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NEW SMART CITY CLUSTERS' CONSTRUCTION LEVEL EVALUATION UNDER ECONOMIC CIRCLES: THE CASE OF SHANDONG, CHINA

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Abstract. China's Shandong Province plans to create a new smart city cluster that is development-focused, demand-led, people-oriented, and data-driven. This entails the scientific assessment of construction levels, analysis of potential hurdles, and formulation of upgraded strategies. However, existing research has mainly focused on measuring single or multiple traditional smart cities, therein overlooking the construction level of new smart city clusters. Thus, this study takes the new smart city clusters in Shandong Province and uses both entropy method and the Moran index to analyze the construction level and spatial differences in the four dimensions of social livelihood, economic production, innovation-driven development, and safeguard measures. Results show that the construction level of the provincial capital economic circle is uneven and has polarization issues. Meanwhile, the construction level of Jiaodong economic circle is relatively good, although the economic driving capacity needs further improvement. The low urbanization rate of the Lunan economic circle occupies a gathering zone with low construction levels, making the construction of digital villages necessary. Targeted suggestions in improving the radiation-driven capacity of core cities, improving digital infrastructure, and developing smart industries are then forwarded to promote the establishment of new smart city clusters and achieve top-notch economic growth.

Keywords: new smart city cluster, construction level, economic circle, high-quality economic development.

JEL Classification: H45, O18, R34, R58.

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Introduction

Smart city construction has now become an effective means to promote urbanization, improve urban governance, develop the digital economy, and promote high-quality economic development (Vishnivetskaya & Alexandrova, 2019; Johnson, 2008). In 2016, the Chinese government forwards the "new smart city cluster (SCC)", stating that it would "support mega cities to benchmark with international advanced levels and build world-class SCCs" (Hu & Ma, 2021; Sun & Zhang, 2020). To positively respond to the national policy and promote high-quality economic development, Shandong Province put forward the "integrated development of a new SCC" and "building a new national SCC". The new SCC in Shandong Province is the focus of this study, thereby also examining potential issues which may arise during construction and development of the new SCC in Shandong Province.

Extant studies on smart cities have three primary aspects: measurement objects, measurement indicators systems, and measurement methods. For the first aspect on measurement objects, existing studies usually take a single smart city (or multiple smart ones) as the research object and analyze their traditional smart city construction mode and path, although they usually lack systematic research on new SCCs (Fan et al., 2016; Li et al., 2018). For the second aspect on measurement indicators selection, the most studies construct the measurement indicators system from social, economic, resource, environmental, and other dimensions whilst largely overlooking the characteristics of the new SCC, hence the need for further improvement (Qi & Ba, 2016; Shen et al., 2018; Li et al., 2020). For the third aspect on evaluation methods, the existing literature tends to use entropy weight method, Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS), and the analytic hierarchy approach. Whenever the data in the measurement indicators system is polarizing, this may result in mistakes in the calculation results because the TOPSIS technique determines the construction level score using maximum and minimum values.

Moreover, because the analytical hierarchy method is an empirically based weighting method which incorporates subjective factors, ensuring the objectivity of the measurement process is important when determining the construction level of new SCCs. Additionally, the impartiality of the calculation results should also be strengthened. The above methods for evaluating the state of smart city buildings are prone to errors and contain subjective aspects, which makes the results lack objectivity. Furthermore, most extant studies focus on smart cities construction from a single perspective, and do not comprehensively measure the construction level of new smart cities (Qi & Ba, 2016; Liu, 2016; Qu, 2016).

Existing research results on smart cities can provide a reference herein; however, there remains a need to improve and refine all three aspects of measurement objects, measurement indicators system, and measurement methods. Hence, this study first evaluates the construction level of new SCCs in Shandong from the perspective of the three major economic circles. By comparing the construction differences between different economic circles, the advanced experiences of the leading economic circles and cities are explored and the potential problems of the lagging economic circles and cities are investigated. Firstly, it develops a thorough assessment indicator system for the development stage of a new SCC in Shandong Province following a literature review from four aspects: social livelihood, economic production, inno-

vation-driven development, and safeguard measures, considering the policy documents and the status quo of building a new SCC. Next, the level and spatial differences in the development of new SCCs are examined from various angles using both the entropy value method and the Moran index. Finally, the issues and flaws in the development of new SCCs in Shandong Province are thoroughly examined, and policy recommendations are accordingly made.

As mentioned, this study investigates and evaluates the new SCCs in Shandong Province four directions: social livelihood, economic production, innovation-driven development, and safeguard measures, and proposes relevant policy recommendations following analysis results to improve the construction level of new SCCs in Shandong. This study has three contributions: (1) Following the existing economic circle, the study analyzes the construction level of new SCCs within and between economic circles, incorporates the economic circle with the new SCC, enrichens the research on the construction level of new SCCs in existing research by providing significant insights, and offers suggestions for the follow-up studies. (2) Using the Moran index, it examines space-time difference in the development stage of new SCCs within and between economic circles, unearths the advanced experience of leading regions, compiles the potential issues in underdeveloped areas. (3) The analytical results offer guidelines for policymakers to design adequate policies for enhance the construction level of new SCCs.

The remainder of the study is as follows. A summary of the literature on the state of smart city research is provided in Section 1. Research object and methods are then introduced in Section 2. The ideas and metrics used to build the system for assessing the construction level of new SCCs in Shandong Province are tackled in Section 3. Section 4 sees prospective issues and flaws examined together with the geographical variances in construction levels for new SCCs in Shandong. Following these findings of the assessment, Section 5 provides appropriate policy suggestions. The study finally provides a conclusion of the study's findings, assesses its flaws, and identifies possibilities for future studies.

1. Literature review

SCC creation has reached new heights in development given the novel breakthroughs in Information and Communication Technology (ICT), making more drastic changes in social structure, production, and way of life. Although many scholars have examined the smart city from various angles and areas, the assessment subject, measurement indicators system and measurement methodologies are the current focus of extant studies on measuring smart cities from a construction level.

For the measuring object, studies have assessed the stage of smart cities from the perspective of both single and multiple cities. Fan et al. (2016) investigated the stage of creation of smart cities using specific cities as examples thus making their exploration more specific, the recommendations more targeted, and provides recommendations reference for other cities. The construction levels of two or more cities can be compared and analyzed when assessing the level of smart city construction when investigating the development expertise of leading cities (even the construction inadequacies of lagging regions) to explain the purpose and direction of smart city construction and to develop strategies to raise smart city construction

levels (Liu et al., 2018). Beijing, Tianjin, Shanghai, and other cities have rich experience in smart city construction, thus choosing these cities as research objects provide other cities with further experience and a more mature perspective in smart city construction. The Chinese Province of Guangdong was also used as a research object to assess the ideas and directions of smart city construction and provide other local governments with a reference for promoting smart city construction and the scientific planning implementation of smart city strategies (Li et al., 2018).

For the evaluation indicators system of the construction level of the new SCC, most extant studies choose from infrastructure, information resources, technological innovation and other aspects. Smart city development surely requires both hardware and software infrastructure, and ICT advancement also needs the pooling of human capital. Additionally, the development of new SCCs of involves significant government involvement, thus an assessment system can be built from 3 directions: technology, people, and system (Nam & Pardo, 2011). To gauge the growth of smart cities in small and medium-sized Chinese cities, Qi and Ba (2016) first established a framework for smart city by measuring indicators based on infrastructure level, intelligent application level, governmental implementation, and general population support network. Shen et al. (2018), following the China Smart City Wisdom Degree Measurement Report, partitioned the evaluation indicators of smart city development into five components, namely infrastructure, people, governance, economy, and environment along with 18 representative indicators. All these point to smart city construction ultimately being a complex system project. A scalable dispersed smart city measurement system may be created by combining smart devices, ICT, and development processes when constructing a smart city which greatly considers the utilization of big data and information technology (Yan et al., 2020).

Hierarchical analysis, TOPSIS, and principal component analysis have all been used to assess smart city construction level. Qi and Ba (2016) evaluated and analyzed it using hierarchical analysis and provided helpful references for future smart city development planning. Liu (2016) also evaluated the smart city development using both the entropy approach and TOPSIS for building an assessment indicators system. Qu (2016) established the measurement indicators system of smart city construction potential from five aspects: information infrastructure, economic development level, scientific and technological support capability, urban industrial development level, and urban competitiveness. This was done by systematically sorting out the smart city measurement indicators system in each region and conducting measurement analysis through the principal component analysis. Some extant studies also evaluated the smart city construction level from a spatial perspective, including using geostatistical analysis and weight-based methods to build an urban planning information measurement system. This spatial integration of information measurement systems provides another foundation in designing smart cities (Persai & Katiyar, 2018).

