Evaluation of regional manufacturing quality competitiveness based on analytic network

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ABSTRACT. *The rapid development of manufacturing industry calls for further enhancement of regional manufacturing quality competitiveness (MQC). Against this backdrop, this paper constructs an evaluation index system for regional MQC in light of the operation features of regional manufacturing quality, and establishes an evaluation model based on analytic network process (ANP) considering the mutual influence and constraints between the evaluation indices. Taking China's Zhejiang Province as an example, the proposed model was verified through empirical calculation on Super Decision (SD) software. The results show that quality subjects and quality benefits are the main influencing factors of Zhejiang's MQC; Hangzhou achieved the highest comprehensive score of regional MQC, followed by Ningbo and Jiaxing. Quzhou, Lishui and Zhoushan were at the bottom of the ranking of comprehensive score; quality bases and quality benefits are major bottlenecks to the improvement of regional MQC in Zhejiang, which should be reformed in future. The proposed model and the ANP method are desirable tools for objective evaluation of the MQC, as quality development has become a national strategy of China.*

RÉSUMÉ. *Le développement rapide de l'industrie manufacturière demande un renforcement supplémentaire de la compétitivité de la qualité de fabrication (MQC, le sigle de « manufacturing quality competitiveness » en anglais) régionale. Dans ce contexte, cet article construit un système d'indice d'évaluation pour la MQC régionale à la lumière des caractéristiques opérationnelles de la qualité de fabrication régionale et établit un modèle d'évaluation basé sur un processus de réseau analytique (ANP, le sigle de « analytic network process » en anglais) tenant compte de l'influence mutuelle et des contraintes entre les indices d'évaluation. En prenant comme exemple la province du Zhejiang en Chine, le modèle proposé a été vérifié à l'aide de calculs empiriques sur le logiciel Super Decision (SD). Les résultats montrent que les sujets de qualité et les avantages de qualité sont les principaux facteurs d'influence de la MQC du Zhejiang; Hangzhou a obtenu le score global le plus élevé en termes de MQC régionale, suivi par Ningbo, Jiaxing et Quzhou ; Lishui et Zhoushan se trouvaient au bas du classement du score global; les bases de qualité et les avantages de qualité sont les principaux obstacles à l'amélioration de la MQC régionale à Zhejiang, qui devraient être réformés à l'avenir. Le modèle proposé et la méthode d'ANP sont des outils souhaitables pour une évaluation objective de la MQC du fait que le développement de la qualité étant devenu une stratégie nationale de la Chine.*

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KEYWORDS: manufacturing quality competitiveness (MQC), analytic network process (ANP), super decision (SD), quality bases, quality subjects, quality supports, quality benefits.

MOTS-CLÉS: compétitivité de qualité de fabrication (MQC), processus de réseau analytique (ANP), super decision (SD), bases de qualite, sujets de qualite, supports de qualite, avantages de qualité.

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1. Introduction

The development of manufacturing industry directly reflects the productivity of a country, and helps to distinguish between developing and developed countries: in developed countries, manufacturing takes up an important share of the national economy. The manufacturing level depends on quality, and manufacturing competition is ultimately quality competition. The quality of manufacturing industry measures the comprehensive strength and core competitiveness of regional manufacturing industry, revealing how much manufacturing satisfies the needs of social and economic development. As the global industrial transformation enters a new round, the quality of manufacturing industry has become the focus of competition in the international market.

Regionalization is an obvious trend for the quality of products and enterprise capability of quality development in the manufacturing industry. The regional manufacturing quality has attracted the attention of consumers, investors and investment officers. With the proliferation of the block economy, more job opportunities have emerged in regions with good overall manufacturing quality. Therefore, the key to understanding the quality competitiveness of regional manufacturing industry lies in the comprehensive evaluation of the manufacturing quality in this region.

