Analysis of Spatial-Temporal Evolution of Quality of Life in counties in Shandong Province

Jiaxi Chen 1*, Zifang Yu 2

1 College of surveying and Mapping Science and Engineering, Shandong University of Science and Technology, Qingdao, Shandong Province, 266510, China
2 College of surveying and Mapping Science and Engineering, Shandong University of Science and Technology, Qingdao, Shandong Province, 266510, China

*Corresponding author’s e-mail: 472847628@qq.com

Abstract: Existing researches on the quality of life have mostly used socio-economic data for analysis and less research on the use of multi-source data; more research on large cities and less research on small and medium-sized regions; more research on single years and less research on evolution. This article uses Shandong province as an empirical case, using multiple data sources such as remote sensing data, PM2.5 meteorological data, socio-economic data, by selecting key indicators, a county-level quality of life indicator system based on the three dimensions of economy, society, and the environment was constructed, and using a variety of spatial analysis methods to analyze the quality of life in 137 counties (cities) in Shandong Province in the four years from 2000 to 2015. The results are as follows: (1) The overall spatial difference in the quality of life in Shandong Province is quite large, and the polarization is severe. (2) Unbalanced development in all dimensions; unbalanced development of quality of life in municipal and non-municipal districts. (3) Radiation power is not strong in high quality of life areas, lack of core cities in low quality of life areas. According to the status quo, this article proposes reasonable targeted measures and suggestions.

1. Introduction
The core of the concept of development has always been "people-oriented", and the improvement of the quality of life is the key to the implementation of the concept of people-oriented development [1]. With the rapid development of economy, people's consumption level and purchasing power are also gradually improving. the living standards of residents have been significantly improved, and spiritual and material life has been enriched. As the product of the development of civilization, the city is the carrier of economic development, maintaining the vital interests and happiness of the people. In the National New urbanization Plan (2014-2020) issued by the State Council in 2014, the State Council pointed out that we must deeply realize the great significance of urbanization to economic development, persist in taking urbanization as the core, and take improving the quality of urbanization as the goal, so as to improve the quality of life of the people. On October 18, 2017, General Secretary Xi Jinping pointed out at the 19th CPC National Congress that the principal contradiction in China's society has been transformed into a contradiction between the people's growing needs for a better life and unbalanced and inadequate development, ensuring and improving people's livelihood has become the most concerned issue for the people, and it is also the most important issue at this stage. Only when the people's quality of life is
improved can the people gain a sense of happiness. In China, the concept of building a harmonious society and "people-oriented" development emphasizes that social development should be "people-centered", so the improvement of people's quality of life has become a new goal of China's current urban development.

In 1958, the American economist Galbraith put forward the concept of quality of life for the first time in his book the affluent Society. In 1967, the American sociologist Wade studied the quality of life as a separate field. In recent years, foreign academic circles continue to explore the research methods of urban quality of life. In 2016, Si Chen and others used GIS technology to extract land use features, thus put forward an objective urban quality of life measurement method [3]. Hasnett Devan et al used data aggregation method to assess urban sustainability and quality of life in (Kamloops), a small city in Canada, in 2016, and proposed that this method is suitable for any region to assess sustainability and quality of life [4]. In 2019, Ioanna Anna and others put forward the paradigm of "human scale development". They think that this method can define the quality of life index more comprehensively, and make a quantitative study on the weight of the index [5]. From a geographical perspective, evaluating the quality of life has become the norm., Huynh D T studied the quality of life of Ho Chi Minh City residents in a typical urban model in 2015 [6], Sommers B ranked 16 counties in Maine in 2016 [7]. In terms of research scale, some scholars have refined the study area to towns. In 2013, Rezvani M R used subjective and objective indicators to measure the quality of life in the town of Nulabad, Iran, and graded the happiness of a family, while revealing the importance of subjective and objective dimensions [8]. In 2017, Ezgi Taçoral et al. assessed the quality of life in the Turkish town of Kemaliya under the traditional residential model, and studied the impact of socio-cultural, infrastructure and regional factors on the quality of life [9].