The measurement perspective, measurement indicators system, and measurement method of these studies' results could forward a source for the evaluation of new Shandong SCCs at the construction stage. However, traditional smart cities measurement received the most attention in the current study, compared to new smart cities and their city clusters which re-

ceived less attention. Concurrently, the chosen approach requires additional development to analyze regional disparities, while the developed indicators system should further accurately reflect the features of emerging SCCs.

To analyze their spatial differences when assessing the construction level of new SCCs in Shandong Province, it is necessary to first combine the specifications and characteristics of new smart city construction, followed by building a suitable measurement indicators system, and finally choosing a suitable method. This study assesses the construction level of new SCCs in Shandong Province using the entropy method and examines the geographical variations between economic circles and cities based on the three main economic circles in the province through the Moran index.

2. Research objects and methods

2.1. Research subjects

Unlike traditional SCC, new SCC seeks to create a full system of services which benefit the population through a shared and inclusive information resource system and an effective urban governance system, thereby effectively advancing the fusion of urban development and information technology and ultimately achieving high-quality economic development. Since China entered the stage of new smart city construction, the province of Shandong has actively responded to various enabling national policies. In 2019, Shandong Province issued China's first provincial-level local standards for new smart city construction and subsequently carried out provincial-level pilots in some regions. In 2020, Shandong launched the "Shandong Province New Smart City Construction Indicators", becoming the first set of provincial local standards for improving the development of new SCCs through grading and classification. Documents such as the 14th Five-Year Plan for the Construction of a Digital Strong Province in Shandong Province, the Guiding Opinions on Accelerating the Construction of New SCC, and other related documents clarified the planning and route for the creation of new SCCs and were subsequently released by the Shandong Provincial Government. A total of 12 prefecture-level cities in the province were chosen as part of the Top 100 digital cities in 2022 according to the 2022 China Digital City Competitiveness Research Report, making it the province with highest number of cities in the list. Shandong has also emerged as a model province in the creation of a new SCC in northern China.

Though the creation of new SCCs is the main objective of Shandong Province's 14th Five-Year Plan the document also emphasizes the need to accelerate the construction of 3 economic circles (the provincial capital economic circle or PCEC, the Jiaodong economic circle or JDEC, and the Lunan economic circle or LNEC), establish an effective economic circle collaboration mechanism, and enhance cross-city and cross-regional cooperation mechanisms. Given the abovementioned three economic circles referred herein namely as the PCEC, JDEC, and LNEC, this study examines the building stage and growth of Shandong Province's new SCC. It specifically explores the degree of construction and geographical variations of new SCCs in Shandong Province and makes rational policy recommendations based on the local circumstances.

2.2. Research methodology

2.2.1. The research methodology and feasibility analysis

1. Entropy method

Entropy, originally a physical concept, has been increasingly used by digital infrastructure and information theory scholars to calculate the degree of information uncertainty. When information entropy is low, disorder is likewise low and, in turn, indicates greater indicator reliability. Meanwhile, when information entropy is high, disorder is also high and, in turn, indicates poorer indication reliability. The method is reliable in objectively assigning weights, whose primary step is calculating the weight coefficients based on how different each assessment indication is from the others (Shi et al., 2022). It has also been widely used in mechanical efficiency measurement (Yu et al., 2022), energy storage charging station performance measurement (Zhang et al., 2022a), data system maturity measurement (Zhang et al., 2022b), and other subject areas.

In assessing the new SCC's building status in Shandong Province, indicator weights were calculated using the entropy approach, which simplifies the calculation process and increases the efficiency of indicators processing without compromising result accuracy, thereby making the process of dealing with a complex measurement system with numerous indicators more objective and straightforward (Han & Liu, 2011).

2. Moran Index

Scholars generalizing the research objects or data tend to consider whether some spatial connection exists between different research objects – this is especially true when it comes to spatial relationships. Here, spatial autocorrelation was thoroughly evaluated using the Moran index (Zhang et al., 2020; Fotheringham, 2009). The Moran index has been widely used in disciplines such as environmental efficiency analysis of public buildings (Liu et al., 2021), ecological quality assessment (Karbalaei et al., 2021), and coordination analysis of social security and economic development (Li et al., 2021).

The Moran index objectively could depict the geographical disparities in the construction level of new SCCs in Shandong as a thorough assessment approach to quantify spatial autocorrelation. Thus, the Moran index is used herein to assess the spatial autocorrelation between cities and economic circles in the development of new SCCs.

2.2.2. Research method specifics

First, the construction level of new SCCs in Shandong Province was evaluated and analyzed using the entropy approach. Then, the spatial differences were analyzed using the Moran index and were executed as follows:

1. Data normalization based on standardized translation

When usually evaluating the research object, differences in type and dimension normally exist between indicators. Hence, this study adopts the standardized translation entropy method to standardize the indicator data and eliminate the influence of indicator scale on the measurement results (Zhu & Wei, 2015). To harmonize the assessment metrics for the Shandong

Province's new SCC's construction level, the current study employed the expression below:

$$X_{ij} = \frac{X_{ij} - \overline{X_j}}{S_j} \left(i = 1,2,\ldots n; j = 1,2,\ldots m\right), \tag{1}$$

where $\overline{X_j} = \frac{1}{n}\sum_{i=1}^{n} X_{ij}$ and $S_j = \frac{1}{n}\sum_{i=1}^{n}(X_{ij} - \overline{X_j})^2$ $(j = 1,2,\ldots m)$ are the sample mean and sample standard deviation of the *j*th measurement indicators value, respectively.

2. Calculation of weight value and measurement indicators based on entropy method

From Eq. (1), the dimensionless data X'_{ij} will show negative values after normalization, which is required in the entropy method $X_{ij} \rangle 0$. Therefore, X'_{ij} need to be translated to obtain the new data.

(1) Normalization

Let $R_{ij} = X'_{ij} + A$, A be the translation amplitude, and ensure that $R_{ij} \rangle 0$. The following expression thus holds true:

$$P_{ij} = \frac{R_{ij}}{\sum_{i=1}^{n} R_{ij}}. \tag{2}$$

(2) Deriving the indicator entropy value

The entropy value of the *j*th E_j indicator is,

$$E_j = -k\sum_{i=1}^{n} P_{ij} Ln P_{ij}, \tag{3}$$

where, $k = \frac{1}{Lnn}$, where *n* is the number of cities and $0 \le E_j \le 1$.

(3) Deriving the indicator entropy redundancy D_j.

$$D_j = 1 - E_j. \tag{4}$$

(4) Calculation of the weight W_j results.

$$W_j = \frac{D_j}{\sum_{i=1}^{m} D_j}. \tag{5}$$

(5) Construction level indicators calculation.

Using the weight method combined with Indicators weighting summation, the comprehensive measurement indicators T_j is calculated as the following expression:

$$T_j = \sum_{j=1}^{n} W_j \times X'_{ij}. \tag{6}$$

3. Spatial variation analysis based on the Moran index

(1) The global Moran index calculation

The global Moran index *I* was obtained based on the composite measurement indicators derived using the entropy method above and combined with Eq. (7), which is expressed as follows:

$$I = \frac{\sum_{i=1}^{n}\sum_{j\neq 1}^{n} w_{ij}\left(x_i - \overline{x}\right)\left(x_j - \overline{x}\right)}{S^2 \sum_{i=1}^{n}\sum_{j\neq 1}^{n} w_{ij}}, \tag{7}$$

where, I denotes the global Moran index, x_i denotes the construction level indicators of city i, w_{ij} denotes the spatial weight matrix, and the Queen spatial adjacency method is used herein.

(2) Based on the global Moran index, a test for Z was conducted and was calculated as follows:

$$Z = \frac{1 - E(I)}{\sqrt{V(I)}}, \tag{8}$$

when Z is equal to 0, spatial components are independent of one another. When greater than 0, spatial components are positively correlated with one another: the higher the value, the stronger the correlation. When less than 0, spatial components are negatively correlated with one another: the stronger the value, the stronger the correlation.

(3) Calculation of local Moran index

The local Moran index was obtained by combining Eq. (9) as I_i which was as follows:

$$I_i = \frac{n(x_i - \overline{x})\sum_{j=1}^{n}(x_j - \overline{x})}{\sum_{i=1}^{n}(x_i - \overline{x})}. \tag{9}$$

The value I_i of is not limited to [–1, 1]. The greater the absolute value, the greater the degree of gathering. A positive value indicates that the space has the same properties as the surrounding region, while a negative value shows that the spatial unit has differing attributes from the surrounding area.

3. Measurement indicators system of the new SCC construction level

Pivotal to assessing the construction level of SCCs is applying a set of indicators which are both scientific and sensible. By reviewing the literature in related fields of the new SCC, the evaluation indicator system of the construction level of the new SCC was determined based on the "14th Five-Year Plan for Building a Digital Strong Province in Shandong Province" and the "Shandong Province New Smart City Pilot Demonstration Construction Work Plan" issued by the Shandong Provincial Government. The evaluation system of the construction level of new SCC is formed from the four aspects of social livelihood, economic production, innovation-driven development, and safeguard measures. See Table 1 below for details.