The existing studies on quality concentrate on quality in this region. Microscopic issues like product control and enterprise quality management. As a product of the industrial revolution, quality has been widely understood from the angle of scientific management as the precise control and process regulation in product manufacturing. With the development and maturity of modern management theory, this concept has been introduced to enterprise management, forming the quality management theory based on organization operation and improvement. Focusing on the microscopic quality of products and enterprises, the academic circle has not reached a consensus on quality concepts at industrial and regional levels, such as the regional manufacturing quality competitiveness (MQC).

However, it is clearly stated in the guidelines for “Made in China 2025” that China’s manufacturing industry must “transform its competitive advantage from low cost to quality effectiveness”, and shift from price competition that relies on lowering factor costs to quality competition that pursues high added value. As a result, the manufacturing policy-makers must scientifically measure the competitiveness arising from “quality”.

2. Literature review

The regional MQC evaluation is a new focus in quality research. The existing studies mainly focus on two microscopic aspects (i.e. influencing factors of quality and the evaluation theories on quality competitiveness), failing to tackle the macroscopic issues.

Concerning the influencing factors of quality, the Malcolm Baldrige National Quality Award (MBNQA) (1993) put forward the seven factors affecting the quality of enterprise operation. Flynn (1994), (Alexander, 2002) and (Ku-mar, 2002) summarized the influencing factors of quality from different angles. (Brust *et al*., 2002) shifted their attention towards the macro performance of quality competition.

Concerning the evaluation theories on quality competitiveness, the relevant studies mainly concentrate on international trade, enterprise quality management and service industry development. Various evaluation theories on quality competitiveness have been constructed through theoretical analyses for different objects and problems. On international trade, the product quality is mostly described by the core variable of transaction “price” in new trade theory, aiming to disclose the impacts of product quality on the international competitiveness of a country or a region. On enterprise quality management, the previous research, in light of quality management theory, has explored the effects of internal factors (e.g. quality input and management) on the market performance of enterprises. On service industry development, the status and advantages of the service industry are analysed from the perspective of consumer evaluation, using methods and theories that evaluate consumer satisfaction. With different theoretical bases and emphases, the above studies lead to varied evaluation systems and methods, which cannot be directly applied to the analysis of the MQC.

In 2006, the General Administration of Quality Supervision, Inspection and Quarantine (GAQSIQ) and the National Bureau of Statistics jointly released the *Communiqué of the People's Republic of China on the 2005 National Quality Competitiveness Index of Manufacturing*, marking the first systematic evaluation of China’s macro-quality level and quality development capability (Black *et al*., 1996). Since then, many Chinese experts and scholars have been devoted to the study of macro-quality, pushing the evaluation of enterprise quality competitiveness to the macro level (Wen, 2005; Jiang, 2005, Ennew, 1995). However, there is still little report on the evaluation of the regional MQC.

The Delphi method and the analytic hierarchy process (AHP), which can make use of public statistics, are two of the most popular evaluation methods for the MQC. Nevertheless, these methods fail to achieve a desirable outcome when applied to evaluate the regional MQC, owing to the multiple indices, relationships and system levels of regional MQC evaluation and the complex dependence and feedbacks between the layers, indices and alternatives in the layered evaluation system. This calls for a scientific and rational evaluation model for the regional MQC.

Considering the above, this paper sets up a regional MQC evaluation model based on the analytic network process (ANP), and applies it to evaluate and analyse MQCs in different regions of China’s Zhejiang Province in 2016, aiming to grasp the accurate regional MQCs of the province and provide a theoretical reference for improving regional RQC.

3. Construction of evaluation index system

The regional manufacturing quality is an all-inclusive term, covering the quality inputs and supports in the early phase, the product quality in the manufacturing process, and the quality benefits of the final outcome. The evaluation of regional MQC requires systematic, comprehensive and complex assessment of various factors against multiple and, sometimes duplicate, indices. The evaluation result is not authentic and credible unless the duplicate indices have been streamlined into non-redundant indices.

