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Multi-index Quantification and Its Statistical Model Constraint to Improve the Quality of Project Evaluation

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Abstract: With the transformation of geological prospecting units in China to multiple business areas, the types and contradictions of identification and evaluation of technological achievements have also increased substantially. Taking 288 project achievements completed by a Bureau in the six years from 2016 to 2021 as an example, this paper quantitatively extracts and sets up a variety of award scoring parameters, and divides the outstanding project achievement awards into: Geological exploration, engineering construction, mining development, ecological civilization construction, surveying and mapping geographic information, scientific research and prediction, and technical advisory services. The selection scope covers all industrial categories in the transition period of geological prospecting units. The evaluation results reflect the role of opening up the grade and encouraging the advanced. The revision and formulation of the management method has improved a lot in terms of fairness, impartial and rationality, but the leading role in scientific and technological innovation is still insufficient and needs to be further improved. By statistical analysis, the distribution model of the quantitative score of the award is established, and it is considered that the better award results should conform to the normal distribution or T distribution with initial right deviation. With the evaluation system from the emphasis on output value to the emphasis on innovation-oriented, the mathematical statistics distribution law of the evaluation result score should show the change of $\tilde{A}$ distribution characteristic form under the condition of á= 4.

Keywords: Quantitative Assessment; Geostatistics; Variogram;
Geological-significance Appraisal and Reward of Geological Exploration Projects

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1 Introduction

In the new era, the connotative high-quality development has increasingly become the driving force for the development of geological prospecting units, and the business of geological prospecting units has also transformed from a single traditional geological prospecting to a variety of fields related to the integration of mineral resources and the construction of ecological civilization, and various units in the geological prospecting industry are serving the implementation of the concept of large geology. Therefore, it is imperative to use the quantitative evaluation and assessment index system of scientific and technological achievements adapted to the new era.

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2 Determination of Quantitative Evaluation Threshold and Evaluation Index

2.1 Quantitative Entry Threshold

The appraisal and evaluation of technological achievements is a lagging evaluation, a consideration of the use value of scientific and technological achievements and the ability to solve practical problems, which not only reflects the strength of a unit, but also reflects its recognition and guidance to technical personnel. At present, geological prospecting units have extensive business types and numerous and complex technical service fields in the new period. New requirements have been put forward for the evaluation and evaluation of year-end technological achievements in the overall scope.

Taking these all kinds of completed projects which from 2016 to 2021 five years as the sample research objects of all kinds of subordinate units of the bureau apply for participating in the award project, the business types and industrial service areas of the research object have undergone tremendous changes with the industrial transformation. The traditional business sectors of the research object are mainly divided into geological exploration, mining development, geological construction (geotechnical engineering), marine geology, trade and overseas mining investment. The public welfare and professional fields of the projects are also divided into domestic and foreign projects (including public welfare, independent investment and commercial projects), foreign cooperation projects, etc. Only projects with no quality, safety and major machinery and equipment accidents are eligible to participate in the evaluation. Completion time range of the project: For projects completed (accepted) in the selection year and the previous two years, commercial projects that fail to participate in the evaluation for more than two years due to confidentiality reasons may also participate in the evaluation with the written consent of Party A.

In order to strengthen the quality management in the process of project completion, the projects applying for the selection of outstanding project achievement awards shall meet the following requirements: the projects must be reviewed and accepted by the competent department of the project (or the project investor), and the relevant results and data of the project have been filed as required; Commercial projects can be declared only with the (written) consent of Party A. [1, 2]

2.2 Screening of Quantitative Evaluation Indicators

The excellent project achievements must be the achievements completed and accepted in the previous year, and reflect the three new characteristics (new technology, new method, new technology and practicability) in the field of applied technology achievements.

Selection procedures for outstanding project achievement awards: (1) Classified registration; (2) Selection by professional groups; (3) Comprehensive evaluation of the meeting; (4) Reporting, publicity and other steps. Firstly, the functional departments shall draw up the procedures for declaration and selection. The awards for outstanding projects are divided into seven categories: geological exploration, mining development, engineering construction, ecological civilization construction, surveying and mapping geographic information, scientific research and technical advisory services, each of which contains several subcategories or professional types.

