Evaluation of Shenzhen's Technological Sustainability Development Using SDGs Comprehensive Index

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Abstract. This paper constructs an evaluation system for Shenzhen's technological sustainability development based on the Sustainable Development Goals (SDGs) of the United Nations. It aims to comprehensively assess the level of technological sustainability in Shenzhen. Corresponding SDGs indices are selected under two dimensions of technological productivity and technological support capability. The entropy weight method is utilized to calculate the weights of different indicators. The evaluation of Shenzhen's technological sustainability is then conducted using social statistical data from 2008 to 2022. The results show that Shenzhen's sustainability development composite index has continuously increased over the past fifteen years. Although the COVID-19 pandemic hindered Shenzhen's technological progress, its average annual growth rate still exceeded 2.6% during this period.

Keywords: SDGs, Comprehensive Index, Sustainability Development.

1 Introduction

In 2015, during the 70th United Nations General Assembly, 193 member states unanimously adopted the 2030 Agenda for Sustainable Development (2023 ASD). This comprehensive agenda comprises 17 Sustainable Development Goals (SDGs) and 169 specific targets [1]. The primary objective of these goals is to address challenges across the realms of finance, societal dynamics, and ecological considerations in an integrated manner, aiming to guide humanity toward a path characterized by enduring sustainability and robust adaptability [2]. SDG 8 centers on fostering growth in the economy, generating employment opportunities, and ensuring dignified work for all; SDG 9 strives to establish infrastructure with resilience, encourage sustainable industrial development, and cultivate innovation; SDG 16 endeavors to establish societies characterized by peace and inclusivity, ensuring access to justice for everyone, alongside effective and accountable institutions at every level; and SDG 17 enhances the mechanisms for execution and revitalizes global collaborations to promote sustainable development [3-6]. These SDGs can serve as indicators to evaluate Shenzhen's technological sustainability.

Monitoring and statistical work on the 2023 ASD is a core task for the international statistical community in the next decade and beyond. Accurate and sufficient data can quantify a country or region's sustainable development status and reflect the implementation and progress towards

MSIEID 2023, December 08-10, Guangzhou, People's Republic of China

DOI 10.4108/eai.8-12-2023.2344387

the agenda [7, 8]. However, the large number of indicators and abundant data make it difficult to express the index content in a readable way using just statistics and textual descriptions. This is not conducive to reviewing and analyzing a country or sub-region's sustainable development status over a year or several years [9-11]. Constructing an evaluation index system that maps development indicators in a specific field to corresponding SDGs remains an active research area.

As a frontier city for technological development in China, Shenzhen also needs to further enhance its international influence and soft power in science and technology cooperation [12]. However, in the field of technological innovation, Shenzhen still faces many problems and challenges, including inadequate top-level design and mechanisms, the need to improve modes and depth of technological innovation and cooperation, and shortage of specialized talents [13]. This study aims to construct a comprehensive index evaluation system for Shenzhen's technological sustainability using SDGs indicators and existing socio-economic data. The calculation of weights for each indicator, leading to the derivation of the corresponding composite index for technological sustainability, employs the entropy weight method (EWM). This method can also serve as an evaluation basis for other cities.

2 Methodology

2.1 SDGs Indicator System

Drawing on the theoretical essence of sustainable development and employing the Sustainable Development Goals Global Indicator Framework (SGIF) as the basic framework, this study constructs an indicator system with reference to the “SGIF for the SDGs”, combined with Shenzhen's current sustainable development status. By sorting out the correspondence between relevant indicators and SDGs, the indicator system for Shenzhen's sustainable development oriented to SDGs is established from two dimensions: technological productivity and technological support capability.