Our evaluation index system was established on the basis of the competitiveness in four aspects, namely, quality bases, quality subjects, quality supports and quality benefits. The goal is to make the system systematic, scientific, comprehensive, operable, dynamic and flexible. Specifically, the quality bases reflect the quality of manufacturing infrastructure, including standards, metering, inspection, testing and certification; the quality subjects demonstrate the micro-quality of manufacturing industry, ranging from product quality to brand recognition; the quality supports refer to the external supports to manufacturing quality construction, such as innovation input, safety supervision, quality management and quality culture; the quality benefits stand for the economic and livelihood benefits of the final outcome.

A total of 22 evaluation indices were designed for the four aspects. An index was considered as positive if its value was consistent with the target value, and negative if otherwise. The final evaluation index system for regional QMC (Table 1) was established based on the selected regional QMC indices, considering the features of quality management in manufacturing industry.

Table 1. Regional QMC evaluation index system

Goal layer	criteria layer	Index layer	Index direction
Regional Manufacturing Quality Competitiveness A	quality bases B1	standard compliance rate of enterprises above designated size C11	+
		Number of major amendments per thousand national standards C12	+
		Number of calibration measurement capability C13	+
		Number of Public service platform of Inspection, testing and certificationC14	+

		Number of testing institutions with national CMA certificationC15	+
	quality subjects B2	the qualification rate of manufacturing products C21	+
		Output value of new industrial products above Designated Size C22	+
		Number of product brands C23	+
		Share of independent brand products in total export C24,	+
	quality supports B3	the rate of R&D and GDP C31	+
		The density of human resource C32	+
		qualification rate of the he Quality and Safety MonitorinvC33	+
		the number of the death in the accidents per billion GDP C34	-
		Management system certification coverage (%) C35	+
		The rate of enterprise adopting excellent performance evaluation mode C36	+
		Discredit rate of regional enterprisesC37	+
	quality benefits B4	Disposable income of urban and rural residents C41	+
		The rate of disposable income of urban and rural residents C42	-
		Consumption rateC43	+
		Profit rate of enterprises above designated sizeC44	+
		Labour productivity C45	+
		Proportion of tax to GDP (%)C46	+

4. Research method and model construction

4.1. ANP

The ANP was proposed based on the AHP by Professor T. L. Satty of the University of Pittsburgh in 1996. As a multi-criteria decision-making model, the ANP can adapt to non-independent hierarchical structure and solve the problems with internal dependence and feedbacks. The main construction steps of the ANP model are as follows:

(1) Establishing the ANP evaluation network (Figure 1) based on the principles and evaluation index system of the ANP: The objectives and demands, i.e. the control layer and the network layer, should be determined through status analysis; then, the relevant important indices and their relevance should be identified based on the objectives and demands.

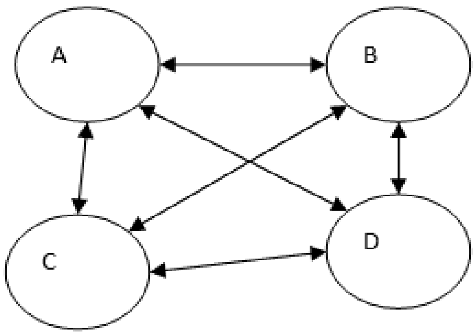

Figure 1. ANP network structure

(2) Questionnaire survey and expert evaluation: Representative experts should be selected to rate each item in the designed questionnaire through pairwise comparison against the 1~9 AHP scale; then, the expert scores should be integrated by the geometric mean method.