Social livelihood (C_1) – The daily needs of city dwellers increase as the SCCs are developed. The goals and priorities of a new SCC's construction should therefore be determined by quickly understanding public wants current issues. The creation of the new SCC hinges on a human-centered design, and the information and digital development of the new SCC could enhance the public's daily work efficiency and life quality. The digital inclusive finance indicators (C_{11}) may show how inhabitants' everyday lives and jobs have improved from a

Table 1. Measurement indicators system of the new SCC construction level

Primary Indicators	Primary Indicator Weights	Secondary indicators	Secondary Indicator Weights
Social livelihood C_1	0.2419	Digitally-inclusive finance indicators C_{11}	0.0533
		Employed population shares of information technology industry C_{12}	0.0411
		Broadband Internet penetration C_{13}	0.0487
		Government data openness indicators C_{14}	0.0486
		Local government Internet service capacity C_{15}	0.0501
Economic production C_2	0.2402	Proportion of e-commerce in GDP C_{21}	0.0488
		Number of computers per 100 people C_{22}	0.0485
		Proportion of enterprises with e-commerce activities C_{23}	0.0424
		Number of new foreign-invested enterprises C_{24}	0.0439
		Proportion of tertiary industry output in GDP $_{C2}5$	0.0571
Innovation-driven development C_3	0.2544	Provincial model digital economy park C_{31}	0.0558
		Provincial small and micro enterprise entrepreneurial innovation demonstration base $_{C3}2$	0.0464
		Enterprises entering the cultivation base of high-tech enterprises in Shandong Province in 2020 C_{33}	0.0479
		Percentage of government spending on science and technology C_{34}	0.0528
		Comprehensive science and technology innovation level indicators C_{35}	0.0512
Safeguard measures C_4	0.2635	Proportion of R & D expenditure in GDP C_{41}	0.0602
		Proportion of R & D research and experimental development personnel in employment C_{42}	0.0521
		Number of effective invention patents increased by 10,000 people C_{43}	0.0453
		Change in talent demand (%) C_{44}	0.0561
		Number of college students per 100,000 people C_{45}	0.0497

variety of angles, such as the intensity of usage, scope of coverage, and level of digitalization. The employed population's shares of information (C_{12}) may also show how SCC alters the people's labor force participation rates and labor income (Guo et al., 2020; Ojo et al., 2019).

The Internet has also assumed an important basic support role in the living and consumption fields, along with production, manufacturing, finance, and commerce, thus broadband Internet penetration (C_{13}) reflects the construction level of digital infrastructure (Oloja et al., 2019; Rajabiun & Middleton, 2013). Local governments act as organizers and decision-makers in the process of building local SCCs, and they also strive to build smart governments. Thus, the government data openness indicators (C_{14}) and local government Internet service capability (C_{15}) are used to reflect the digitalization level of each government (Attard et al., 2015; Jakaitis et al., 2009).

Economic production (C_2) – SCC construction promotes economic development, and the development of economic production could, in turn, improve the development of new SCCs construction, creating a feedback loop where both are complementary and develop synergistically. The digitalization of enterprises plays an important role in regional industrial upgrading, green development, and intelligence enhancement, hence the proportion of e-commerce in Gross Domestic Product (GDP) (C_{21}), number of computers per 100 people (C_{22}), and the proportion of enterprises with e-commerce activities (C_{23}) reflects the development degree of digitalization of enterprises in each region (Haji, 2021; Peng et al., 2021; Sarma & Pais, 2011).

With the growing trend of economic globalization, foreign investment has increased the diversity of capital composition and has become an important part of the economic motive force to promote SCC construction, with the number of new foreign-invested enterprises (C_{24}) characterizing the scale of foreign investment (Ye et al., 2021; Zeng et al., 2012). The generation of positive environmental advantages, as well as the realization of socioeconomic benefits, should all be taken into account when creating an SCC centered on big data and information technology. Because the key to quickening the conversion of old and new movements and encouraging the development of SCC is the industrial structure, the proportion of tertiary industry output in GDP (C_{25}) is used to characterize the industrial structure (Agumbayeva et al., 2019; Cheng et al., 2018).

Innovation-driven development (C_3) – The development of new ICT may effectively assist the creation of new SCCs because the vitality of new SCCs hinge on innovation-driven growth and intelligence-led development. The pilot policies of SCC have effectively promoted economic development and technological innovation; hence the general direction of established policy innovation should be maintained. This means that the provincial model digital economy park (C_{31}), the provincial small and micro enterprise entrepreneurial innovation demonstration base (C_{32}), and enterprises entering the cultivation base of high-tech enterprises in Shandong in 2020 (C_{33}) reflect the willingness of communities to implement national programs and the significance of local governments in building SCC clusters (Lounsbury et al., 2019; Nambisan et al., 2019; Sahut & Peris-Ortiz, 2014; Zeng et al., 2010). The development and innovation of technology, which requires good environment and material protection, cannot be separated from government support. Thus, the percentage of general public spending on science and technology (C_{34}) and the comprehensive science and technology innovation level indicators (C_{35}) are used herein to reflect the importance of local government to technological innovation (Wang et al., 2021; Kogan et al., 2017; Baden-Fuller & Haefliger, 2013).

Safeguard measures (C_4) – The building of a thorough system of safeguard measures is necessary to ensure the new SCC construction's seamless implementation due to it being a lengthy and complicated systemic project. Advancements in technology and science support the creation of SCCs with sustainable growth, improve the ability of independent innovation, usher key breakthroughs in technology, and inject new vitality to economic development. Simultaneously, social progress could also be promoted, thus the proportion of Research and Development (R&D) expenditure in GDP (C_{41}) and the proportion of R&D and experimental development personnel in employment (C_{42}) both reflect the importance of science and

technology innovation, while the number of effective invention patents increased by 10,000 people (C_{43}) reflects scientific research output (Janssen & Abbasiharofteh, 2022; Audretsch & Belitski, 2020; Huang & Chen, 2020; Heij et al., 2020). Human capital is a crucial component in creating SCCs and is a supporter of scientific and technical progress. However, as China's population ages and the demographic dividend gradually disappears, the "talent dividend" becomes a fresh engine for Chinese economic progress – human capital thus becomes characterized by both the change in talent demand (C_{44}) and the number of college students per 100,000 people (C_{45}) (Gerhart & Feng, 2021; Sima et al., 2020).

4. Empirical analysis

4.1. Measurement of the construction level of the new SCC in three economic circles of Shandong Province

The entropy method was used herein to determine the weights of each indicator based on the measurement indicators system and indicator data of the construction level of new SCCs in Shandong Province (see Table 1 above for details). The scores of the three main economic circles and each city in the comprehensive level were then calculated based on their respective weights (as shown in Table 2, Appendix Table A1). The construction levels of new SCCs were compared at the economic circle level, while the average construction level indicators

Table 2. Construction level indicators of new SCCs in Shandong Province

Economic Circle	City	Social livelihood	Economic production	Innovation-driven development	Safeguard measures	City Composite Indicators	Economic Circle Composite Indicators
PCEC	Jinan	4.567	3.827	4.894	3.997	4.323	3.031
	Zibo	2.625	3.019	3.131	3.128	2.981	
	Dongying	2.995	3.075	2.992	3.515	3.151	
	Tai'an	3.003	2.374	2.748	2.515	2.659	
	Dezhou	2.317	2.569	2.816	3.003	2.685	
	Liaocheng	2.422	2.544	2.149	2.669	2.447	
	Binzhou	2.459	2.606	3.186	3.553	2.968	
JDEC	Qingdao	4.27	5.397	3.735	3.722	4.26	3.413
	Yantai	3.047	3.518	3.557	3.021	3.283	
	Weifang	3.229	3.156	3.622	3.095	3.276	
	Weihai	3.674	3.065	3.133	2.76	3.15	
	Rizhao	3.002	2.697	2.845	3.78	3.094	
LNEC	Zaozhuang	2.933	2.425	1.966	2.318	2.403	2.431
	Jining	3.007	2.388	2.825	2.231	2.607	
	Linyi	2.561	2.723	2.309	2.738	2.583	
	Heze	1.888	2.616	2.089	1.953	2.131	

of the cities contained in each economic circle was used as SCC construction level indicators at the economic circle level due to the differences in the number of cities included in each circle. Issues which transpired during the building of a new SCC in Shandong Province were examined from the perspectives of both the economic circle and construction dimension by comparing the scores of each city in an economic circle. The data used in this research are from Shandong Statistical Yearbook, China Urban Statistical Yearbook, the bulletin of Shandong Provincial Department of Industry and Information Technology, and the statistical bulletin of national economic and social development of each city in Shandong Province.

