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Example Analysis of Multi-index Comprehensive Evaluation Index

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Abstract: The multi-index comprehensive evaluation index is based on the fundamental model for measuring multidimensional concepts, compiling individual indicators into a single index. It is commonly used to assess the overall situation of objective entities from various perspectives. With the innovative development of human society and the continuous advancement of statistical index theory and technology, the application of multi-index comprehensive evaluation has gradually expanded into various fields such as industrial production, social welfare, national defense, and economic systems, resulting in the formation of several mature, stable, and distinctive index examples. Through case analysis, one can discover the underlying universal laws and deep logic, providing theoretical guidance and reference for the practical application of multi-index comprehensive evaluation indices.

1. Introduction

Under new historical conditions, the development of various fields in human society is influenced by both internal and external environments and is driven by information technology, exhibiting an overall trend of evolving from individual independence towards complex interconnections. Therefore, in many instances, it is necessary to utilize certain technologies, combine qualitative and quantitative indicator data, comprehensively consider subjective and objective factors, and assess phenomena and problems based on the method of constructing multi-index comprehensive evaluation indices.

The multi-index comprehensive evaluation index method refers to the compilation of individual indicators into an index based on the fundamental model for measuring multidimensional concepts. It is commonly employed to address the issue of evaluating the overall situation of objective entities from various perspectives. The result is typically presented as a quantified evaluation value, enabling evaluators to achieve objectives such as classification, comparative ranking, and degree assessment through this outcome, ultimately providing robust support for decision-making on practical issues[1].

Regarding the construction and practical application of comprehensive evaluation indices across different fields, both domestic and international research have been conducted extensively, resulting in mature experiences and distinctive examples of indices. For instance, the "U.S. Military Strength Index" report[2], published by the American Heritage Foundation, a U.S. think tank, employs a hierarchical aggregation method to quantitatively analyze 13 indicators across three major categories using five rating scales. This comprehensively assesses the U.S. military's position in the global

military strength comparison, the challenges and threats faced in safeguarding major national interests, and the military capabilities in achieving predetermined strategic objectives[3]. Its methodologies, such as "objective-driven, indicator coherence, and operational verification," are all worthy of reference. The "Informatization Development Index", published by the China Electronics and Information Industry Development Research Institute, serves as a comprehensive indicator for assessing the development level of the national quantitative evaluation system. First introduced into the national five-year plan evaluation category in 2006, this index is based on the Information and Communication Technology (ICT) diffusion stage theory[4]. Its indicator system is mature, robust, highly targeted, and widely comprehensive, playing a significant role in the strategic evaluation and long-term planning of China's informatization development.

By conducting a systematic analysis of over thirty representative and authoritative index examples from both domestic and international fields, we have found that, despite the differences in the application domains, construction objectives, indicator systems, and specific methodologies of these indices, their underlying logic, intrinsic mechanisms, and procedural approaches remain consistent despite variations. A profound examination of these characteristic patterns is conducive to the practical application of multi-index comprehensive evaluation indices.

2. Characteristic Patterns

For typical index examples, upon systematic analysis of its construction principles, system architecture, index construction, and evaluation methods, five universal laws can be discovered.

2.1. Evaluation Objective-driven

Upon reviewing and analyzing relevant research theories and examples, we have discovered that establishing evaluation objectives based on needs is both the initial step in conducting multi-index evaluations and in constructing comprehensive evaluation indices. This step directly influences the overall design of the index system, as well as the definition and selection of specific indicators.

Dr. Su Weihua, in his work 'Research on the Theory and Methodology of Multi-index Comprehensive Evaluation'[5], posited six physical processes for conducting multi-index comprehensive evaluations, as illustrated in Figure 1.