(3) Construction of super matrix and consistency test: First, the indirect dominance was compared between the elements of the control layer, and the weight vectors were derived by the characteristic root method; then, the local weight matrix was obtained through the consistency test; Similarly, the internal and external relationships between the elements in other sets were contrasted, forming the unweighted super matrix Was of the priority vectors for the mutual influence between the elements in the network layer.

$$W_s = \begin{bmatrix} W_{11} & W_{12} \cdots & W_{1n} \\ W_{21} & W_{22} \cdots & W_{2n} \\ \cdots & \cdots \cdots & \cdots \\ W_{n1} & W_{n2} \cdots & W_{nn} \end{bmatrix} \quad (1)$$

(4) Derivation of the weight of each factor through supermatrix calculation: Considering the impacts of extra-group factors on this control criterion, the supermatrix should be normalized, that is, weighting the elements in Ws, producing the weighted supermatrix W^{-}. To disclose the dependence between the elements, the weighted supermatrix should receive stability treatment, forming the limit relative sorting vectors:

$$W^{\infty} = \lim_{k\to\infty} (\frac{1}{N})^{n} \sum_{k=1}^{n} W^{-k} \quad (2)$$

If the limit value converges to a unique solution, the local weights should be sorted in order of the elements to yield the local weight vectors, that is, the weight of each element.

(5) Calculation of the evaluation value by linear weighting: The comprehensive evaluation value should be obtained by comprehensive evaluation based on linear weighting. The evaluation formula can be expressed as:

$$P = \sum_{i=1}^{n} W_j S_{ij} \quad j = 1,2, \dots, n \quad (3)$$

where P is the comprehensive evaluation value; S_{ij} is the attribute value after the standardization of index j in region i in the index layer; W_j is the final weight of index j in the index layer.

4.2. Super matrix calculation software (Super Decisions)

The ANP features complex and difficult computations, as it considers the information feedbacks between different element sets and the mutual dependence between elements in the same set. It is difficult to apply the ANP in actual decision-making problems without the aid of computer software. Here, the Super Decisions software is adopted for empirical calculation, yielding the weight of each index. Developed by Rozann W. Satty and William Adams, this software programs the ANP calculation process, laying the basis for ANP applications.

4.3. Construction of evaluation model

The ANP-based regional MQC evaluation model was constructed based on the ANP principles and the evaluation index system (Figure 2). The control layer and the network layer were designed through in-depth analysis. The former consists of multiple criteria, while the latter consists of various indices. The important indices and their relevance were determined according to the evaluation objectives, and then the ANP network model was set up, in which two-way arrows indicated the mutual influence between indices.

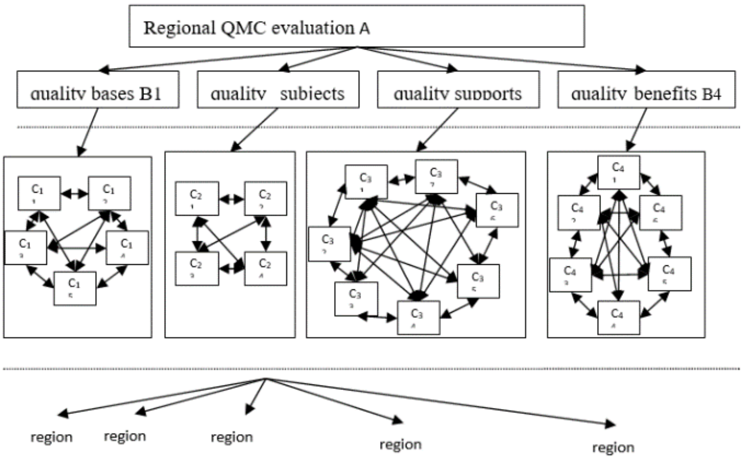

Figure 2. ANP-based evaluation model for regional MQC

5. Empirical analysis

5.1. Regional overview

Located in south-eastern of China, Zhejiang Province is made up of eleven prefectures, namely, Hangzhou, Ningbo, Wenzhou, Huzhou, Shaoxing, Jiaxing, Lishui, Taizhou, Jinhua, Quzhou and Zhoushan. Since the reform and opening-up four decades ago, Zhejiang has undergone rapid development of manufacturing industry, growing into a leading manufacturing base in China. In 2016, the industrial enterprises above designated size in Zhejiang achieved an added value of over RMB 1.7 trillion yuan, indicating that the manufacturing industry had become a pillar to the economy of this province.