For the seven major categories of projects, the chief engineer of the Bureau, members of the expert pool and/or external experts shall be organized to form an expert group for evaluation, and the expert group shall be responsible for evaluating and scoring all the projects. The number of members of each expert group depends on the number of projects to be evaluated, which is generally 3-5 and can be part-time. The avoidance system shall be adopted for the projects declared by the units where the experts belong.

In the professional group selection, in order to promote the improvement of the overall completion quality of the project and reflect that the bureau-level project is truly an excellent project achievement award, the application conditions and selection criteria for the excellent project achievement award should be as follows: the first prize $N \geq 90$ points; Second prize $90 > N \geq 80$ points; Third prize $80 > N \geq 75$ points. See Table 1 for the specific scoring standard. The scoring result shall have two decimal places and shall not be rounded. Only projects with an average score of 75 or above in the expert group are eligible to be shortlisted, otherwise, they will not be shortlisted. The detailed rules for the evaluation and specific scoring criteria of various projects include: project design quality, implementation, technical complexity, project work quality, results and benefits, etc., and the weights of each part are different. In order to highlight the service production purpose of the project, the achievement benefit score accounts for the largest weight.

Table 1 Scoring Criteria for Outstanding Project Achievement Award

Assessment index (score)	Scoring criteria		Standard score
Project design quality (5 points)	Review results	Excellent	5
		Good	4
		Qualified	3
Project implementation (15 minutes)	Complete relevant work according to the requirements of construction period		5
	Complete all planned workload		10
	Extension of construction period or reduction of workload caused by force majeure		No points are deducted
Technical complexity (5 points)	Complex		5
	Medium		4
	Simple		3
Quality of project work (20 points)	Acceptance results	Excellent	18-20
		Good	15-<18
		Qualified	12-<15
Benefits of project results (40 points)	By project output value scale and Comprehensive score of achievement scale	Large scale	35-40
		Medium	30-<35
		Small	20-<30
Promote industrial development or Transformation and upgrading (10 points)	It has a good role in promoting the development of traditional industries.		10
	Developing or engaging in emerging industries is conducive to industrial transformation.		
Potential economic and social benefits (5 points)	It has great potential economic value and can promote employment.		4-5
	It has certain potential economic and social benefits.		2-4
	Potential economic and social benefits are small or not obvious		0-2

Table 1 refers to Table 2 for the division of project output value scale in the scoring standard table; Project achievement scale (taking mineral exploration as an example) The scale division standard of some mineral resources/reserves is shown in Table 3 and 4, and the project achievement scale of other specialties shall be implemented according to their respective standards. (1) For the above two large-scale projects, 3-5 points can be added respectively; (2) The scale division of mineral resources/reserves is only for the major of mineral geology; Other majors can be scored according to the characteristics of relevant fields. If there is a clear standard for the scale of achievements, they will be scored according to the standard. (3) The scale of mineral resources/reserves shall be determined by Grade 333 and above, and Grade 334 resources are not included in the statistical scope. The determination of resource/reserve scale of projects such as resource/reserve verification (survey) and overburden mineral resource survey shall be subject to the resources/reserves obtained from the new prospecting project [3, 4]; (4) If there are more than one mineral, the largest mineral is the main score, and the rest of the minerals can be added appropriately (1-5 points) depending on the size of the scale; (5) Compared with traditional industries, new industries have been engaged in or developed in the past three years. Can be used as a new industry [5].

Table 2 Brief Table of Classification of Output Value Scale of Each Category (Unit: 10,000 yuan)

Subcategory or specialty	Small	Medium	Large scale	Oversize
Regional Geology	<200	200-500	500-800	≥800
Mineral Geology	<200	200-500	500-800	≥800
Marine geology	<100	100-300	300-600	≥600
Materialized remote	<50	50-150	150-400	≥400
Laboratory tests	<40	40-100	100-200	≥200
Geotechnical engineering	<100	100-300	300-600	≥600
Construction project	<1000	1000-3000	3000-6000	≥6000
Mining	<200	200-500	500-800	≥800
Mineral processing	<50	50-150	150-400	≥400
Investigation and control of geological hazards	<100	100-300	300-600	≥600
Soil and environment investigation and remediation	<100	100-300	300-600	≥600
Mine Geological Environment Protection and Land Reclamation Scheme	<20	20-50	50-100	≥100