This study selects 7 evaluation indicators to assess the region's technological sustainability by mapping to SDGs indicators. Specifically, (1) Technological productivity: invention patent grants per 10,000 population corresponds to the proportion of Gross Domestic Product (GDP) allocated to research and development expenditures, as outlined in SDGs indicator 9.5.1; number of scientific researchers corresponds to SDGs indicator 9.5.2 measures the density of researchers per million inhabitants in full-time equivalent, while SDGs indicator 9.b.1 assesses the proportion of value added from medium and high-tech industries in the total value added within the industrial sector; (2) Technological support capability: Per capita GDP corresponds to the rate of annual growth in real GDP per capita, denoted by SDGs indicator 8.1.1, and the percentage of standard college students, in accordance with SDGs indicator 8.6.1, which evaluates the share of youth (aged 15-24 years) not participating in education, employment, or training; government sci-tech funds as a percentage of general public budget expenditure corresponds to indicator 16.6.1 of SDGs examines the ratio of primary government expenditures to the initial approved budget, categorized by sector (or budget codes or equivalent classifications); broadband Internet users per 10,000 population corresponds to SDGs indicator 17.8.1 assesses the percentage of the population utilizing the Internet. The specific indicator system is shown in Table 1.

Table 1. Shenzhen SDGs indicator system for technological sustainability.

Heading level	Indicator Name	Corresponding SDGs Indicators
Technological Productivity (TP)	Authorized invention patents per 10,000 population	9.5.1 Evaluates the share of GDP allocated to research and development activities
	Number of scientific researchers	9.5.2 Measures the density of researchers in full-time equivalent per million inhabitants
	Proportion of High-tech Product Output Value in Total Industrial Output Value	9.b.1 Percentage of value added from industries classified as medium and high-tech in relation to the overall value added
Technological Supporting Capacity (TSC)	Per Capita GDP	8.1.1 Yearly percentage increase in the real GDP per person
	Proportion of Undergraduate Enrollment in Universities and Colleges	8.6.1 Percentage of individuals between the ages of 15 and 24 who are not engaged in education, employment, or training
	Proportion of Government Science and Technology Funding in General Public Budget Expenditure	16.6.1 Percentage of primary government expenditure within the initial approved budget, categorized by sector or code
	Broadband Internet Subscribers Per 10,000 People	17.8.1 Percentage of individuals within the population who have access to and utilize the Internet

2.2 Sustainable Development Index

Weights calculated based on information entropy can better avoid evaluation bias to some extent, and have been widely used in fields such as ecological environment assessment, economic development, and social sciences [14-16]. Therefore, this study adopts utilizing a method based on entropy to assign weights to individual indicators. It summarizes the index values of Shenzhen's corresponding 7 socio-economic systems from 2008 to 2022 for analyzing the dynamic changes of technological sustainability at different levels over time. The calculation steps of the entropy weight method are as follows:

(1) Data normalization: the min-max normalization method is used to process all the data. The normalization formula is as follows:

$$a_{it}^* = \frac{a_{it} - min(a_{it})}{max(a_{it}) - min(a_{it})} \quad (1)$$

where ait represents the value of the i indicator at time t. A positive value indicates the indicator promotes sustainability, and a higher value means a higher level of sustainability. A negative value means the indicator hinders sustainability, and a higher absolute value means a lower level of sustainability.

(2) Calculate the information entropy ei of the ith indicator over the whole time period, as shown in the following formula:

$$e_i = -\frac{1}{\ln n} \sum_{t=1}^{n} a_{it}^* \times \ln a_{it}^*, 0 \leq e_i \leq 1 \quad (2)$$

(3) Calculate the weight wi of the ith indicator, which reflects the importance of that indicator.

$$w_i = \frac{1 - e_i}{\sum_{i=1}^{n} (1 - e_i)} \quad (3)$$

(4) The technological sustainability composite index is used to evaluate the technological development level of each year.

$$U_{it} = \sum_{i=1}^{n}(w_i \times a_{it}^{*}), t = 1,2,3 \quad (4)$$

3 Results

3.1 Weight calculation

The weighted values for each indicator are: SDGs 9.5.1 - 19.42%, SDGs 9.5.2 - 11.42%, SDGs 9.b.1 - 14.69%, SDGs 8.1.1 - 10.63%, SDGs 8.6.1 - 19.69%, SDGs 16.6.1 - 13.52%, SDGs 17.8.1 - 10.63%. The specific proportions are shown in Fig. 1.