As China's economy shifts from high-speed growth to high-quality development, quality renovation has become an inevitable choice to ensure that economic growth satisfies social demand and promotes sustainable development. Against this backdrop, all prefectures in Zhejiang must pursue manufacturing transformation and upgrading by improving supply quality, and promote the high-quality development of the society and economy through that of the manufacturing industry.

5.2. Data sources and processing

The research data were obtained from the statistical bureau, the environmental protection department, the construction department, the industry and commerce department, the commercial committee, the quality supervision bureau, as well as other units of Zhejiang Province. Inspired by fuzzy comprehensive evaluation, the research data were processed in the following steps.

5.2.1. Determining the membership function

The membership function of a fuzzy set is called the fuzzy distribution, if the fuzzy set is defined on the real number field R. The assignment method refers to the subjective selection of a fuzzy distribution according to the nature of the problem and the determination of the parameters in the distribution based on the measured data. Here, the membership function is determined considering the features of the original data $x_i, 1 \leq i \leq 11$, which correspond to the different indices of the 11 prefectures. Then, the membership $y_i, 1 \leq i \leq 11$ of $x_i, 1 \leq i \leq 11$ was computed by the membership function, laying the basis for the horizontal comparison of the same index across different cities.

(a) If the index data partially obey the normal distribution, they should be processed as a normal distribution function in combination with a certain base value. These indices include standard compliance rate of enterprises above designated size (%), coverage of metering standard/standard materials (%), death toll of safety accident per RMB 100 million yuan (persons) (negative index) and share of independent brand products in total export (%). The specific membership function can be expressed as:

$y_i \begin{cases} 1 - e^{-(x_i - a)^2, x_i > a} \\ 0, \quad x_i \leq a \end{cases}$ (As a positive index, x_i should be maximized, $a = \min_{1 \leq i \leq 11}\{x_i\}$);

$y_i \begin{cases} -e^{-(x_i - a)^2, x_i > a} \\ 1, \quad x_i \leq a \end{cases}$ (As a negative index, x_i should be minimized, $a = \min_{1 \leq i \leq 11}\{x_i\}$).

(b) If the index data are from the same sample space, they should be normalized as the original data for membership calculation. These indices include the number of revised national standards per 1,000 national standards (each). The specific membership function can be expressed as:

$$y_i = x_i / \sum_{i=1}^{11} x_i$$

(c) If there are provisions on the index in relevant documents or national/regional plans, the index data should be subjected to linear processing according to these provisions. These indices include the qualification rate of manufacturing products (%), ratio of service industry added value to the GDP (%), the energy consumption per RMB 10,000 yuan of GDP (ton of standard coal equivalent/RMB 10,000 yuan), profit rate of enterprises above designated size (%), and ratio of tax to the GDP (%). The specific membership function can be expressed as:

$y_i = 40\frac{x_i - a}{b-a} + 60$ (As a positive index, x_i should be maximized, $a = \min_{1 \le i \le 11}\{x_i\}$, $b = \max_{1 \le i \le 11}\{x_i\}$);

$y_i = 40\frac{b - x_i}{b-a} + 60$ (As a negative index, x_i should be minimized, $a = \min_{1 \le i \le 11}\{x_i\}$, $b = \max_{1 \le i \le 11}\{x_i\}$).

If specific values are given in relevant documents or national/regional plans, the above minimum or maximum values should be adopted for processing; if relevant values are specified in these files, the relevant values should be adopted for processing. For example, the mean ratio of service industry added value to the GDP is 57% (the value of a) in middle-income countries and 74% in developed countries (the value of b); the qualification rate of manufacturing products should reach 94.8% in 2020 according to the 13th Five-Year Plan of the GAQSIQ (the value of a).

(d) The original data should be taken as the membership for the following indices: comprehensive satisfaction of service quality, one-time acceptance rate of completed project (%), percentage of days with good air quality (AQI) (%), public satisfaction of eco-environment quality, pass rate of quality safety monitoring (%), and comprehensive level index of market order.