Subcategory or specialty	**Small**	**Medium**	**Large scale**	**Oversize**
Investigation and utilization of clean energy	<50	50-150	150-400	≥400
Green mine and resource protection	<100	100-300	300-600	≥600
Geographic mapping	<50	50-150	150-400	≥400
Information Technology	<50	50-150	150-400	≥400
Scientific research and prediction	<40	40-100	100-200	≥200
Technical advisory services	<30	30-80	80-160	≥160

Table 2 shows that: (1) The above standard is the work funds for a single project, in which geophysical exploration, geochemical exploration, remote sensing projects and geographic mapping projects can be the special work funds for a single project. (2) The upper limit value is not included in the medium and large scale. See Table 3 and 4 for the classification standard of mineral resources/reserves scale of relevant partial minerals.

Table 3 Standards for Classification of Mineral Resources/Reserves (Some Minerals)

Serial number	**Name of mineral**	**Unit**	**Scale**		
			Large scale	**Medium**	**Small**
1	Iron				
	(Lean ore)	Ore (100 million tons)	≥1	0.1～1	<0.1
	(Rich ore)	Ore (100 million tons)	≥0.5	0.05～0.5	<0.05
2	Manganese	Ore (10,000 tons)	≥2000	200～2000	<200
3	Vanadium	V_2O_5 (10,000 tons)	≥100	10～100	<10
4	Titanium				
	(Rutile primary ore)	TiO_2 (10,000 tons)	≥20	5～20	<5
	(Rutile Placer)	Minerals (10,000 tons)	≥10	2～10	<2
	(Primary ilmenite)	TiO_2 (10,000 tons)	≥500	50～500	<50
	(Ilmenite placer)	Minerals (10,000 tons)	≥100	20～100	<20
5	Copper	Metal (10,000 tons)	≥50	10～50	<10
6	Lead	Metal (10,000 tons)	≥50	10～50	<10
7	Zinc	Metal (10,000 tons)	≥50	10～50	<10
8	Nickel	Metal (10,000 tons)	≥10	2～10	<2
9	Cobalt	Metal (10,000 tons)	≥2	0.2～2	<0.2
10	Molybdenum	Metal (10,000 tons)	≥10	1～10	<1
11	Antimony	Metal (10,000 tons)	≥10	1～10	<1
12	Gold				
	(Rock gold)	Metal (ton)	≥20	5～20	<5
	(Placer gold)	Metal (ton)	≥8	2～8	<2
13	Silver	Metal (ton)	≥1000	200～1000	<200
14	Zirconium (Zircon)	Minerals (10,000 tons)	≥20	5～20	<5
15	Graphite				
	(Crystalline)	Minerals (10,000 tons)	≥100	20～100	<20
	(Aphanitic)	Ore (10,000 tons)	≥1000	100～1000	<100
16	Phosphate rock	Ore (10,000 tons)	≥5000	500～5000	<500
17	Natural Sulfur	S (10,000 tons)	≥500	100～500	<100
18	Pyrite	Ore (10,000 tons)	≥3000	200～3000	<200
19	Crystal				
	(Piezoelectric crystal)	Single crystal (ton)	≥2	0.2～2	<0.2
	(Melted crystal)	Minerals (tons)	≥100	10～100	<10
	(Optical Crystal)	Minerals (tons)	≥0.5	0.05～0.5	<0.05
	(Craft Crystal)	Minerals (tons)	≥0.5	0.05～0.5	<0.05
20	Gypsum	Ore (10,000 tons)	≥3000	1000～3000	<1000
21	Barite	Ore (10,000 tons)	≥1000	200～1000	<200

Refer to Table 4 (Continued) for scoring and evaluation of the scale of some non-metallic mineral resources/reserves.

