Research Team finally calculates the IDI and the 3 first calss indicators of PSTI in 2008.

TABLE2: THE IDI AND MAIN INDICATORS OF PSTI (2008) [12]

Indicator	IDI	Scale Indicator	Structure Indicator	Effect Indicator
Proportion	100%	30%	30%	40%
Value	67.89	58.53	52.12	68.83

III. ESDPSTI 2013

By using ESDPSTI 2009, the CRISP Research Team does a trial quantitative evaluation on a nationwide scale. To get a precise IDI, a stable and reliable data source is essential, the data source of 2009 comes from the nationwide survey conducted by CAST and it spends too much. Therefore, the Research Team decides to adopt the data resource which is published in *China Science Popularization Statistics* every year from 2009 [8]. The statistics is conducted by the Ministry of Science and Technology of the People's Republic of China. It's time to update the ESDPSTI since the data resource changes and the awareness of the System deepens.

A. The System Structure and the Index Weights

The new version ESDPSTI still includes three items of indicators: the Scale Index (SI), the Operation Index (OI) and the Effect Index (EI) . And each item has its second class and third class indicators, the structure and the proportion of the System is shown as the following:

TABLE 3: THE EVALUATION SYSTEM OF DEVELOPMENT OF PSTI (2012) [13]

First Class Indicator	Second Class Indicator	Third Class Indicator	The Content
Scale Indicator (SI) (50%)	Scale of Infrastructure Asset (70%)	Museum of Science and Technology Category (50%)	The Total Amount, the Construction Area and the Exhibition Area of the Science and Technology Museum (50%)
			The Total Amount, the Construction Area and the Exhibition Area of the Science and Nature Museum (50%)
		Grass-root Science Facility (10%)	The Total Amount of SP Activity Station (50%)
			The Total Amount of SP Gallery (50%)
		Mobile SP Facility (10%)	The Total Amount of SP Wagon (100%)
		SP Media (30%)	The Total Amount of the Traditional SP Media (50%)
			The Total Amount of SP Website (50%)
	Scale of Human Resource (30%)	Number of Employee of the Science and Technology Museum (50%)	Full-time Employee (50%)
			Part-time Employee (20%)
			SP Works Writer (30%)
		Number of Employee of the Science and Nature Museums (50%)	Full-time Employee (50%)
			Part-time Employee (20%)
			SP Works Writer (30%)
Operation Indicator (OI) (30%)	Fund Collection (50%)	Total Fund (100%)	Annual Funding of the Science and Technology Museum (50%)
			Annual Funding of the Science and Nature Museum (50%)
	SP Activity (50%)	Total Amount of Exhibitions (40%)	Total Amount of Exhibition of the Science and Technology Museum (50%)
			Total Amount of Exhibition of the Science and Nature Museum (50%)
		Total Amount of Lectures (30%)	Total Amount of Lecture of the Science and Technology Museum (50%)
			Total Amount of Lecture of the Science and Nature Museum (50%)
		Total Amount of Competitions (30%)	Total Amount of Competition of the Science and Technology Museum (50%)
			Total Amount of Competition of the Science and Nature Museum (50%)
Effect Indicator (EI) (20%)	Visitors of Museum of Science and Technology Category (50%)	Visitors of the Science and Technology Museum (50%)	Annual Visitor of the Science and Technology Museum (50%)
		Visitors of the Science and Nature Museum (50%)	Annual Visitor of the Science and Nature Museum (50%)
	Reception Capacity of Museum of Science and Technology Category (50%)	Saturation of the Reception Capacity of the Science and Technology Museum (50%)	Annual Visitor per Unit Area (50%)
		Saturation of the Reception Capacity of the Science and Nature Museum (50%)	Annual Visitor per Unit Area (50%)

In the first class indicators, the scale of the PSTI is the fundamental factor and it is weighed as 50%, and the operation involves how the PSTI uses the fund to carry out the SP activities and is weighed as 30%, the effect is essential for the sustainable development of the PSTI.