(e) If the original index data have base values, they should be subjected to linear processing after removing the base values. The specific membership function can be expressed as:

$y_i = \frac{x_i - 100}{100}$(The consumers are neutral when the consumer confidence index is 100).

(f) If the original index data are too small to differentiate between memberships, they should be given base values and subjected to linear processing. These indices include coverage of the three systems for lifetime responsibility of project quality (%). The specific membership function can be expressed as:

$$y_i = 80 + 20x_i$$

(g) The remaining indices should be processed as the membership function of the k-th parabolic type. This treatment could reflect the increasing difficulty in index improvement, and ensure that the membership data are mapped into a reasonable interval, thereby minimizing the membership difference. The specific membership function can be expressed as:

$y_i = (\frac{x_i - a}{b-a})^k$ (As a positive index, x_i should be maximized, $a = \min_{1 \le i \le 11}\{x_i\}$, $b = \max_{1 \le i \le 11}\{x_i\}$);

$y_i = (\frac{b-x_i}{b-a})^k$ (As a negative index, x_i should be minimized, $a = \min_{1 \le i \le 11}\{x_i\}$, $b = \max_{1 \le i \le 11}\{x_i\}$).

5.3. Determine the normalized values according to the membership function

The membership corresponding of each index was calculated separately according to the above analysis. Note that the results on the credit loss and casualty of safety accidents should be sorted in reversed order because the two indices should be minimized. Then, each index was normalized according to the membership, using the quantization function. The resulting score of each prefecture are listed in Table 2 below.

Table 2. Normalized values of evaluation indices

Index	Hangzhou	Ningbo	Wenzhou	Jiaxing	Huzhou	Shanxing	Jinhua	Quzhou	Zhoushan	Taizhou	Lishui
C_{11}	83.15	79.68	85.15	100	87.57	96.96	71.67	69.29	60.00	83.64	71.08
C_{12}	100.	91.83	82.36	85.33	83.11	87.77	82.43	77.46	71.04	84.55	60.00
C_{13}	60.00	97.90	99.89	100	95.45	96.67	91.56	99.00	94.68	98.23	98.69
C_{14}	93.74	60.00	100	97.98	95.98	99.83	97.43	96.03	92.10	98.53	97.56
C_{15}	100	96.52	95.10	92.62	60.00	90.79	95.41	92.99	76.04	91.27	92.42
C_{21}	99.75	98.65	98.73	99.90	99.21	100	99.32	99.50	60.00	99.16	99.75
C_{22}	99.48	97.99	96.50	100	99.02	99.51	98.68	97.24	60.00	98.57	99.32
C_{23}	99.61	98.31	96.30	90.96	96.05	98.27	98.78	92.39	60.00	97.85	100
C_{24}	97.54	100	61.91	74.11	63.91	65.63	64.73	60.00	60.63	74.11	60.00
C_{31}	100	84.39	70.73	92.92	89.19	83.96	76.86	61.45	65.79	72.20	60.00
C_{32}	98.38	89.29	92.82	87.65	92.74	80.00	87.70	96.14	93.18	86.04	100

C_{33}	99.25	98.34	98.65	98.91	98.57	98.92	98.42	98.61	98.73	98.86	99.15
C_{34}	99.93	100	97.61	98.08	91.09	99.82	91.09	60.00	97.61	93.45	60.00
C_{35}	80.58	100	92.98	87.00	84.72	80.00	80.41	81.43	81.12	93.99	95.99
C_{36}	60.00	89.48	92.53	91.64	96.43	93.94	93.29	97.87	99.79	94.65	100
C_{37}	98.42	92.82	82.84	98.81	90.18	80.00	92.77	97.54	100	92.74	90.49
C_{41}	100	96.81	86.01	87.11	80.92	90.07	80.85	60.00	90.19	80.33	60.02
C_{42}	96.18	94.61	99.05	60.00	91.11	94.86	99.50	97.72	89.45	98.60	100
C_{43}	61.67	60.66	100	68.51	70.34	61.46	82.96	64.89	60.00	86.42	79.90
C_{44}	100	97.93	88.97	93.10	93.10	90.34	89.66	88.28	60.00	93.10	99.31
C_{45}	96.66	94.45	60.00	93.13	94.78	94.78	90.46	95.54	100	88.16	94.35
C_{46}	95.96	100	64.65	81.48	75.08	63.97	72.39	60.00	97.98	67.68	63.97