The research on the field of quality of life in China began in the middle and late 1980s, represented by Professor Lin Nan, who combined the methods of questionnaire survey and mathematical statistics [10]. Taking Lin Jihong as the representative, based on the questionnaire survey results of 13 cities in Jiangsu Province, this paper makes an empirical study on Jiangsu concentrated residential areas by using structural equation model [11]. In 2016, Youfang selected 15 central cities for economic development across the country to study the quality of life of residents from both subjective and objective angles [12]. So far, the domestic research on the quality of life is mostly concentrated in large cities, and the data sources and analysis methods used are relatively single [13-15], only Zeng Wen and Zhou Ruirui take the county as the spatial unit. The GIS spatial analysis method was used to study the spatial differentiation pattern of county quality of life in Jiangsu Province and Ningxia Province [16-17].

2. Establishment of index system

2.1. Establishment of index system

How to construct the evaluation system of quality of life is not used in different countries, and the evaluation criteria are also different. There are two representative research methods, one is the Scandinavian research method, which pays attention to the real living conditions of residents, and evaluates the quality of life by paying attention to the most basic elements such as clothing, food, housing, transportation and so on. The other is the American quality of life research method, which focuses on people's subjective satisfaction with the quality of life [18].

In addition, the evaluation system of quality of life is a dynamic concept. It is found that in the study of Scandinavian research methods, there is no unified questionnaire, and the selection of indicators is too subjective. Can not establish a complete and scientific index system, so this paper chooses the second index research method. By drawing lessons from the research results of previous scholars and considering the accessibility of county data, starting from the concept of "people-oriented", select three primary dimensions that affect the quality of life (including nine secondary indicators that affect the quality of life): economic dimension, social dimension and environmental dimension.
Table 1. County Life Quality Evaluation Index System

| Evaluation dimension | Evaluation index                                      | Index weight | Index direction          |
|----------------------|------------------------------------------------------|--------------|--------------------------|
| Economics            | Per capita GDP                                       | 1/9          | Positive direction       |
|                      | Per capita fiscal expenditure                        | 1/9          | Positive direction       |
|                      | Per capita savings balance                           | 1/9          | Positive direction       |
| Society              | Number of teachers per 10,000                        | 1/9          | Positive direction       |
|                      | Number of beds per 10,000 people in medical institutions | 1/9          | Positive direction       |
|                      | Number of beds per 10,000 people in welfare homes    | 1/9          | Positive direction       |
| Environment          | NDVI                                                 | 1/9          | Positive direction       |
|                      | Summer surface temperature                           | 1/9          | Negative direction       |
|                      | PM2.5                                                | 1/9          | Negative direction       |

2.2. Calculation of scores
(1) standardized processing of data.
Because the dimensions, orders of magnitude and positive and negative directions of each index are different, the extreme value standardization method is used to process the data, and each index is processed into a standardized value between [0-1].

The standardization formula of positive indicators is:

\[ X'_i = \frac{x_i - x_{min}}{x_{max} - x_{min}} \]  \hfill (1)

The standardization formula of negative indicators is as follows:

\[ X'_i = \frac{x_{max} - x_i}{x_{max} - x_{min}} \]  \hfill (2)

In formula (1) (2), \( X'_i \) represents the standardized value of item i, \( x_i \) represents the original value of item i, \( x_{max} \) and \( x_{min} \) represent the maximum and minimum values of item i.

(2) calculate the final score of each county (city) for each year.
The formula for calculating the score is as follows:

\[ S = \sum_{i=1}^{n} w_i \times X'_i \]  \hfill (3)

In the formula: \( S \) is the final quality of life score of the county (city) in that year, which is distributed between [0-1]. The higher the value, the higher the level of quality of life. \( w_i \) is the weight of item i and \( X'_i \) is the standardized value of item i.

3. Research methods and data sources

3.1. Overview of the study area
Shandong Province is located in the eastern coastal area of China, adjacent to Jiangsu and Anhui in the south, Hebei Province in the north, Henan Province in the west, and Japan and South Korea in the east. As an important province in northern China, Shandong Province is an important part of the Bohai Bay area and an important part of the eastern development strategy, with obvious geographical advantages. At the end of 2017, the urbanization rate of Shandong Province reached 60.28%, with a total population...
of 100.06 million at the end of the year, including 60.62 million urban people; the total GDP in 2017 was 7.263415 trillion yuan.