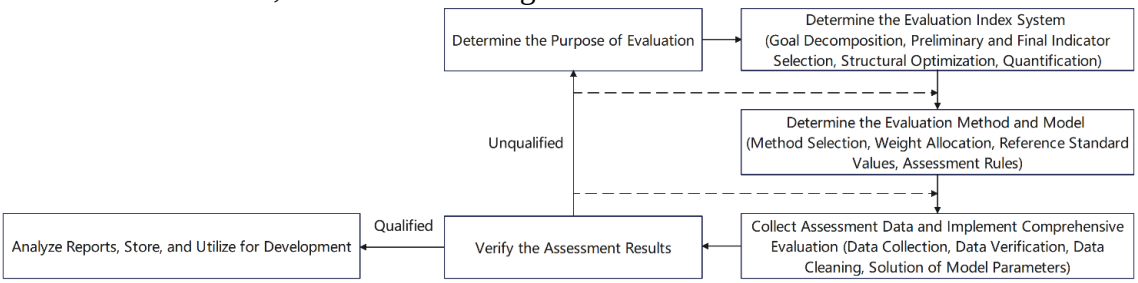

Figure 1: Multi-index Comprehensive Evaluation Process

It is evident that 'establishing the evaluation objective' constitutes the initial phase, namely the starting point for conducting a comprehensive multi-index assessment. Only upon clarifying the evaluation objective can one make a targeted selection of specific indicators that reflect the evaluation purpose, subsequently establishing an indicator system.

A distinctive feature of the "American Military Power Index" is its assessment with pre-established strategic objectives. It conducts comprehensive evaluations based on the U.S. military's goal of "winning two simultaneous regional conflicts"[6]. From the perspective of military power assessment alone, using pre-established strategic objectives as a guide for military strength evaluation enhances

the directionality and clarity of purpose in military strategic assessments. Similarly, the "Quadrennial Defense Review" issued by the U.S. Department of Defense serves as a directive document for national defense policy, utilized by the U.S. military to analyze potential threats. It is also a programmatic document on national defense and military affairs for successive governments. One of its characteristics is "threat-based requirement determination," whereby the purpose of the assessment is to analyze the strength of adversaries and the threats and challenges faced by the United States, in order to identify future needs and clarify the direction for military buildup[7].

2.2. Logical Theoretical Support

In constructing any comprehensive index, it is imperative to have a core theory for support. The structural design of the indicator system, the selection of elements, and the allocation of weights all rest upon the underlying logic inherent in this core theory.

The Asia Power Index, introduced by Lowy Institute in 2018, adheres to the 'broad hegemonic power' theory that integrates military deterrence, economic dominance, and cultural authority[3]. According to this, the indicator system and weights are designed as follows, see Table 1.

Table 1: Asia Power Index Indicator System

Category	Measurement criteria	Weight(%)
Resources (55%)	Economic resources	17.5
	Military capability	17.5
	Resilience	10
	Future resources	10
Influence (45%)	Diplomatic influence	10
	Economic ties	15
	Defense networks	10
	Cultural influence	10

The "2016 China Development Index Report"[8], published by the National Development and Reform Commission, also clearly reflects the "core theory support for index construction." The China Development Index, based on the five major development concepts proposed by the Fifth Plenary Session of the 18th Central Committee of the Communist Party of China, measures and compares the development status and progress levels of the country, between provinces, and within cities. It respectively derives the "innovation, coordination, green, openness, and sharing" development indices at the national, provincial, and urban levels. The index's indicator system is divided into three levels, comprising 5 first-level indicators, 15 second-level indicators, and 197 third-level indicators. The 5 first-level indicators correspond to the five major development concepts, while the second and third-level indicators are concrete transformations of the five major development concepts.

So that a systematic and mature index, especially the selection of its first-level indicators and the determination of indicator weights, must be supported by macro policies or classic theories in field.

2.3. System Architecture Design

Any evaluation index system can be presented in the simplest form of a two-tier structure: the first tier represents the overall objective, and the second tier represents the indicators. If the specific object of evaluation is considered as the third tier (the base layer), it formally becomes a "three-tier" structure.

The number of levels in a comprehensive evaluation index system is related to the total number of indicators and the number of subordinate units directly controlled by each upper layer. Using graph theory terminology, the number of subordinate units controlled by each upper layer is called the "hierarchical out-degree"[9]. If there are too many levels, the number of indicators within each level

will decrease. Research indicates that a general comprehensive evaluation index system with a depth of 3 to 6 levels is more reasonable, and the ideal hierarchical out-degree is between 4 to 6[9].