5.4. Results analysis

5.4.1. Numerical analysis

The weights of the indices on the index layer was obtained through ANP modelling and SD computation, all of which satisfied the weights of the final evaluation indices (Table 3). On this basis, the author calculated the evaluated MQC of each prefecture in Zhejiang (Figure 3) and the evaluation results of the four criteria. The following judgements can be made from these results:

(1) The four criteria can be ranked as quality subjects, quality benefits, quality bases and quality support by their impacts on the regional MQC. In the ranking of index layer weights, the top six places were occupied by the qualification rate of manufacturing products, profit rate of enterprises above designated size, number of product brands, share of independent brand products in total export, standard compliance rate of enterprises above designated size, and disposable income of urban and rural residents. It can be seen that quality subjects are the key to regional MQC. The major influence from standard compliance rate of enterprises above designated size, and disposable income of urban and rural residents in the index layer reveals the growing research interest in the application of enterprise standards and the final

livelihood outcome of regional manufacturing quality, which provides a direction for the future improvement, transformation and upgrading of manufacturing quality. Hence, the variation in the above indices should be noticed before further improving regional manufacturing quality and laying down relevant reform policies.

Table 3. Index weights of regional MQC evaluation

Standard layer	weight	Index layer	weight	Final weight	Standard layer	weight	Index layer	weigh	Final weight
B1	0.2279	C11	0.2698	0.06149	B3	0.2096	C33	0.1934	0.03238
		C12	0.2074	0.04727			C34	0.1766	0.02800
		C13	0.1655	0.03772			C35	0.1043	0.04054
		C14	0.1811	0.04127			C36	0.0757	0.03702
		C15	0.1762	0.04016			C7	0.1619	0.02186
B2	0.3004	C21	0.3095	0.09297	B4	0.2621	C41	0.2053	0.01587
		C22	0.2514	0.07552			C42	0.1626	0.03393
		C23	0.223	0.06699			C43	0.1397	0.05381
		C24	0.2161	0.06492			C44	0.1995	0.04262
B3	0.2096	C31	0.1545	0.03238			C45	0.1552	0.03662
		C32	0.1336	0.02800			C46	0.1377	0.05229

(2) The evaluation results show that Hangzhou achieved the highest comprehensive score of regional MQC, followed by Ningbo and Jiaxing. Quzhou, Lishui and Zhoushan were at the bottom of the ranking of comprehensive score. According to the comprehensive level of quality development, the eleven prefectures can be divided into three categories:

Category 1 (regions above provincial level of comprehensive quality development): Hangzhou and Ningbo fall into this category. The mean comprehensive score of regional MQC of the two prefectures stood at 93.28, about 1.06 times of the provincial level.

Category 2 (regions at provincial level of comprehensive quality development): Taizhou, Jiaxing, Huzhou, Shaoxing, Wenzhou and Jinhua fall into this category. The mean comprehensive score of regional MQC of these prefectures stood at 86.01, about the same as the provincial level (88.00) and 0.92 time of that of Category 1 prefectures.

Category 3 (regions below provincial level of comprehensive quality development): Lishui, Zhoushan and Quzhou fall into this category. The mean comprehensive score of regional MQC of these prefectures stood at 81.93, about 0.93 time of the provincial level and 0.88 time of that of Category 1 prefectures.