Table 4 Mineral Resources/Reserves Scale Classification Standard (Some Minerals) (Continued)

Serial number	Name of mineral	Unit	Scale		
			Large scale	Medium	Small
22	Limestone				
23	(Limestone for calcium carbide) (Limestone for alkali production) (Limestone for fertilizer) (Limestone for flux)	Ore (100 million tons)	≥0.5	0.1～0.5	<0.1
24	(Limestone for glass) (Limestone for making ash)	Ore (100 million tons)	≥0.1	0.02～0.1	<0.02
25	(Limestone for cement, Including chalk)	Ore (100 million tons)	≥0.8	0.15～0.8	<0.15
26	Dolomite (Metallurgical) (For fertilizer) (For glass)	Ore (100 million tons)	≥0.5	0.1～0.5	<0.1
27	Other clay				
	(Clay for casting)	Ore (10,000 tons)	≥1000	200～1000	<200
	(Clay for brick and tile)	Ore (10,000 tons)	≥2000	500～2000	<500
28	(Clay for cement batching) (Laterite for cement batching) (Loess for cement batching) (Mudstone for cement batching)	Ore (10,000 tons)	≥2000	500～2000	<500
29	(Clay for insulation material)	Ore (10,000 tons)	≥200	50～200	<50
30	Cement admixture (Andesitic porphyrite) (Diorite porphyrite)	Ore (10,000 tons)	≥2000	200～2000	<200
31	Stone for building	Ore (10,000m^3)	≥5000	1000～5000	<1000
32	Stone for facing	Ore (10,000m^3)	≥1000	200～1000	<200
33	Marble				
	(For cement)	Ore (10,000 tons)	≥2000	200～2000	<200
	(For glass)	Ore (10,000 tons)	≥5000	1000～5000	<1000
34	Groundwater	Allowable production (M^3/day)	≥100000	10000～100000	<10000
35	Mineral water		≥5000	500～5000	<500
36	Carbon dioxide gas	Gas volume (100 million cubic meters)	≥300	50～300	<50
37	Geothermal	Electric (thermal) energy (MW)	≥50	10～50	<10

Note: (1) Medium and small sizes do not include their upper limit figures; (2) The super-large scale shall be 2 times of the lower limit of the large scale standard; (3) For the classification standard of mineral resources/reserves of other minerals, please refer to the Notice on Printing and Issuing the Classification Standard of Mineral Resources and Reserves Scale [6] (GTZF [2000] No. 133).

3 Analysis of the Results of Quantitative Assessment

In order to reflect fairness, the scoring results of each award-winning project are entirely based on expert scoring, without human intervention, and the score falls in which area corresponds to the corresponding award level; The number of awardees for a single prize-winning project is limited to 12 for the first prize, 10 for the second prize and 8 for the third prize. The ranking order of the winners shall be determined according to the ranking order of the detailed information table of the main project completion personnel submitted by each unit.

3.1 Statistical Analysis of Quantitative Assessment Results

In the six years from 2016 to 2021, 332 projects reported to participate in the bureau-level evaluation were evaluated with improved quantitative criteria, and the difference between the scores of different judges for the same project was reduced. With the new quantitative evaluation method, the phenomenon of experts scoring by impression and feeling has been significantly reduced, and the controllable and controllable quantitative scale of the scoring scale has been significantly enhanced. The newly revised method for the selection of outstanding project results has added more project categories.

Generally speaking, the distribution of project scores does not conform to the trend of conventional "normal function distribution". The preliminary analysis shows that there are two main reasons for the great disparity in the scoring values of some projects: one is that the judges have different standards for the quantitative scoring factors in the scoring method; Secondly, the social benefits of some achievements have the characteristics of a posteriori lag, and it is difficult to evaluate the comprehensive benefits and scale types of the projects just completed in the previous year. Thirdly, the selection of individual judges is different in the degree of familiarity with the project and the degree of professional counterparts. In view of the former problem, The main solution is to strengthen and require the judges to control the quantitative calculation scale, and avoid the randomness of individual subjective scoring in principle. The solution to the second problem is to postpone some projects with the characteristics of a posteriori lag in social benefits until their scale benefits are reflected, so that they can get a higher level of evaluation. The third kind of problem avoids the need to put forward higher requirements on the professional counterpart of the judges, the familiarity with the project and the sense of responsibility. It shows that with the emergence of new problems, it still needs to be revised and improved in time, and the methods and measures to solve these problems.