To observe the construction level of SCC in each economic circle and city more intuitively and clearly, this study classifies the SCC construction indicators of 16 cities in three economic circles of Shandong Province into four levels: strongly high, slightly high, medium, and low levels by natural breakpoint method (Bao et al., 2022).

The indications of the construction level of new SCCs in each of the three major economic circles are shown in the top half of Figure 1 below, while the indicators of the level of city creation are shown in the lower half of the same Figure. JDEC in Shandong Province has the greatest construction level with a "strongly high" level, followed by the PCEC which is at a "slightly high" level, and then by the LNEC which is at a "low" level. The new SCC construction level is clearly different in each of the 16 cities comprising the province's economic hub, thereby demonstrating the overall tendency that the new smart city construction level

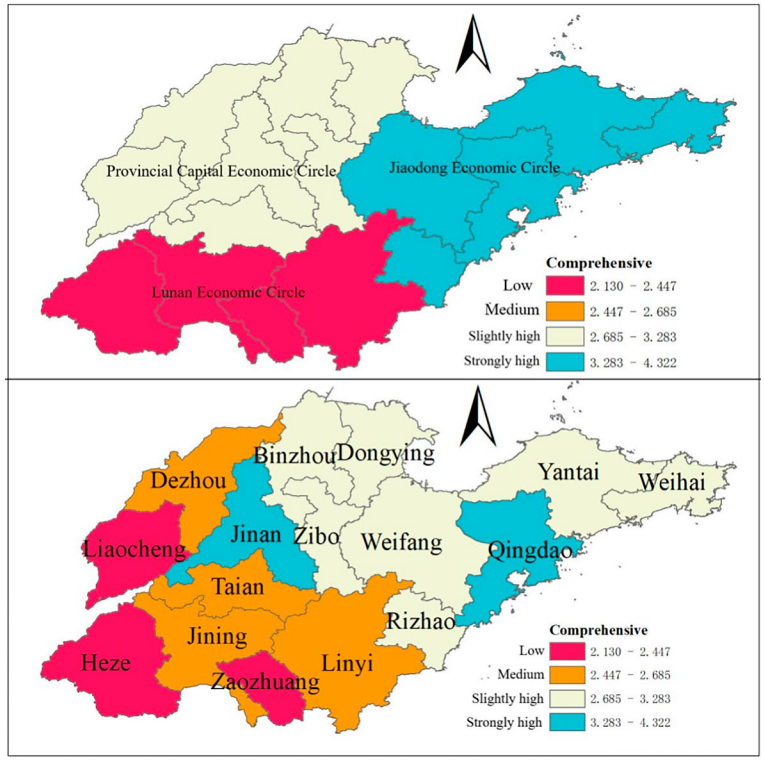

Figure 1. Comprehensive construction level indicators of new SCCs in Shandong Province

in the eastern area is higher than that in the western region. The new smart city construction level of each city in JDEC is at both "slightly high" and "strongly high" levels. Although the PCEC *in toto* is at a "slightly high" level, the city of Jinan, which is included in the PCEC, is at a "strongly high" level. This differs from the city of Liaocheng which has a "low level", making the PCEC the only economic circle with all four types of construction levels. The construction level of the SCC in the LNEC is relatively backward compared with the other two economic circles, and the best construction level cities, Jining and Linyi, are only "medium" level, compared to Heze and Zaozhuang which are at a "low" level.

To further examine the construction level of new SCC in all three economic circles, this study analyzes the construction level of new SCC in each economic circle in detail from the four dimensions of social livelihood, economic production, innovation-driven development, and safeguard measures (Figure 2 below provides further details).

(1) PCEC

① Social livelihood – The PCEC has outstanding development scores on the social livelihood dimension. Among them, Jinan's social livelihood indicator is 4.567, which is at a "strongly high level". Meanwhile the social livelihood indicator of Liaocheng, Binzhou, Dezhou, and Zibo are in 2.317~2.625 range, denoting a "medium" level.

② Economic production – Its economic production indices vary from 2.374–3.827. Clearly, there is a regional imbalance in the economic production of various cities in the PCEC.

③ Innovation-driven development – From the innovation-driven analysis perspective, the PCEC could be split into two groups: the first group is Jinan and is led by cities with relatively high construction levels. This includes the city of Jinan, Binzhou, Zibo, and Dongying whose innovation-driven development indicator value ranges from 2.992~4.894, of which Jinan is at a "strongly high" level; the second group is cities

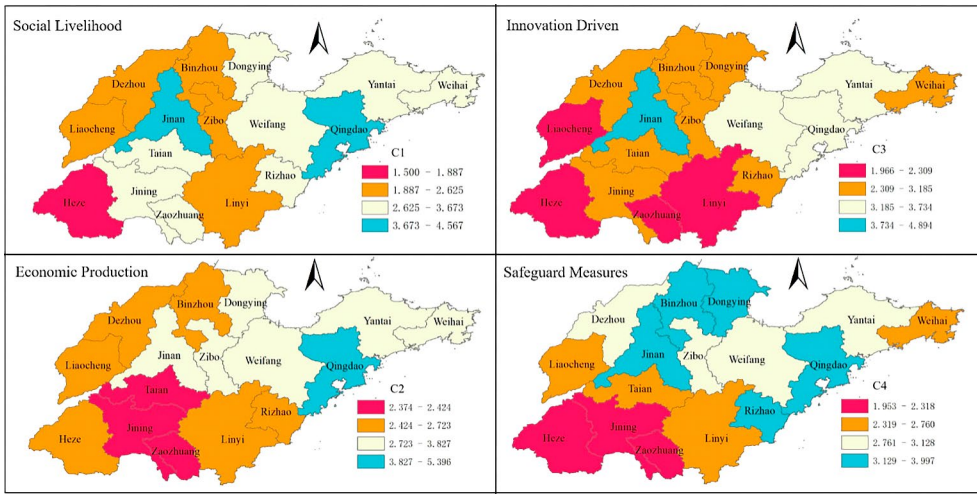

Figure 2. Construction level indicators of new SCCs in Shandong Province by dimension

with relatively low construction levels, including Dezhou, Tai'an and Liaocheng, and the value range of the innovation drive indicator is 2.149~2.816.

④ safeguard measures – From the social safeguard measures dimension, the PCEC is outstanding: Jinan, Zibo, and Dongying are at a "strongly high" level, while both Liaocheng and Tai'an relatively lag behind at a "medium" level with their safeguard measures ranging from 2.515–3.997.

(2) JDEC

① Social livelihood – The JDEC also has outstanding development scores, with social livelihood indicators ranging from 3.002–4.270 and are all at the "slightly high" level and above.

② Economic production – For economic production, the city of Qingdao leads with a score of 5.397 and is the only city in the province with a "strongly high" level. The others are also in a leading position, with economic production indicators ranging from 2.697–5.397 (all with the exception of the city of Rizhao, which is at the "medium" level. The other four cities are at the "slightly high" level).

③ Innovation-driven development – From this dimension, the construction level of cities is at a "slightly high level" and "medium" level with innovation-driven development indicators ranging from 2.845–3.735. The city of Qingdao has a "slightly high" level and the cities of Rizhao and Weihai are at a "medium" level.

④ Safeguard measures – The quantitative indicators of safeguard measures range from 2.760–3.780, where the cities of Rizhao and Qingdao have outstanding performance in the dimension of safeguard measures and are both at a "strongly high" level. Weihai is at a "medium" level and should thus improve its emphasis on human resource and talent introduction and cultivation.

(3) LNEC

① Social livelihood – The performance of the LNEC in the social livelihood dimensions is average, with only the cities of Jining and Zaozhuang being better developed and having a "higher" level. The construction level of the cities of Linyi and Heze are relatively low, with social livelihood indicator values ranging from 1.888~3.007.

② Economic production – From the economic production perspective, the construction level of economic production is relatively low, with the value of the economic production indicator ranging from 2.388~2.723.

③ Innovation-driven development – From the innovation-driven development perspective, the innovation-driven development indicators of cities in the LNEC range from 1.966–2.825 which are at a low level (except for Jining, which is at a "medium" level).

④ safeguard measures – From the safeguard measures dimension, a significant gap exists between the LNEC and the other two economic circles, with the LNEC's values ranging from 1.953 to 2.738.

4.2. Analysis of spatial differences in the construction level of new SCCs in three economic circles of Shandong Province

4.2.1. Spatial differences in the construction levels of new SCCs in Shandong Province from the perspective of economic circles

The SCC construction activities in each economic circle and city within Shandong Province are not isolated from each other: they even have a spatial correlation. With the data presented in Table 2, this study counts the global Moran index of the construction level of new SCCs at a value of 0.117 along with a p-value of 0.020, and it passes the significance level test at the 5% level, it thereby supports spatial correlatedness hypothesis forwarded herein.