3.2. Research methods

3.2.1. Global spatial autocorrelation
Spatial correlation reflects the degree of correlation between a certain geographical phenomenon or a certain attribute value in a regional unit and the same phenomenon or attribute value in the adjacent regional unit [19], so as to reflect the spatial distribution of geographical phenomena or a certain attribute value.

This paper analyzes whether the county quality in Shandong Province has agglomeration characteristics by measuring the global Moran’s I index. The global Moran’s I index formula is:

\[ I = \frac{n}{S_0} \sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij} (x_i - \bar{x})(x_j - \bar{x}) \sum_{i=1}^{n} (x_i - \bar{x})^2 \]  

In the formula: \( n \) represents the number of units in the study area, that is, the number of counties (cities) in Shandong Province; \( x_i \) and \( x_j \) are the observations of \( i \) and \( j \) counties (cities) respectively; \( \bar{x} \) is the average score of county quality of life in Shandong Province; \( w_{ij} \) is the element in the spatial weight matrix \( w \); \( S_0 \) is the sum of all elements in \( w \).

3.2.2. Local spatial autocorrelation
The local Moran'I index is to disperse the global Moran'I index to the local space, which is for every distributed object in the space:

\[ I_i = \sum W'_{ij} Z_i Z_j \]  

In the formula: \( Z_i \) and \( Z_j \) are the standardized values of observations and the row standardization of \( W'_{ij} \). The z test of LISA is:

\[ Z(I_i) = \frac{I_i - E(I_i)}{\sqrt{\text{var}(I_i)}} \]  

3.2.3. Spatial variation function
Spatial variation function, also known as semi-variation function, is a basic method to describe the randomness and structure of regional variation. It is assumed that \( Z(x_i) \) and \( Z(x_i+h) \) are the observations of \( Z(x) \) on spatial position \( x_i \) and \( x_i+h \), respectively (\( I = 1, 2, ..., N(h) \)), then spatial variation function can be expressed as:

\[ \gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} [Z(x_i) - Z(x_i + h)]^2 \]  

In the formula: \( N(h) \) is the sample size with a separation distance of \( h \). The spatial variation function is defined under the condition that the regionalized variable satisfies the stationary and intrinsic assumptions. When the semi-variation function is large, the spatial autocorrelation weakens.

The main characterization parameters of spatial variation function are nugget value, nugget coefficient, pedestal value, range variation and fractal dimension. For specific interpretation, please refer to the study of Jin Cheng [20].

3.2.4. Center of gravity and standard deviation ellipse of quality of life
The center of gravity of quality of life is an important index to measure the score distribution of urban or regional quality of life. By studying the moving direction and distance of the center of gravity of quality of life, we can understand the direction and intensity of the distribution of quality of life scores. The center of gravity of quality of life is actually the measurement of the concentrated trend of quality of life, while the discrete trend of quality of life is mainly measured by standard deviation ellipse [21].
The standard deviation ellipse consists of a long axis, a short axis, a deflection angle and an ellipse center. The long axis represents the degree to which the quality of life deviates from the center of gravity of the quality of life in the main direction, and the minor axis represents the degree to which the quality of life deviates from the center of gravity in the secondary direction.

The formula for calculating the center of gravity of quality of life is:

\[ X = \frac{\sum P_i \cdot X_i}{\sum P_i}, Y = \frac{\sum P_i \cdot Y_i}{\sum P_i} \]  

In the formula: X and Y are the horizontal and vertical coordinates of the center of gravity of the quality of life respectively; \( X_i \), \( Y_i \) and \( P_i \) are the horizontal and vertical coordinates and scores in the i quality of life research unit, respectively.

The formula for calculating the standard deviation ellipse is:

\[ SDE_X = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n}} \quad SDE_Y = \sqrt{\frac{\sum_{i=1}^{n} (y_i - \bar{y})^2}{n}} \]  

\[ \tan \theta = \frac{A + B}{C} \]  

\[ A = \left( \sum_{i=1}^{n} x_i^2 - \sum_{i=1}^{n} y_i^2 \right) \]  

\[ B = \sqrt{\left( \sum_{i=1}^{n} x_i^2 - \sum_{i=1}^{n} y_i^2 \right)^2 + 4 \left( \sum_{i=1}^{n} x_i y_i \right)^2} \]  

\[ C = 2 \sum_{i=1}^{n} x_i y_i \]

In the formula: \( SDE_X \) and \( SDE_Y \) are the standard distances of the major axis and the minor axis of the standard deviation ellipse, \( x_i \) and \( y_i \) are the coordinates of the element i, \( \bar{x} \) and \( \bar{y} \) are the coordinates of the average center of the element, and \( n \) represents the number of elements. The \( \tan \theta \) represents the angle in the direction of the ellipse, where \( \bar{x}_i \) and \( \bar{y}_i \) are the deviations between the coordinates and the average center.