(3) Concerning the four criteria, Hangzhou and Ningbo took the first and second places in the rankings of quality subjects, quality supports and quality benefits, while Jiaxing and Taizhou maintained the lead in quality bases.

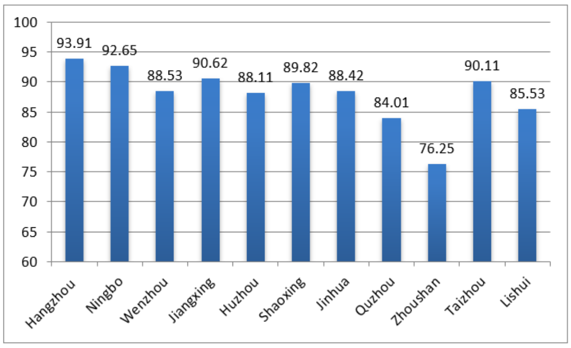

Figure 3. The final result of regional MQC evaluation

5.4.2. Feature analysis

(1) There are significant regional differences in the MQCs of the eleven prefectures. In general, the improvement of prefectural MQC hinges on the efforts of the prefecture, the local socioeconomic level, and the inter-connected development between prefectures. For instance, the prefectures in the northeast of Zhejiang enjoy relatively high socioeconomic level, mature quality infrastructure, good quality policies and sound inter-connected development. Thanks to these natural advantages, the prefectures in this part of Zhejiang (e.g. Hangzhou, Ningbo and Jiaxing) are leaders in manufacturing quality development. By contrast, the prefectures in southwest Zhejiang fall behind in regional MQC, owing to the relatively backward socioeconomic level and weak inter-connected development.

(2) There is no absolute correlation between regional MQC and prefectural size. Here, the prefectural size is represented by the urban population. For example, Wenzhou has the second largest urban population in Zhejiang, but falls short in quality

enhancement ability and quality benefits. Thus, Wenzhou achieved a relatively low score in comprehensive evaluation of regional MQC. In future, both quantity and quality should be highlighted in the development of regional manufacturing quality.

(3) Regional MQC promotion requires balanced development in all aspects. Regional MQC covers many aspects, including quality bases, quality supports, quality subjects and quality benefits. The sound development of manufacturing quality in a prefecture relies on the balanced and orderly development in all four aspects. There should be no short board. On this basis, the prefecture can receive a high MQC score if it does well in several aspects. For example, Hangzhou and Ningbo ranked high in the overall ranking because they performed excellently in every aspect of the MQC, as evidenced by their high rankings in all four primary indices.

(4) In light of standard deviation and variation coefficient, the four aspects of MQC can be ranked as quality subjects, quality bases, quality supports and quality benefits. This means the prefectures are close in the level of quality subject but differ greatly in the other three aspects. There are two implications of this ranking: First, all prefectures in Zhejiang have made great efforts to improve the overall manufacturing quality of the province in a coordinated manner; Second, the MQC gap between the prefectures, closely related with how much each prefecture consolidates its quality bases and quality supports, contributes to the great difference between the prefectures in quality benefits.

6. Conclusions

According to the process of quality development, this paper innovatively introduces the relevant evaluation indices of regional manufacturing quality, and establishes a regional MQC evaluation index system. Then, an ANP-based evaluation model was constructed, considering the mutual influence and constraints between the indices in the index system. Taking Zhejiang Province as an example, the proposed model was verified through empirical calculation on SD software, yielding desirable outcomes.

According to the evaluation results on regional MQC of Zhejiang in 2016, Hangzhou achieved the highest comprehensive score of regional MQC, followed by Ningbo and Jiaxing. Quzhou, Lishui and Zhoushan were at the bottom of the ranking of comprehensive score. Quality subjects and quality benefits have much greater impacts on the MQC of each prefecture than quality bases and quality supports.

This study further improves the evaluation system of regional manufacturing quality, and provides a valuable reference to the improvement of regional manufacturing quality. The future research will implement ANP and SD to eliminate the noises on the evaluation indices in research and practice.

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