Reviewing numerous index examples, the depth of the index system structure ranges from 3 to 6 layers, and the hierarchical out-degree is concentrated within the range of [2, 8], see Table 2.

Table 2: Comparison of Typical Index Hierarchical Depth and Out-degree

Index	Hierarchical Depth	Hierarchical Out-degree Range
U.S. Military Power Index	3	3-6
Global Firepower Index	3	3-8
Quadrennial Defense Review	3	5-6
Formal Bilateral Influence Index	4	2-4
Russian Military Construction Statistical Indicator System	5	2-8
UK National Defense Construction Statistical Indicator System	4	2-8
Asia Power Index	5	2-6
Global Innovation Index	6	2-5
China Information Development Index	4	1-5
Comprehensive Statistics Indicator System for Building a Moderately Prosperous Society in All Respects	3	4-14
China Digital Economy Development Index	3	2-5

2.4. Construction of Individual Indicators

When constructing specific indicators, it is essential to clarify what indicators the evaluation index system is composed of, as well as the concept, calculation scope, calculation method, and measurement unit of each indicator. The construction process of any single indicator is a logical thinking process, which includes the basic steps that shown in the figure 2 below[10]:

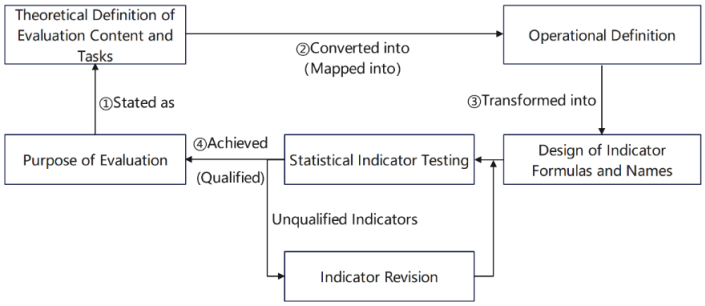

Figure 2: Process of Constructing Individual Indicators

Taking the "US Military Power Index" as an example, the US National Security Agency positions the military to "address two major regional conflicts simultaneously." Therefore, the "US Military Power Index" report interprets the demand for military power as "achieving decisive victory in two major regional conflicts that occur almost simultaneously, and conducting combat operations characterized by rapid response and high probability of success, while minimizing the risk of significant casualties." This standard is used to measure and evaluate the US military strength. Based on the theoretical definition of the evaluation content and tasks, the first-level indicators are determined as "Global Combat Environment, Threats to US Vital Interests, and US Military Condition." Taking "US Military Condition" as an example, it is further transformed into operational definitions, namely "Capability" (assessing the current status and future development of equipment), "Scale" (whether it can meet the needs of two major wars), and "Readiness" (whether it can meet the readiness goals set by each military branch), to provide a concrete description of the military condition.

Finally, it is converted into specific bottom-level indicators. Taking "Capability" as an example, its lower-level indicators include the service life of equipment, the scale of modernization projects, and the capabilities of the equipment, etc[11].

At the same time, it can be found that the number of bottom-level indicators generally remains within the range of [20, 200], as shown in Figure 3. This situation arises to reduce the complexity of statistical calculations and to enhance the sensitivity and robustness of the index.