3.2.5. average change index of quality of life score
The average change index of county quality of life score standardizes the annual average change rate in each research unit, so that the change rate in different periods is comparable, and the calculation formula is as follows:

\[ S = \frac{E_{t_2} - E_{t_1}}{E_{t_1}(t_2 - t_1)} \]  

In the formula: s is the average change index of quality of life, \( E_{t_2} \) and \( E_{t_1} \) are the county quality of life scores in \( t_2 \) and \( t_1 \) years, respectively.

3.3. Data sources
(1) the social and economic data of Shandong Province from 2000 to 2015 come from the Shandong Statistical Yearbook and the National Economic Development and Social Statistics Bulletin of various counties (cities).

(2) NDVI (Normalized vegetation Index) and land surface temperature are obtained by interpretation of remote sensing data.

The remote sensing data come from the Landsat tm/etm+ data provided by (USGS), the official website of American geological exploration.
(3) PM2.5 data: the PM2.5 data come from the raster data of 0.01° × 0.01° provided by the atmospheric composition analysis organization (ACAG).

3.4. Data preprocessing
NDVI is one of the important parameters to reflect the growth and coverage of green plants. The range of values is [-1, 1]. A positive value indicates that there is vegetation cover and the value increases with the increase of coverage.

The NDVI calculation formula is:

\[ \text{NDVI} = \frac{\text{NIR} - \text{R}}{\text{NIR} + \text{R}} \]  

In the formula: NIR is the reflection value of the near infrared band of the image, and R is the reflection value of the red band of the image.

The single window algorithm is selected for summer land surface temperature (LST) inversion [22]. The inversion formula is:

\[ T_s = \frac{(a_6(1-C_6-D_6)+(b_6(1-C_6-D_6)+C_6+D_6)T_{sebor}-D_6T_a)}{C_6} \]  

In the formula, \( \varepsilon \) is the surface emissivity and \( \tau \) is the total atmospheric transmittance from the ground to the sensor. After radiometric calibration, atmospheric correction and geometric correction, the NDVI calculation and summer land surface temperature (LST) inversion are carried out, and each grid is assigned, and the average values of NDVI and summer land surface temperature (LST) of each county from 2000 to 2015 are obtained.

4. Spatial-Temporal Evolution pattern of county quality of life in Shandong Province

4.1. Overall characteristics of Spatial-Temporal pattern of county quality of life in Shandong Province
After calculation, the score table of quality of life of counties in Shandong Province over the years can be obtained. By connecting the score table of arcGIS 10.2 with the county vector map of Shandong Province, the quantile method is used to grade 137 counties (cities), and the spatial differentiation map of quality of life of counties in Shandong Province for four years is obtained (figure 1).

It can be seen from the picture that there are obvious regional differences in the quality of life in the counties of Shandong Province, showing high coastal areas in the northeast and southeast, low inland areas in the northwest and southwest, and obvious coastal agglomeration characteristics in the areas with high quality of life. The agglomeration centers are mainly Qingdao, Yantai, Weihai and Weifang. The areas with medium quality of life are mainly concentrated in central and southern Shandong. In terms of spatial form, Dongying area, Jinan area and Zibo area are the agglomeration centers; the areas with poor quality of life are mainly concentrated in southern Shandong and western Shandong. In the spatial form, it mainly takes Dezhou area, Liaocheng area and Heze area as the agglomeration center. Among them, Qingdao, Weihai, Yantai, Weifang and Dongying constitute the main body of the "Blue Peninsula Economic Circle". This economic circle is China's first regional development strategy with the theme of marine economy. Qingdao will become the economic development center, modern service center and cultural center of the eastern coastal region of our country. According to the spatial differences of the scores of quality of life in 137 counties (cities) in Shandong Province, the quality of life space in counties in Shandong Province generally reflects the ladder state of high in northeast and southeast coastal areas and low in southwest and northwest inland areas. and the areas with better quality of life are clustered in the coastal areas.
Figure 1. 2000-2015 Spatial-Temporal differentiation pattern of overall quality of life in counties of Shandong Province

4.2. Spatial-Temporal evolution of the center of gravity of quality of life and standard deviation ellipse

According to the total score of county quality of life in Shandong Province for four years, the changes of the center of gravity and standard deviation ellipse of quality of life from 2010 to 2015 are obtained (figure 2).