In the second class indicators, it considers about 3 pairs of sides corresponding to each other. The more the infrastructure assets, the more human resources are needed; the more the fund is collected, the better the SP activities are carried out with the precondition that the fund is carefully and rationally used; the more the visitors to SP venues, the greater challenge to their reception capacity. They're directly proportional to their pair counterparts.

In the third class indicator, Museums of Science and Technology Categories are paid the most attention since they are playing a leading role in all infrastructures and the data of them are easier to get. The SP Media includes the traditional type and the new media type (mainly the websites) . As the complement of the venues, the Grass-root Science Facility and the Mobile SP Facility are also taken into consideration. Since for 3 years (2009-2011) the number of the Science Education Bases keeps 387 unchanged and they overlap with some Museums of Science and Technology Category [9], so they are not included in the new version Evaluation System.

B. Data Collection

The China Science Popularization Statistics is conducted by the Ministry of Science and Technology in conjunction with the relevant departments: the Party Central Committee, the State Council Departments and the Provincial Science and Technology Administrative Departments. And the Institute of Scientific and Technical Information of China (ISTIC) is in charge of the data collection and concise analysis as well as yearbook publishing. By making use of the data from the yearbook, the Research Team reduces their workload greatly.

C. Data Processing

During the data dimensionless process, the Research Team selects the data by the end of 2009 as the benchmark data, the reason lies in two aspects: firstly, since the *Development Plan on Popularization of Science and Technology Infrastructure (2008-2010-2015)* is promulgated in 2008, the research group needed to do the PSTI evaluation to see whether the *Plan* worked well, secondly, the items of statistical analysis of *China Science Popularization Statistics* had been fixed since 2009, it could meet the needs of ESDPSTI.

The following formula is used to fulfill the dimensionless procedure:

$$X_i = \frac{X - X_{Ai}}{X_{Ai}} \times 100 \quad (3)\,[13]$$

Here, X_i is the quantized value of the indicator, X is the annual data value, X_{Ai} is the data value in 2009.

During the dimensionless process of the Scale of Infrastructure Asset, a more complicated formula is used

since it examines 3 subordinate indicators: the Total Amount of the Museums of Science and Technology Category, the Gross Floor Area and the Exhibition Area.

$$X_1 = \frac{(X_A - X_{A1})/X_{A1} + (X_B - X_{B1})/X_{B1} + (X_C - X_{C1})/X_{C1}}{3} \quad (4)\,[13]$$

Here, X_1 is the quantized value of the Scale of Infrastructure Asset, X_A is the Total Amount of the Museums of Science and Technology Category, X_B is the Gross Floor Area, and X_C is the Exhibition Area of the annual data value, while X_{A1}, X_{B1}, X_{C1} are corresponding data value in 2009.

The dimensionless process of the Reception Capacity of Museums of Science and Technology Category obeys the following formula:

$$X_{Ai} = \frac{X'}{60} \times 100 \quad (5)\,[13]$$

Here, X_{Ai} is the quantized value of the Reception Capacity of Museums of Science and Technology Category, the value of X´ is determined by dividing the total amount of the visitors by the total exhibition area. The *Construction Standards on Science and Technology Museums* requires that annual visitors of the permanent exhibition are 30-60 per square meter [6]. Here the upper and lower threshold is 0 and 60.

D. The IDI of 2010 and 2011

The formula of IDI calculating has also changed:
IDI=SI×50%+OI×30%+EI×20% (6) [13]

According to the formula, IDI of 2010 is 8.84 with the Scale Indicator 6.15, Operation Indicator 9.84 and Effect Indicator 14.00; and the IDI of 2011 is 19.22 with the Scale Indicator 20.02, Operation Indicator 14.76 and Effect Indicator 23.90. The significant increase indicates the rapid development of China PSTI, and the comparable weakness of the Operation Indicator reveals the science popularization fund collection and activities should be improved.

IV. DISCUSSION

In the Age of Big Data and in CRISP which has a research tradition of evaluation, the Evaluation System is established and improved. The data source changes as well as the researchers' understanding of PSTI changes, both at the depth and the emphasis aspects. This leads to the improvement, but the regulation of the indicators' professionalism and high degree of distinctions are always being obeyed as well as the principles of systematization, typicality, dynamic, concisely scientific, quantification, comprehensiveness and operability.