3.2 Analysis of the Results of Quantitative Evaluation and Award Levels

After the quantitative assessment, all kinds of award grades are automatically matched with the corresponding grades of the award evaluation of the management method. The selection criteria have been given in the application conditions of the excellent project achievement award of the Bureau: the following score (N) criteria should be reached: first prize $N \geq 90$ points; Second prize $90 > N \geq 80$ points; Third prize $80 > N \geq 75$ points; No award $N < 75$ points. Accord to that comparative analysis of the standard, The evaluation data of all kinds of awards for outstanding projects at the Bureau level from 2016 to 2021 are counted, and the proportion of all kinds of awards is shown in Figure 1.

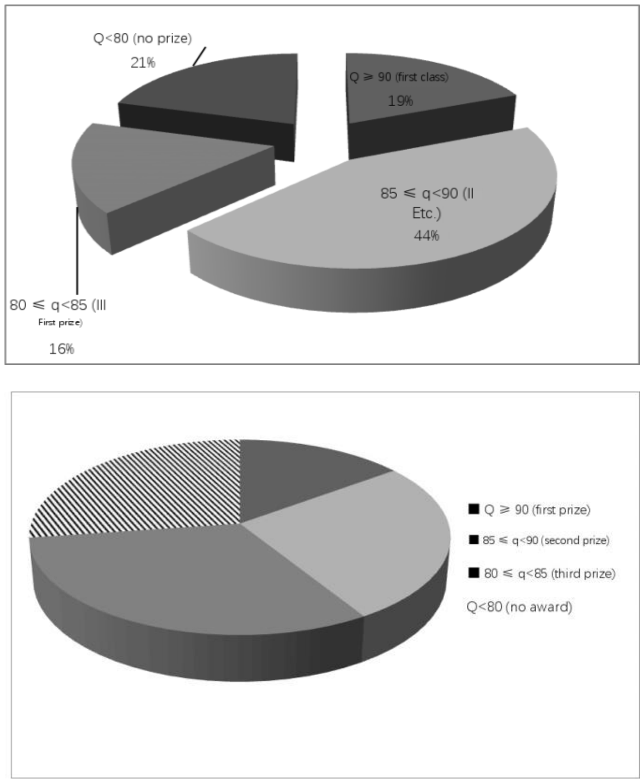
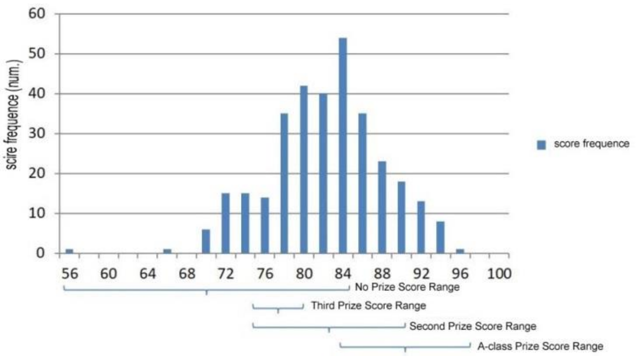


Figure 1 Pie chart of the proportion of various awards (left: actual awards; Right: Award set by score)

To sum up, the revised quantitative evaluation criteria are better than the original one, especially the determination of project achievement benefits and scoring factors of emerging new industries, which obviously play a leading and regulating role in scientific and technological innovation, making the evaluation results more reasonable and more in line with the direction of industry transformation and expansion. The disadvantage is that there are too many second-class awards and the proportion is too concentrated.

Analyzing the mathematical statistics distribution law of the evaluation results of various projects in this Bureau from 2016 to 2021, Figure 2, according to the setting of the evaluation results awards, shows that the distribution law of the award scores is obviously similar to normal distribution, but it is positively biased, that is, "big head and small tail" type, the analysis is that there are too many first and second-class awards and too few third-class awards. In particular, there are too many first-class and second-class awards. And the first, second and third awards are set by the threshold. Therefore, with the improvement of the quality of the project, the threshold score may be set too low, which should be improved. In-depth analysis of the results of quantitative evaluation and reward levels shows that the tendency of "good humanism" also exists to a certain extent in the evaluation. We should strive to improve the assessment method again.