Figure 2. 2000-2015 Changes in Quality of Life Center of Gravity and Standard Deviation Ellipse

In 2000, the center of life quality was located in Yiyuan County; in 2005, the center of life quality shifted northward to the junction of Yiyuan County, Zichuan District and Linqu County; in 2010, the center of life quality continued to shift to the northeast and moved to the interior of Linqu County, and moved to a large extent; in 2015, the center of life quality center shifted to the southwest for the first time, but with a small extent, still within Linqu County. During the ten years from 2000 to 2010, the
center of gravity and standard deviation ellipse of quality of life shifted to the northeast as a whole, which is the same as the spatial differentiation of the total score of county quality of life, that is, the overall quality of life is high in the northeast and low in the southwest, indicating that during this time, regardless of environmental, economic and social factors, the development of the northeast coast is in the forefront of Shandong Province as a whole. Until 2010, the focus of quality of life shifted to the southwest for the first time, indicating that the quality of life in inland areas gradually optimized from 2015 to 2015, narrowing the gap with the coastal areas of the northeast and southeast.

| Year | CenterX   | CenterY   | XStdDist | YStdDist | Rotation |
|------|-----------|-----------|----------|----------|----------|
| 2000 | 118.2312497 | 36.3446196 | 1.13298976 | 2.465394476 | 76.22883217 |
| 2005 | 118.2338698 | 36.38761683 | 1.146063372 | 2.525280392 | 76.18738349 |
| 2010 | 118.3994496 | 36.42681382 | 1.116715792 | 2.576180359 | 76.88884542 |
| 2015 | 118.3536894 | 36.40344038 | 1.113931035 | 2.53910921 | 76.38041525 |

4.3. Spatial variation of county quality of life in Shandong Province
The main results are as follows:
(1) from the changes of the indexes of platform value, nugget value and nugget coefficient, the spatial difference of county quality of life in Shandong Province is increasing, and the pedestal value in 2015 is 5.7 times that of 2000 pedestal value. at the same time, the nugget value is also increasing, and the nugget value in 2015 is 5.8 times that of 2000, but the nugget coefficient as a whole is in a downward trend, indicating that in the increasing spatial differences in quality of life.

Table 3. Fitting parameters of variability function of counties quality of life in Shandong Province

| Year | 2000  | 2005  | 2010  | 2015  |
|------|-------|-------|-------|-------|
| Co   | 0.00052 | 0.00047 | 0.00142 | 0.003  |
| Co+C | 0.00265 | 0.00454 | 0.02303 | 0.01504 |
| Co/(C+C) | 0.196   | 0.104   | 0.061   | 0.199   |
| a    | 398700 | 875200 | 911000 | 735500   |
| Model | Gaussian | Gaussian | Gaussian | Gaussian   |
| R²   | 0.938 | 0.876 | 0.917 | 0.890 |

(2) through the selection of the least square method, we find that the Gaussian model can get better fitting results, which shows that the county quality of life in Shandong Province has obvious continuity, and the model determination coefficient is higher and the fitting degree is better.
5. Spatial agglomeration characteristics of county quality of life in Shandong Province

5.1. Overall spatial agglomeration characteristics

This paper calculates the global Moran's I of the county quality of life score in four years in Shandong Province, and the results are shown in Table 3, but Table 3 only takes the county quality of life score in four years as the index and takes the county as the spatial unit. The result of this spatial agglomeration is only based on the analysis of static data, ignoring the process of evolution, in order to better analyze the changing process of county quality of life pattern in Shandong Province.

Therefore, this paper analyses its dynamic development, selects three time periods, 2000-2005, 2005-2010, 2010-2015, calculates the average change index of quality of life according to formula (6), and uses the global Moran's I to calculate the correlation, to investigate the overall spatial distribution pattern of the change index. The results are shown in Table 4.