To further analyze the local spatial correlation of each city in the new SCC in Shandong, the GeoDa software was used to calculate the local Moran index and a scatter diagram was drawn (as shown in Figure 3), with black representing cities in the PCEC, red representing cities in the JDEC, and blue representing cities in the LNEC. The specific analysis here is as follows:

(1) Low-low gathering area – This area is mostly found in cities in the LNEC in Shandong Province's southwest. Heze, Jining, and Zaozhuang in the LNEC have relatively low construction levels, and are thus jointly part of the low-low gathering area.

(2) High-high gathering area – This area is mostly in cities within the JDEC. These include the cities bordering Qingdao, all of which are coastal cities.

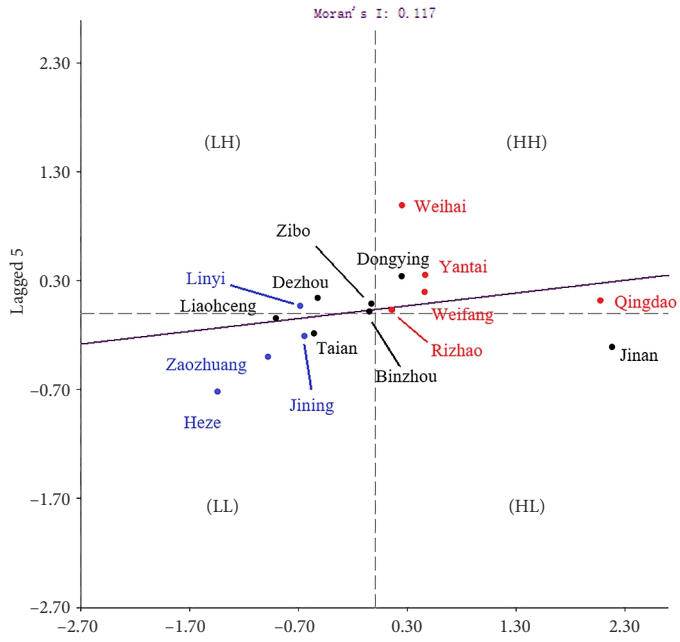

Figure 3. Local Moran index scatter diagram of the construction level distribution of new SCC in Shandong Province in 2020

(3) Low-high gathering area – The low-high gathering area includes the cities of Zibo, Dezhou, Binzhou, and Linyi. Following Figure 1, Linyi is at the "medium" level, while Zibo, Weifang, and Rizhao in its vicinity are at the "slightly high" level in terms of construction level, and are therefore also assigned to the low-high gathering area.

(4) High-low gathering area – Only the city of Jinan is in the high-low gathering region. As the central city of the PCEC, Jinan's construction level is significantly greater compared to other cities.

4.2.2. Spatial differences in the construction level of new SCC in Shandong Province under the construction dimension

To analyze the construction level of the new SCC in further detail, this study further analyzes the four directions of social livelihood, economic production, innovation-driven development, and safeguard measures. Following Table 2, GeoDa software was used to derive the global Moran index (Table 3). Table 3 shows that the social livelihood Moran index, economic production Moran index, and innovation-driven development Moran index are at 0.135, 0.095, and 0.075 respectively. All these pass the 5% level significance test. the Moran index of safeguard measures is 0.169, which also passes the 1% level significance test.

Global index sometimes masks the instability of local states (Pravitasari et al., 2014). To further reveal the degree of spatial clustering of social livelihood, economic production, innovation-driven development, and safeguard measures on a local scale, Geoda software was used to conduct linear system analysis (LISA) cluster analysis on 2020 data which resulted in a table showing their spatial autocorrelation. The spatial autocorrelation and spatial differences are shown in Table 4.

(1) PCEC development scores are complicated and the development of each city is uneven. Jinan, as the core city of Shandong Province, is located in a high-low gathering area in four dimensions. From the social livelihood dimensions, the PCEC does not form a high-high gathering area: the cities of Dezhou, Binzhou, Zibo, and Liaocheng are in the low-low gathering area, having construction levels at the "medium" level. From the economic production dimension, Zibo and Dongying are in the high-high gathering area due to their high construction level and their proximity to the JDEC, which has a high construction level. Tai'an, Liaocheng, Binzhou, and Dezhou are classified into the low-low gathering area because they are at the "medium" level and below. For the innovation-driven development dimension, Zibo and Binzhou scored higher and were adjacent to Jinan, hence were in a high-high gathering area. The cities of Dongying, Dezhou, Liaocheng, and Zibo, along with neighboring Binzhou and Jinan scored high, and were thus assigned to the low-high gathering area due to their own poor construction level. From the safeguard dimension, this forms a high-value gathering area, with Dezhou, Binzhou, Zibo, and Dongying in the high-high gathering area.

On the whole, it has only formed a valuable gathering area in the dimension of safeguard measures, but relatively lags behind in the construction of the three dimensions, namely social livelihood, economic production, and innovation driving is relatively lagging behind, with more cities scoring low that those scoring otherwise. Therefore, the PCEC should play a supporting role and create a promotion mechanism brought by the safeguard measures,

Table 3. Global Moran's I in different dimensions

Construction Dimension	Moran's I	p-value
Social Livelihood	0.135	0.048
Economic production	0.095	0.014
Innovation-driven development	0.075	0.040
safeguard measures	0.169	0.004

Table 4. Regional clustering of SCCs' construction level by dimension

Dimensionality	Economic Circle	High-high gathering area	Low-high gathering area	Low-low gathering area	High-low gathering area
Society and people's livelihood	PCEC		Dongying	Dezhou, Liaocheng, Binzhou, Zibo	Jinan, Tai'an
	JDEC	Weifang, Weihai			Rizhao, Qingdao, Yantai
	LNEC	Jining	Linyi	Heze, Zaozhuang	
Economic production	PCEC	Dongying, Zibo		Tai'an, Liaocheng, Binzhou, Dezhou	Jinan
	JDEC	Weifang, Qingdao, Yantai, and Weihai	Rizhao		
	LNEC		Linyi	Jining, Heze, Zaozhuang	
Innovation-driven development	PCEC	Zibo, Binzhou	Dongying, Dezhou, Liaocheng	Tai'an	Jinan
	JDEC	Weifang, Qingdao, Yantai. Weihai		Rizhao	
	LNEC		Linyi	Jining, Heze, Zaozhuang	
Safeguard measures	PCEC	Dezhou, Binzhou, Zibo, Dongying	Liaocheng	Tai'an	Jinan
	JDEC	Weifang, Qingdao, Yantai	Weihai		Rizhao
	LNEC		Linyi	Jining, Heze, Zaozhuang	

strengthen the new supply of the digital society, accelerate the digital transformation of the industry, build a digital technology innovation platform system, and comprehensively promote the development of a new SCC.

(2) The JDEC has formed high-value gatherings in all dimensions, mainly comprised of the cities of Qingdao, Yantai, Weifang, and Weihai. From the social livelihood dimension, it is at a "slightly high level", with the cities of Weifang and Weihai in a high-high gathering area, and Qingdao, Yantai, and Rizhao in a high-low gathering area. For the economic production dimension, Qingdao, Yantai, Weifang, and Weihai boast a higher construction level and are all in a high-high gathering area. Meanwhile, the city of Rizhao is classified as a low-high gathering area because it exists at the "medium level". From the innovation-driven development dimension, its baseline situation is roughly the same as the economic production dimension; the only difference is that Rizhao is influenced by the "low level" of Linyi and is thus assigned to the low-low gathering area. For safeguard measures, Rizhao, which performs poorly in the economic production and innovation-driven development dimensions, has a high construction level and is far ahead of its neighboring cities in the high-low gathering area.

Generally, the JDEC has formed a high-value gathering area in four dimensions. Among which, Rizhao is in a low-low gathering area in the innovation-driven dimension, making it necessary to further strengthen the innovation drive.

(3) The LNEC is relatively backward in terms of overall construction level, resulting in a clustering of mainly low-value cities. In terms of social livelihood dimensions, Jining is assigned to the high-high gathering area due to its outstanding performance. Meanwhile Linyi, Heze, and Zaozhuang have relatively poor construction levels: Linyi is assigned to the low-high gathering area due to the influence of the other two economic circles, while Heze and Zaozhuang are in the low-low gathering area. The assignment of the LNEC is consistent in the three dimensions of economic production, innovation-driven development, and safeguard measures. All four cities are in low-value areas because of their relatively low development level. Zibo, Weifang, and Rizhao, which are adjacent to Linyi, are much higher than Linyi in construction levels, putting Linyi in the low-high gathering area.

Jining is also generally in a high-high gathering area in the dimension of social livelihood, with other cities being in low-value gathering areas. Results herein demonstrate that while creating a new smart city, the LNEC should further strengthen the construction of social livelihood, economic production, innovation drive, and safeguard measures.