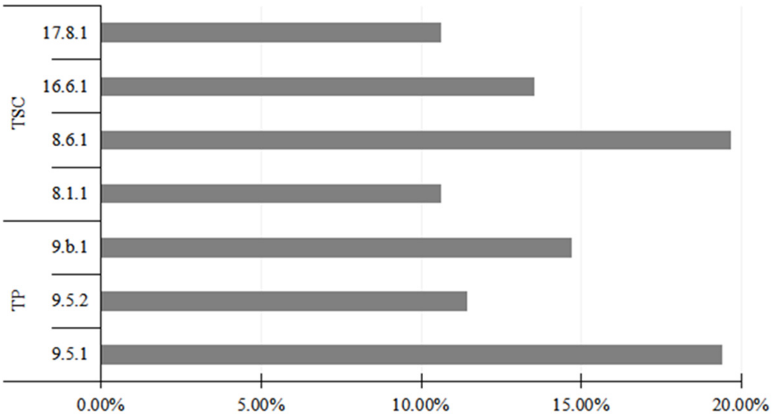

Fig. 1. Weight results for each SDGs

3.2 Evaluation of technological sustainability

Based on the constructed evaluation system for Shenzhen's sustainability, the sustainability indexes from 2008 to 2022 were calculated, as shown in Figure 2. Over time, Shenzhen's sustainability level showed an overall upward trend, with the sustainability index increasing from 0.3185 in 2008 to 0.6825 in 2022, a growth of 93.48%.

Further analysis of Figure 2 shows that Shenzhen's sustainability development presented a regulated growth pattern. Taking 2018 as a demarcation point, it can be divided into two periods - fluctuating upward period (2008-2018) and fluctuation period (2018-2022). From 2008 to 2022, the fluctuation pattern of the sustainability index curve basically presented an "M" shape, with certain declines in 2010-2012 and 2019-2021 respectively. It is inferred that this was due to a significant decrease in the government sci-tech fiscal support index in 2019-2021, which was speculated to be affected by policy-based risk control during the COVID-19 pandemic, with more government funding allocated for epidemic prevention and control.

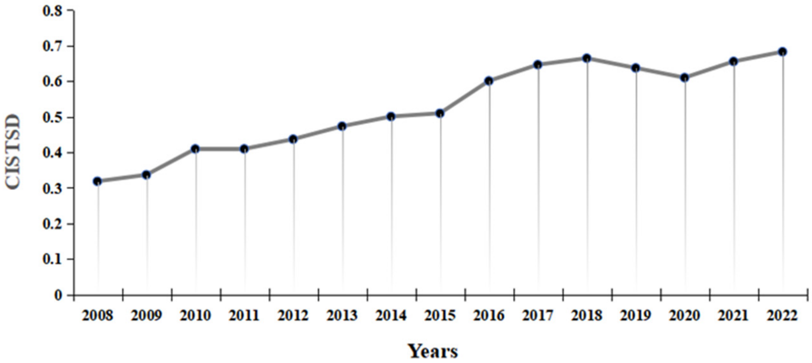

Fig. 2 Comprehensive index of Shenzhen's technological sustainability development (CISTSD)

4 Conclusions

Based on the SDG-based comprehensive evaluation system for Shenzhen's technological sustainability, this paper comprehensively assessed the level of Shenzhen's technological sustainability.

The evaluation results show that Shenzhen's sci-tech industry has performed outstandingly in terms of sustainable development, with a high overall index score, indicating that Shenzhen's sci-tech industry has achieved good results in economic development, resource conservation and environmental protection. The average growth of indicators in the past 15 years was 2.6%, but there are still some problems and challenges due to policies and international situations.

Moving forward, it is essential to continue strengthening sci-tech innovation, promoting green development, enhancing international cooperation and exchanges, and making greater contributions to achieving global sustainable development goals. At the same time, it is also necessary to strengthen policy guidance and market mechanism construction to promote resource conservation and environmental protection, and push forward the sustainable development of Shenzhen's sci-tech industry.

Acknowledgements. This research has been supported by the Special Fund of Guangdong Education Department (2020KZDZX1196), Huizhou Social Science Planning Project (HZ2023GJ129) and Huizhou University Doctoral Initiation Project (2022JB019).

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