The main results are as follows:

(1) The global Moran's I estimates of the four years are all positive, the test results are significant, and the numerical values are decreasing, indicating that the overall trend is decreasing. This shows that since 2000, areas with similar quality of life in counties of Shandong Province have shown a concentrated distribution in space, and with the passage of time, this trend is constantly weakening. The reason is that the overall spatial pattern of county quality of life in Shandong Province is that high-quality areas are concentrated in the eastern coastal areas, while low-quality areas are mostly concentrated in the western and southern inland areas, and this gap is constantly expanding with the development of economic level. This result is only aimed at the county-level spatial scale, which is not contradictory to the spatial difference on other scales, and studies the spatial scale difference. It will also make the results different.

(2) The global Moran's I increased at first and then decreased in the three time periods, and the numerical change was the most obvious in the period from 2010 to 2015. From the positive and negative point of view, the global Moran's I estimates of the three time periods are all positive, indicating that the spatial autocorrelation exists, but it is not very obvious. The estimated values of Moran's I in 2000-2005 and 2005-2010 are 0.3583 and 0.4402 respectively, indicating that the autocorrelation of neighboring regions is gradually increasing in this decade, but the estimated value of Moran's I in the period of 2010-2015 is 0.0640, and the autocorrelation is very low. The three time periods show two states, indicating that the pattern of county quality of life in Shandong Province has a certain degree of instability after 2010.
Table 4. Global Moran's I Index of Counties Quality of Life Score in Shandong Province

| Year | 2000  | 2005  | 2010  | 2015  |
|------|-------|-------|-------|-------|
| Moran's I | 0.5589 | 0.3926 | 0.5436 | 0.5228 |
| E (I)  | -0.0074 | -0.0074 | -0.0074 | -0.0074 |
| Z (I)  | 9.9646  | 7.0786  | 9.7996  | 9.3485  |

Table 5. Global Moran's I Index of Changes in counties quality of life scores in Shandong Province

| Year  | 2000-2005 | 2005-2010 | 2010-2015 |
|-------|------------|------------|------------|
| Moran's I | 0.3583 | 0.4402 | 0.0640 |
| E (I)  | -0.0074 | -0.0074 | -0.0074 |
| Z (I)  | 6.4496  | 7.9818  | 1.2798  |

5.2. Characteristics of local spatial agglomeration

The spatial autocorrelation agglomeration map of county quality of life in Shandong Province is generated by using arcGIS software. It can be seen that the county quality of life in Shandong Province has obvious spatial agglomeration characteristics in four years. In the four years, the "H-H" or "high-high" agglomeration areas are mainly distributed in the "Shandong Blue Peninsula Economic Zone", mainly including Qingdao, Weihai and Yantai. In 2015, Zibo also appeared the phenomenon of "high-high" agglomeration, indicating that all counties (cities) and surrounding counties (cities) in these areas have high quality of life scores. "L-L", that is, "low-low" agglomeration areas are mainly distributed in the marginal areas connected by Heze, Liaocheng and Dezhou, indicating that the counties (cities) and the surrounding counties (cities) in these areas have lower quality of life scores.

Figure 4. 2000-2015 Spatial clustering feature of Counties quality of life in Shandong Province

6. Conclusion

Taking the county as the research unit, this paper studies the spatial layout and spatio-temporal evolution of the county quality of life in Shandong Province from the perspective of geography and the method of geography, this paper takes the county small unit as the research object, establishes the index system objectively and scientifically, highlights the concept of "people-oriented", fully considers the influence
of location factors on the quality of life, and draws the following conclusions:

1) the overall spatial difference of county quality of life in Shandong Province shows that the coastal areas of eastern Shandong and some areas of southern Shandong are high, while the inland areas of central and western Shandong are low, and the polarization is more significant.

2) the development of all dimensions of urban quality of life is uneven, and the development of quality of life in urban and non-municipal areas is not balanced.

3) the radiation power of the areas with high quality of life is not strong, and the areas with low quality of life lack the drive of core cities. The evolution of county quality of life is a geo-spatial process that integrates multiple elements such as economy, society and natural environment, which is affected by many factors.

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