4.3. Comprehensive analysis of the construction level of new SCCs in three economic circles of Shandong Province

The analysis of the scores and spatial differences of the construction level of SCCs in Shandong Province reveal that the construction level of SCCs in Shandong Province is uneven in terms of overall construction dimensions. The specific contents were analyzed from the perspective of both economic circles and construction dimensions.

4.3.1. Comprehensive analysis of the construction level of New SCC in Shandong Province under the economic circle

The creation of SCCs in various economic circles, as depicted in the charts, and the analyses presented above are further described in this section.

(1) The new SCC construction level in Shandong Province remains in an unbalanced state of development. From Figure 1, the construction level of new SCC in the three major economic circles vastly differs, with cities in the JDEC largely being in a "strongly high" level area and cities in the LNEC largely being in a "low level area". Although the PCEC is in the "slightly high" level area, the cities within the circle are divided into four classes. Therefore, Shandong Province should strengthen the institutional framework for regional coordinated development in the creation of new SCC, encourage the integrated development of the three major economic circles of the provincial capitals of Jiaodong and Lunan, establish mechanisms for inter-city and interregional cooperation, and increase regional innovation and development momentum to comprehensively enhance the competitiveness of the province's three major economic arteries.

(2) The construction level of the PCEC is unbalanced in both the singular and overall dimensions. From Figure 2 and Table 4, Jinan is in a high-low concentration area in all four dimensions, and its construction level is much higher compared to neighboring cities. Jinan should continue to improve the leading role of radiation and improve interactions and collaboration with surrounding cities in the exchange and cultivation of skills, knowledge, and resources as the economic center of the provincial capital to jointly build a high-quality economic development demonstration zone and a national kinetic energy conversion regional transmission area.

(3) Following Figure 1, the construction level of the JDEC is at a "strongly high level" and is ahead of the other two economic circles. From Appendix Table A1 and Table A2, it is clear that numerous small and medium-sized enterprises can be found in the JDEC, although the enterprises' digitalization level remains relatively low. Therefore, the economic driving ability of the JDEC is enhanced to provide power for technological innovation and enterprise digitalization.

(4) Figures 1 and 2 reveal that the construction level of new SCC in the LNEC is relatively low – this is mainly due to the relatively large proportion of rural areas and rural population in the LNEC combined with the weak digital infrastructure and the relatively low level of economic development. Therefore, the LNEC should further promote urbanization, focus on the construction of digital villages, encourage the simultaneous development of urban and rural areas, and establish a test region for rural revival and a new highland for change and development.

4.3.2. Comprehensive analysis of the construction level of new SCCs in Shandong Province under the construction dimension

This study combines the measurement results of construction level of new SCCs in Shandong Province and analyzes the common problems among cities in the four dimensions of social livelihood, economic production, innovation-driven development, and safeguard measures.

(1) Social Livelihood

After analyzing the construction level of new SCC in Shandong Province from the social livelihood dimensions coupled with the results shown in Table A1 and Figure 2, it is clear that the application of digital technology in the cities of Liaocheng, Dezhou, Rizhao, Linyi, and Heze should be further popularized. Moreover, Heze and Liaocheng are poorer compared to other cities. Therefore, the construction investment in digital infrastructure should be increased to encourage the establishment of new SCC and accelerate the pace of digital change.

Additionally, by combining indicators C_{14} and C_{15} in Table A1, it shows that the digitalization levels of the local governments in the cities of Zibo, Dongying, and Heze are low, indicating that there remain shortcomings in the construction of smart government in these three cities, and that smart government construction should be sped up to encourage the development of additional SCCs.

(2) Economic production

By analyzing the construction level of the new SCC in Shandong Province from the economic production dimension along with the indicators C_{25} in Table A1, it is clear that Zibo and Dongying, both old industrial bases, have a large gap in the industrial structure and in converting old and new dynamic energy compared to other cities. These cities should therefore focus on the adjustment of industrial structure, strive to develop smart industries, and promote the transformation of both new and old dynamic energy.

By also combining indicators C_{21} and C_{23} in Table A1, it is clear that Tai'an, Weifang, Jining, and Zaozhuang have deficiencies in the degree of enterprise digitization and e-commerce construction. Once e-commerce is poorly developed as an important part of economic development, it eventually leads to the backwardness of the region in economic production. Hence, these cities should focus on developing e-commerce and improving their respective degrees of enterprise digitization.

(3) Innovation-driven development

Technological innovation development heavily hinges on government support. By analyzing the construction level of new SCC in Shandong Province from the innovation-driven development dimension and combined with the indicator C_{34} in Table A2, it is clear that the local governments of Liaocheng, Dongying, Dezhou, Heze, Zaozhuang, and Linyi should continue to serve as a model for the creation of future SCCs, enthusiastically enable certain government advantages, and provide a favorable environment for technological innovation.

Additionally, by combining the indicators C_{31}, C_{32}, and C_{33} in Table A2, the cities of Liaocheng, Qingdao, Rizhao, Weihai, Jining, and Zaozhuang are seen relatively lagging behind in digital transformation, and should therefore continue promoting policy pilot work, focusing on strengthening support for the construction of provincial model digital economy parks, support the construction of provincial demonstration bases for entrepreneurship and innovation of micro and small businesses, and the cultivation of high-tech enterprises.

(4) Safeguard measures

The development of SCC cannot be built without a guarantee of "soft power" such as talents. Innovative talents are powerful engines for economic expansion and are the primary force of technological innovation. The city of Zaozhuang has a low level of human capital

formation, resulting in a weak "soft power" for building new SCCs. The city should strengthen the cultivation of "soft power", including the introduction of talents and the cultivation of local talents, so as to provide continuous impetus for Zaozhuang's economic expansion and technological innovation.

5. Policy recommendations

Previous sections have assessed the construction level of new SCCs in Shandong Province, examined the spatial variations, and highlighted possible issues. From the perspective of the economic cycle and the construction dimension, this study provides recommendations to increase the construction level of new SCCs in Shandong Province in response to possible issues.

5.1. Suggestions for improving the construction level of new SCCs in Shandong Province under the economic circle

Following the analysis results in Chapter 5, considering the heterogeneity of economic circles and cities, the synergistic enhancement strategy of construction level among economic circles should first be formulated from local adaptation and synergistic linkage. Then, according to the construction level of new SCCs in each economic circle along with the traits of the economic circles themselves, enhancement strategies are separately proposed.

5.1.1. Analyze the heterogeneity of economic circles and cities to promote synergistic linkage development

(1) Policies of Shandong Province

Each region in Shandong has a varied construction content, stage, and status. Hence, these diverse features should be duly considered when developing regulations and making suggestions. In the course of developing the new SCC, certain differences in the building subject matter, building method, and construction process of each city exist due to the diversity of its resource endowment and level of economic growth. Consequently, the direction and course of the development should be chosen by considering the region's population, history, geography, economic and social development, and information technology foundation. Thus, when formulating the smart city construction plan, government departments at all levels should carefully sort out the needs and develop a smart city construction plan according to real local circumstances, duly considering the heterogeneity of development in different regions.

(2) Policy Extension

Great amounts of effort should also be exerted into fostering cross-regional synergy when creating a new SCC. This means breaking down administrative barriers and building regional SCC construction management institutions as the first steps in further reforming the oversight system for a more effective SCC construction. Maximizing synergistic benefits, understanding the many factors influencing the institutional structure of the creation of new SCCs (and understanding the forces of supply and demand), establishing a more responsive

and introspective institutional framework, and effectively matching institutional supply and demand structures are all necessary in building an effective and balanced institutional structure system.

The creation sequence and content of the new SCC should also be properly defined during the entire construction process, and the leadership role of incentive construction regulation should also be completely used. To enhance oversight efficiency in SCC creation, it is also essential to strengthen certain development regulations, update methods used to monitor construction regulations, and extensively use contemporary information technology tools such as Arcgis, communication satellites, and remote sensing.

5.1.2. Improve the radiation-driven role of core cities and promote the regional synergistic development of the PCEC

(1) Policies of PCEC

Jinan, having the highest level of new smart city construction in Shandong Province, is in the high-low concentration area, compared to neighboring Tai'an, Liaocheng, Dezhou, and Binzhou which are in the "medium" level and below. The present state of the construction level of the future smart metropolis in the PCEC shows an uneven state, hence enabling conditions should be in full swing to enhance Jinan's radiation-driven role, strengthen the synergistic development in the PCEC, accelerate industrial transformation and upgrading, become springboards for further development, and build a demonstration area for high-quality economic development and key location for regional conduct of dynamic national energy.