(note: There is overlap between the various grades of awards in the figure because the scoring standards for different years are different.)

Figure 2 Histogram of scoring results of 288 award-winning projects of from 2016 to 2021

Generally speaking, the revised evaluation criteria are slightly top-heavy. Although the award score basically reflects the rationality of quantitative fairness, the leading role of scientific and technological innovation is not obvious. Some geotechnical or environmental control projects have higher scores, mainly because of the large scale of output value, but their technical means or technological innovation content is not high. Such evaluation projects should be properly "suppressed" in the future selection. Generally speaking, with the improvement of technical level, the scoring requirements need to be further improved.

Statistics show that the distribution probability curve of the results of excellent project awards in the past two years shows a "big head and small tail" type, that is, the proportion of first and second prize awards is too high, and the proportion of third prize awards is too low, which will lead to the lack of motivation for progress and complacency in improving the quality of project completion. The author believes that the better statistical distribution probability curve of the results should conform to the normal distribution or the Gamma distribution which parameter α=4 in the distribution of the initial right state, that is, the "small head and big tail" type, as shown in Figure 3;

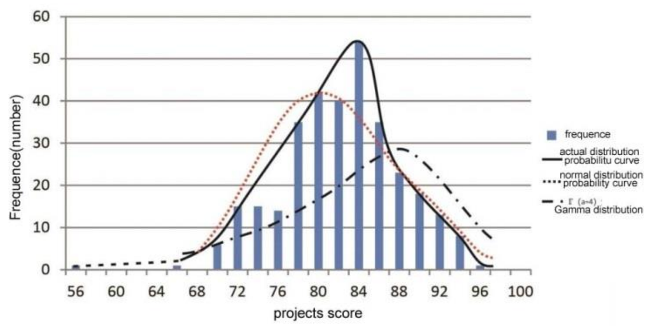


Figure 3 Distribution Trend of Award Results of Excellent Projects of a Bureau from 2016 to 2021 Y

With the advancement of the quantitative evaluation system of scientific and technological projects of a Bureau, the fairness and rationality of the quantitative evaluation system are also required to continue to improve, and the quality of projects should not only focus on output value and profit, but also on the guidance of scientific and technological innovation. It is imperative to raise the threshold and rebuild the evaluation criteria, Table 5;

Table 5 Comparison of Actual Score Threshold and Promotion Threshold Reconstruction Evaluation Criteria of Award-winning Projects from 2016 to 2021

Category	Reward level							
True threshold	First prize		Second prize		Third prize		No prize	
		Proportion (%)		Proportion (%)		Proportion (%)		Proportion (%)
		19		44.0		16		21
A preset threshold value	First prize		Second prize		Third prize		No prize	
		Proportion (%)		Proportion (%)		Proportion (%)		Proportion (%)
	Q≥90	14.76	85≤Q<90	26.46	80≦Q<85	31.47	Q<80	27.29

Based on the comprehensive analysis of the quantitative evaluation results of the scientific and technological projects of a Bureau in recent years, it is considered that it is appropriate to establish a score statistical model that conforms to the law of (Gamma) distribution function under the condition of α = 4. [7-10]

Gamma distribution is a continuous distribution probability function in probability statistics. The parameter αin the Gamma distribution is called the shape parameter, and βis called the scale parameter. A random variable X is said to have a Gamma distribution with parameters α and β, denoted by (α, β), if X has a functional probability density where α> 0 and β> 0. Where both αand β are referred to as shape parameters, It mainly determines the shape of the distribution curve. β primarily determines how steep the curve is.

$$Л(\alpha, \beta) = \frac{\beta^{-\alpha}\chi^{\alpha-1}e^{-\chi/\beta}}{\Gamma(\alpha)}, \chi \geq 0$$ (Л(α,β) — Gamma distribution function)