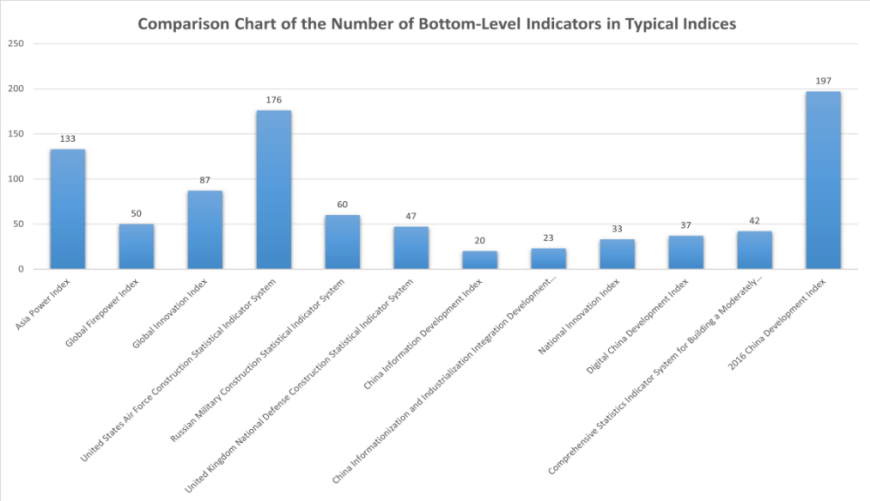

Figure 3: Comparison Chart of the Number of Bottom-Level Indicators in Typical Indices

2.5. Selection of Evaluation Methods

Currently, popular comprehensive evaluation methods at home and abroad mainly include conventional comprehensive evaluation methods (composite scoring method, comprehensive index method, efficiency coefficient method), multivariate statistical comprehensive evaluation methods (principal component analysis evaluation, factor analysis evaluation), as well as fuzzy comprehensive evaluation methods (FCE), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Ratio System Rank (RSR), Analytic Hierarchy Process (AHP), Grey Relational Analysis (GRA), Data Envelopment Analysis (DEA), and Artificial Neural Network Analysis (ANN), etc[1].

Upon comprehensive analysis of numerous index examples, we find that most widely influential and authoritative index examples do not use complex evaluation methods. Some do not even consider weight factors or adopt an equal weighting approach. They are often simple AHP combined with the results of fuzzy comprehensive calculation. For example, ranking military assessments such as the "Global Firepower" military strength comparison, use simple ranking and balanced scorecard methods; comprehensive military power assessments, such as the "SIPRI Yearbook of Armaments, Disarmament, and International Security," mainly use net assessment and SWOT analysis, the "US Military Power Index" adopts a five-point quantification scoring and an arithmetic average weighting method after equal weighting; hypothetical assessments, such as "Comparing Military Forces: Changes in Troop, Geography, and the Balance of Power (1996-2017)" and "The Future of Sea Power in the Western Pacific," use relatively complex methods such as game theory and simulation.

The same applies to the evaluation methods selected for composite indices in non-military fields. For example, the "China Informationalization Development Index" adopts a composite scoring method, and the dimensionless treatment of data uses a method of threshold comparison followed by logarithmic transformation. The calculation formula for its positive indicators is:

$$Z_{ni} = \left[log_2 \left(1 + k \frac{X_{ni}}{\bar{X}_{(n=2010)i}} \right) \right] * 50 \quad (1)$$

In the formula, X_{ni} (where n represents the year and i represents the indicator) denotes the original value of the indicator, and Z_{ni} is the dimensionless value. The determination of weights adopts the expert scoring method, and the index aggregation uses linear weighted summation. The "2016 China Development Index," referring to the national GDP growth rate algorithm, uses the utility value method. The general formula is:

$$y_i = \frac{x_i - x_{i0}}{x_{i1} - x_{i0}} \tag{2}$$

In the formula, x_{i1} and x_{i2} are two determined standard values and the extreme values selected are (0, 100). The index calculation uses an equal-weight linear weighted algorithm.

There are many comprehensive evaluation methods, each with its own characteristics, applicable scenarios and scope. The principal component analysis (PCA) method is more patterned, capable of eliminating the influence of the correlation between indicators, with objective and reasonable weights. However, it requires a large sample size and has a complex process, neglecting subjective factors, making it suitable for one-time evaluation. The fuzzy comprehensive evaluation method has a simple and understandable model, capable of quantifying uncertain information. However, it's highly subjective and cannot solve the repeated problem caused by the correlation between indicators, so often suitable for evaluation problems with fuzziness and uncertainty. To address the limitations inherent in different methods, a combination of evaluation approaches can be used within the same assessment issue to enhance the scientific and precision of the comprehensive evaluation.

3. Summary

Multi-index comprehensive evaluation is an important research field. Comprehensive evaluation and correct assessment of a certain issue can provide effective basis and strong support for the final decision-making. This paper completes the "theory-practice-theory" cycle, paving the way for innovative applications in multi-index evaluation technology.

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