(2) Policy Extension

The focus of regional coordinated development is realizing the barrier-free and cross-border flow of resources and production factors along with advantages such as talent, technology, capital and information from core cities to neighboring cities who often have a short supply – tapping the potential of the vast market space of surrounding cities effectively alleviates the usually harmful levels of congestion seen in urban areas and core cities. This outward flow of advantages provides several necessary conditions. Specifically, it balances the region-wide development gap, realizes the unimpeded flow of factors such as people, logistics, capital, and information, ejects various non-market-oriented behaviors which entrench administrative boundaries, creates a policy system based on regional whole, fully stimulates the role of market, innovation, and cooperation mechanisms in SCC construction and regional coordinated development, improves regional coordination capabilities through a cooperative (instead of competitive) system design, and ultimately improves the overall construction of regional SCCs.

5.1.3. Stimulate the vitality of market players and improve the economic driving ability of the JDEC

(1) Policies in the JDEC

The level of economic development found in the JDEC favorable, although the distribution of resources and firm assistance policies both need improvement. Additionally, technical advancement and business digital transformation are entirely driven by economic expansion. Therefore, the JDEC should completely apply new ICT when developing new SCCs to ad-

vertise information sharing and interoperability as part of the free flow and scientific allocation of factor resources to improve the market performance. Additionally, policies should be scientifically developed to ease the financial limitations on businesses, increase resource allocation efficiency, lower operational expenses, and support the high-quality growth of businesses. Enterprises should also fully utilize the policy dividend during this time, prioritize innovation, increase their market competitiveness, improve the standard of internal management, lessen information asymmetry within and outside of the enterprise, and achieve the high-quality economic development of the enterprise as a whole.

(2) Policy Extension

The presence of large-scale small and medium-sized businesses in the area have emerged as a fresh impetus to aid in the growth of nearby SCC and smart enterprises. Local governments should seek to increase labor productivity and enterprise income when creating policies to help businesses. They should also work together to support the growth of the regional economies. Government should also develop policies to support the growth of small and medium-sized businesses in the area following the region's own development, combine the traits of industries and regions, adhere to the principle of comprehensive planning and adapting to local conditions, encourage businesses to energetically take part in new SCC creation, and support the integration and development of smart industries.

5.1.4. Build digital villages and promote the new SCC construction in the LNEC

(1) Policies of LNEC

Being a significant agricultural province, Shandong has a sizable rural population as well as rural regions that are part of the LNEC. The creation of the new SCCs and digital countryside should be coordinated and promoted, and efforts should be made to encourage the integrated growth of digital urban and rural regions as the LNEC builds SCC. This should accelerate the expansion of urban internet infrastructure into rural areas, enhance the accessibility of technology services, improve free movement of urban and rural elements in both directions, fairly distribute common resources, and establish a digital urban-rural integration growth pattern which connects the city and the countryside while also building and sharing together.

(2) Policy Extension

The development of digital villages and SCC clusters was based on digital infrastructure. Due to its significant positive ripple effect, its performance and popularity define the breadth and depth of the digital economic growth. There should, however, be a specific order of priority coupled with the critical construction regions, including places with big populations but have poor infrastructure, when supporting digital infrastructure projects in vast rural areas. Additionally, the government should provide enabling infrastructure along with the necessary financial support. The local government should also increase the degree of rural digitalization and informatization along with the integration of urban and rural digitalization. They should also encourage the full use of new ICT in agricultural and rural economic growth. The government can even create a pilot area for urban and rural digital integration, establish an urban-rural linkage mechanism, promote the early successes and experience of SCCs construction on the countryside, and achieve the efficient connection and coordinated development of new SCCs construction and digital rural construction.

5.2. Suggestions for improving the construction level of new SCCs in three economic Circles of Shandong Province under the construction dimension

To fully address the common problems in different construction dimensions in each region, this study combines the measurement results of new SCC construction level in Shandong Province found in Chapter 5 and proposes corresponding countermeasures and suggestions for common and salient problems in the four dimensions in each city to provide a reference for encouraging Shandong to build new SCCs.

5.2.1. Social livelihood

(1) Advance the creation of new smart city infrastructure and accelerate the progress of digital transformation

Information infrastructure is the fundamental and guarantee of new smart city construction and importantly promotes future city construction and high-quality economic development, whereas Liaocheng, Dezhou, Rizhao, Linyi, and Heze keep relatively low construction level in new infrastructure and further integrate traditional infrastructure with new ones. Concurrently, local governments should promote the construction of information, digitalization, and intelligence, accelerate the building of new infrastructure represented by GIS, cloud computing, and the urban Internet of Things, and create a centralized innovation service platform for smart city development and accelerate technological innovation. The local government should also build infrastructure such as roads, high-speed railways, base stations, and other infrastructure projects, play its diffusion effect to ensure the steady development of ICT, prevent the phenomenon of mismatch between new technologies and infrastructure, help narrow the regional economic gap, and realize the integrated construction of new SCCs in Shandong.

(2) Build a smart government and promote smart city construction

The quick advancement and widespread use of new ICT aids in the building of smart government systems. Currently, the cities of Zibo, Dongying, and Heze prove to have a relatively low level of government digitization and require further improvement in the building of smart government. While promoting the new SCCs construction, governments of all regions generally control the construction direction and construction method of new SCCs, and realize the refinement, intelligence, and socialization of government management and public services, which promotes the creation of new SCCs. Digital governance, as a widely used means of realizing smart government, allows online services to promote the quality and efficiency of public services, and is an unavoidable step towards a new model of smart government, is the newest trend in the future development of smart government and is gradually becoming a prominent component in the creation of new SCCs.

(3) Policy Extension

For citizens to comprehend and realize the improvements in the quality of life brought about by the construction of SCCs, the government should actively promote new ICT, which also means the creation of community training institutions. Local government agencies should avoid the leaking of residents' personal information, define who has access to what data, and assure data security when employing enormous data for digital governance, and

open sharing of data. To better accelerate the development of smart government and SCCs, rapid development should be pursued as part and parcel of ensuring information and data security. Data security and data authority attribution are thus crucial components and are guarantees in raising the quality of government to digital governance.

5.2.2. Economic production

(1) Develop smart industries, and promote the transformation of old and new dynamics

The cities of Dongying and Zibo in the PCEC are old industrial bases: the traditional industries account for a high proportion, being confronted with the pressure of industrial upgrading, should accelerate the successive conversion of the old and new dynamics, adhere to the direction of high-end, smart, and green oriented development, and promote the digitalization, smart transformation, and upgrading of the industry. Therefore, the cities of Dongying and Zibo should increase their industrial structure adjustment, combine industrial industry with digitalization and informatization, vigorously develop "manufacturing industry + Internet", "manufacturing industry + artificial intelligence", "manufacturing industry + Big Data", and empower traditional industries with digitalization and intelligence. When promoting SCC creation, government should base on overall national industrial development and fully consider the actual situation of the cities themselves and promote industrial upgrading by developing smart industries.

(2) Develop e-commerce and improve enterprise digitalization

The cities of Tai'an, Weifang, Jining, and Zaozhuang have a relatively poor development level in e-commerce and should therefore attach more importance to the role of e-commerce in regional industrial upgrading, green development, and smart level upgrading, establish the service consciousness of the supporting industry development, improve platform, logistics, talent, and park support along with other software and hardware necessary for industry development, and ultimately strive to create a favorable growth environment for its development. Enterprises should also fully utilize the policy dividend from the development of SCC, effectively enhance independent R&D and innovation level, reduce internal and external information asymmetry, and optimize the internal control quality. They should also start from the long term, accelerate the digital technology layout in various fields of enterprise production, management, and marketing (among others), lower labor expenses, and enhance operational and company production efficiency for them to gain a stronger competitive advantage and recognize their own digital growth.

(3) Policy Extension

The government should also strengthen its policy orientation, delegate an authority to manage and use fiscal funds, actively carry out the creation of infrastructure, and improve the efficient creation of SCCs construction. It should also introduce and improve relevant policies and bills to provide financing facilities for traditional enterprises, help enterprises invest more conveniently in R&D, and promote traditional enterprises to realize industrial digitalization and intelligence as soon as possible. Cities with more traditional enterprises should further increase investment in the creation of new SCCs and enhance their level of urban intelligence, informatization, and digitalization following the actual trend of larger digital economy development.

5.2.3. Innovation-driven development

(1) Focus on the government's function and capitalize on its benefits

As an administrative subject, the government has guidance and authority in the creation and operation of new SCCs. The local governments of Liaocheng, Dongying, and Dezhou in the PCEC and Heze, Zaozhuang, and Linyi in the LNEC need to attach importance to the whole planning of the new SCC, integration of urban resources, policy guarantee, and standard setting to provide favorable conditions and environment for the creation of the new SCC. When developing new SCCs, the government can provide financial and material guarantees for science and technology innovation by increasing financial expenditure on science and technology.