Comparing the 2 versions of the Evaluation System, the improvement could be seen as the following:

Firstly, in the first class indicator, version 12 changes the Structure Indicator into Operation Indicator, their sub-indicators both include 2 parts: fund and SP activities,

but the new names which emphasize the dynamic development are more appropriate and reasonable.

Secondly, in version 12, each sub-index is given a weight, which makes every person with the data could do the calculation work, but in version 08, only the first class indicator is given weight, which makes the calculation blurred and only the specialist enterprise with the professional software could do the calculation.

Thirdly, in version 12, the weight of each item in first class indicator is changed from 30%, 30%, 40% to 50%, 30%, 2 0%. That is to say, the research group increases the weight of scale indicator, and accordingly, reduces the weight of effect indicator. The proportion adjustment comes from the opinions of panel members of the invited experts, and their opinions come from the practice work.

Fourthly, in version 12, the second class indicators are more clear and reasonable. "Main Types and Magnitude", "Property" and "Staff" are changed into "Scale of Infrastructure Asset" and "Scale of Human Resource", which solves the item overlap of the old version; "Fund and Expenditure" is changed into "Fund Collection", which gives up the investigation of the expenditure; "Exhibition Resources and Activities" is changed into "SP Activity", which invisibly put the exhibition resources into "Scale of Infrastructure Asset", "Social Effect" and "Citizens Benefit Rate" are changed into "Visitors of Museums of Science and Technology Category" and "Reception Capacity of Museums of Science and Technology Category", making the data more accessible to fit the principle of operability.

Fifthly, in version 12, the third class indicators are more concise and reasonable, and the data could be obtained from the authoritative *China Science Popularization Statistics*, the Research Team needn't manpower and finance to do questionnaires and feedbacks. "Museums of Science and Technology Category" (including the total amount, the gross floor area and the exhibition area) covers "Total Exhibition Area / Gross Floor Area" and "GFA per Million People", "Gross-root Science Facility" covers "Average Length of Single Outdoor Facility", "Mobile SP Facility" covers "Average Travelled Distance of Single Mobile Facility", "SP Media" covers "Average Information of SP Website Facility" and "Asset Value of Facility per Million People" and "Asset Value of Facility Exhibition Resource per Million People" are deleted.

Sixthly, the third class indictors in version 12 are set mainly for the Museum of Science and Technology Category. In the past, the definition and partition of the Museum of Science and Technology Category defined by CRISP are quite different from *China Science Popularization Statistics*. The former divides the Museum of Science and Technology Category into Science and Technology Museum, Science and Nature Museum and Science and Industry Museum [11], the latter divides it into Science and Technology Museum, Science and Nature Museum (also named as Science and Technology Related Museum) [7]. From 2012, the definition and the partition of the latter are adopted. This is some kind of naturalization to make things easy.

V. CONCLUSION

As an important carrier of science popularization, the development of popularization of science and technology infrastructure determines the level of national science popularization capacity, it is indispensable to build a scientific evaluation system of PSTI.

The PSTI evaluation system is unique both domestically and internationally. There is no successful experience for reference, so it needs a process of continuous improvement. It develops together with the development of the social environment, and it turns to be more scientific and convenient.

The new established ESDPSTI consists of the main factors of PST, and it is an organic whole of interrelated aspects. It obeys the principle of systematic, typicality and dynamic, it corresponds to the social demands. In the assessment procedure, it focuses the key point, guides the direction and considers the differences. It is quantitative-based and qualitative supplemented. It has certain academic value.

By using the new evaluation system, CAST could use the data collected by the Ministry of Science and Technology of China. It makes the evaluation procedure easier and more science and technology museums which are not administrated by CAST are also included.

The evaluation system exists to measure the development of China PSTI, and after the indicator system is built up and the data is dimensionless processed, we could compare the data on the same indicator this year with the previous year to see clearly the progress or the regression. Basing the precise data analyzing, CRISP could give the government advice on policy making.

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