With the overall improvement of the scientific and technological level of a Bureau, the gradual expansion of industrial types, and the emphasis on different industrial leading directions with market changes, the evaluation and scoring should be more scientific, and the mathematical statistical distribution law of the result scores should change to the form of Γ distribution characteristics under the condition of α = 4, as shown in Figure 4. Then the form of the function becomes as follows:

$$Л(4, \beta) = \frac{\beta^{-4}\chi^{3}e^{-\chi/\beta}}{\Gamma(4)}, \chi \geq 0$$

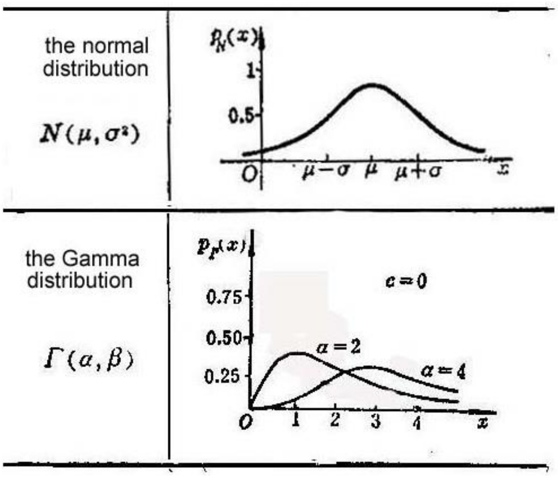


Figure 4 Control Improvement Diagram of Statistical Distribution Model of Score Data of Evaluation Results

The size of βparameter will determine the shape of the function distribution curve. According to the mean value of the total statistical data is 84, the theoretical mathematical expectation of the distribution function =α (β=84, whenαis 4, the value of β parameter is 21, then the χ value in the distribution function is the score of each item in each year, so the distribution probability density of the distribution function can be solved. By using the probability density curve characteristics of the distribution function when the value of α is 4, the number of award grades set each year is controlled and decided (compared with the actual probability density curve obtained from the histogram, it is analyzed that too many first and second grade awards are set). It is suggested that the proportion of the first and second class awards should be reduced appropriately in the future, which should be controlled at 10% and 20% respectively. Third-class awards should be slightly increased, the proportion should be controlled at 30% ±, the entry threshold of various awards should be slightly raised, from 75 points to 80 points, and the low-score items with reserved scores in the last 30% -40% ± should not be awarded. Vigorously guard against the tendency of "good humanism" in the evaluation. We should strive to improve the assessment method again [14, 15].

4 Conclusion

The quantitative assessment and evaluation of project achievements should put innovation in the first place, and should play a radiation-driven role in continuously encouraging and improving project quality, science and technology, and market-led projects. Just as China's total economic output is large but not strong, and the problem of overstaffing, puffiness and weakness is quite prominent, many domestic geological prospecting units are also mainly reflected in their weak innovation ability. The industry is still in the middle and low end of the industry value chain, and everything is done in a swarm [11-13].

1) The quantitative evaluation standard is an evaluation method based on rigid indicators. Through quantitative evaluation, the artificial tendency and a certain degree of arbitrariness in the evaluation process of achievements are reduced and avoided, which reflects a more fair and just recognition in the evaluation process of various technical achievements. Looking at the insufficient use value of some scientific and technological achievements and the effect of solving practical problems in the short term, we can encourage local exploration units to pay more attention to the improvement of their scientific and technological content in the completion of projects.
2) The distribution law of mathematical statistics of the quantitative evaluation score of the Bureau should change to the characteristic form of Γ distribution under the condition of α = 4.
3) The evaluation index does not fully reflect the current scientific and technological innovation in leading the transformation and upgrading of

traditional mining industry and accelerating the development towards green, safe, intelligent and efficient direction; There is no response to the rapid rise of modern big data, artificial intelligence, cloud computing, mobile interconnection, intelligent exploration, intelligent mining, Internet of Things in Mining and other aspects of the integration of modern information technology and mining development, so the indicators need to be further improved and strengthened. The introduction of more assessment indicators is in line with the actual situation of broadening the business in the transition period. It promotes the transformation and upgrading of the capacity of geological prospecting units, and conforms to the current situation of the integration of mining and land and the strengthening of ecological civilization advocated in the transitional period.

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