(2) Continuously promote policy pilot work

Liaocheng, Rizhao, Weihai, Jining, and Zaozhuang have relatively poor digital transformation scores and have fewer pilot areas. These cities should therefore summarize the typical experiences and practices of pilot cities (such as Jinan and Qingdao) share the typical experiences and practices with other cities, and improve the collaborative progress of new SCCs in Shandong Province. Jinan has effectively promoted local technological innovation and economic development through policies such as setting up e-commerce demonstration areas, model digital economy parks and smart factories – these show that the established policy practice has achieved more significant results and is a typical case of policy innovation for economic progress and helping the development of new SCC.

(3) Policy Extension

All cities should adhere to the general direction of existing policy innovation, follow the support and guidance of the government for each smart city pilot area, and constantly explore new ideas for policy practice. Local governments should also take the establishment of national smart city demonstration cities as a starting point, deepen their respective supply-side structural reform, and continuously provide policy support and guidance to pilot cities to allow them to become demonstration highlands for development of SCCs.

Meanwhile, the government can summarize the development experience of existing pilot cities and strive to make pilot SCC construction more expansive in combination with the new indicator systems and development concepts. When setting up new pilot cities, it is also necessary to consider differences in population size in different regions along with social factors such as administrative level and factor resources. This means that the construction of SCC should seek common ground while reserving differences, combine the actual development of local conditions, fully utilize regional advantages, and execute targeted and reasonable strategic positioning for urban development.

5.2.4. Safeguard measures

(1) Continuously promote "hardware and software" construction of SCC

Both the "human factor" and "material factor" play a role in different dimensions of SCC construction. Dezhou, Liaocheng, Weihai, Jining, and Zaozhuang should attach importance to the value of talent in enhancing regional smart city construction. They should provide a good material foundation for talents. The PCEC also wants to become a national dynamic

energy conversion demonstration area, while the LNEC wants to become a new highland of transformation development – both of these should enhance the importance of human capital. Dezhou, Liaocheng, Weihai, and other cities in the LNEC should nonetheless prioritize the value of talent in advancing the creation of regional SCCs, further improve the level of local talent training, and actively court foreign talent and technology to fully participate in the development of local SCCs to provide enough knowledge supply to advance the creation of SSCs and materialize their own local industrial revolution. Central government should thus offer a superior hardware and software environment for talent, accentuate regional strengths, and promote the cultivation and introduction of talent. Local governments should also formulate more active, open, and effective policies to support talents, improve the incentive and assessment mechanisms for the innovation of talents, and provide competent individuals with additional incentives and more liberty to encourage their innovative efforts.

(2) Policy Extension

The creation of SCCs and the emergence of breakthrough companies in technology forms a gathering effect of human capital and other factors, which promotes industrial upgrading and enrichens the current understanding of the SCC building process. This provides further impetus to abandon the extensive traditional development path and choose the path of technological innovation and economic development. Cities with no established talent-gathering hubs can draw on the development experience of advanced regions, rely on new ICT, realize the development of industrial information networks, hasten the integration of traditional industries and the digital technology sector, boost operational efficiency in the sector, and encourage the enhancement and modernization of industrial structure.

Conclusions

Shandong also proposed in its 14th Five-Year Plan building a new picture of a better digital life and create a new national SCC. In the course of new SCC creation in the province, various problems and areas for improvement inevitably spring up. This mainly includes strengthening the driving role of core cities, stimulating the vitality of market players, building digital villages, accelerating digital transformation, increasing government support, and improving the level of human capital. This study aims to improve these contents and increase the development of new SCCs in three major economic circles in Shandong Province along with (and as part of) the high-quality economic development of the province.

The three economic circles of Shandong Province serve as the research object herein and was explored following objective and systematic standards. A measurement system for the construction level of SCCs was established, and both the entropy method and Moran index were used to examine the construction level and spatial variations of new SCCs. The following recommendations are forwarded based on the analysis: 1) The PCEC should improve its current imbalance in regional development; 2) The JDEC should augment its economic driving force; 3) The LNEC should improve its existing enabling infrastructure, along with the specific improvement measures of each city in the four aspects of social livelihood, economic production, innovation-driven development, and safeguard measures.

Scholarly discussion on the creation of new SCCs and following related studies can use the research concepts, methodologies, and countermeasure recommendations herein as reference. However, due to the length limitation, an in-depth analysis of the new smart city construction level of each single economic circle was not conducted. Future studies may fill this gap and analyze the potential problems and shortcomings of every economic circle and propose countermeasures in a more targeted and specific manner.

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Author contributions

Author Contributions: Xuhui Cong was responsible for the organization of survey, data analysis, and discussion; Sai Wang was responsible for the data collection and analysis; Zhipeng Qi was responsible for the literature review; Liang Wang was responsible for the research design and data analysis; Mirosław J. Skibniewski was responsible for the linguistic check and modification.

Disclosure statement

The authors declare no conflict of interest.

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APPENDIX

Table A1. Scores of each indicator of social livelihood and economic production

City	Indicators									
	C11	C12	C13	C14	C15	C21	C22	C23	C24	C25
Jinan	0.257	0.266	0.247	0.223	0.112	0.138	0.245	0.120	0.134	0.283
Zibo	0.175	0.161	0.141	0.090	0.069	0.194	0.131	0.158	0.112	0.130
Dongying	0.197	0.122	0.194	0.099	0.112	0.242	0.200	0.156	0.106	0.035
Tai'an	0.130	0.111	0.112	0.106	0.267	0.096	0.102	0.104	0.110	0.160
Dezhou	0.079	0.104	0.110	0.105	0.162	0.114	0.129	0.123	0.101	0.150
Liaocheng	0.094	0.102	0.102	0.124	0.162	0.131	0.104	0.098	0.106	0.172
Binzhou	0.127	0.106	0.135	0.114	0.112	0.143	0.101	0.127	0.101	0.154
Qingdao	0.243	0.134	0.231	0.262	0.162	0.242	0.237	0.270	0.267	0.280
Yantai	0.189	0.118	0.162	0.156	0.112	0.183	0.176	0.118	0.190	0.179
Weifang	0.163	0.112	0.140	0.153	0.213	0.184	0.151	0.096	0.152	0.175
Weihai	0.213	0.114	0.206	0.194	0.162	0.128	0.161	0.114	0.159	0.175
Rizhao	0.169	0.109	0.115	0.171	0.162	0.118	0.166	0.110	0.102	0.152
Zaozhuang	0.154	0.107	0.135	0.151	0.162	0.093	0.109	0.107	0.117	0.157
Jining	0.146	0.104	0.115	0.150	0.213	0.091	0.116	0.098	0.120	0.149
Linyi	0.149	0.102	0.112	0.145	0.112	0.109	0.109	0.104	0.128	0.205
Heze	0.072	0.101	0.080	0.092	0.112	0.140	0.093	0.136	0.103	0.157

Table A2. Score of each indicator of innovation-driven development and safeguard measures

City	Indicators									
	C31	C32	C33	C34	C35	C41	C42	C43	C44	C45
Jinan	0.286	0.262	0.245	0.210	0.242	0.213	0.249	0.102	0.252	0.238
Zibo	0.160	0.125	0.141	0.159	0.211	0.219	0.214	0.094	0.187	0.109
Dongying	0.160	0.154	0.112	0.153	0.183	0.196	0.186	0.136	0.217	0.191
Tai'an	0.160	0.174	0.098	0.102	0.165	0.183	0.132	0.110	0.137	0.101
Dezhou	0.160	0.105	0.159	0.156	0.136	0.252	0.136	0.125	0.102	0.177
Liaocheng	0.160	0.086	0.116	0.085	0.101	0.226	0.112	0.179	0.103	0.082
Binzhou	0.160	0.125	0.151	0.241	0.134	0.260	0.179	0.177	0.122	0.199
Qingdao	0.286	0.125	0.096	0.204	0.239	0.195	0.241	0.093	0.222	0.229
Yantai	0.160	0.105	0.228	0.232	0.180	0.135	0.178	0.110	0.168	0.205
Weifang	0.160	0.213	0.218	0.198	0.132	0.177	0.142	0.139	0.149	0.208
Weihai	0.160	0.115	0.157	0.162	0.203	0.185	0.192	0.108	0.170	0.073
Rizhao	0.160	0.125	0.096	0.213	0.130	0.245	0.150	0.272	0.141	0.188
Zaozhuang	0.033	0.125	0.116	0.110	0.116	0.102	0.101	0.151	0.115	0.142
Jining	0.160	0.174	0.149	0.117	0.118	0.105	0.124	0.128	0.119	0.112
Linyi	0.160	0.105	0.118	0.115	0.090	0.156	0.095	0.152	0.098	0.221
Heze	0.160	0.105	0.106	0.081	0.079	0.041	0.070	0.100	0.083	0.220