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Nonlinear Relationship and Its Evolutionary Trace between Average Degree and Average Path Length of Edge Vertices of China Aviation Network Based on Complex Network

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Abstract: In order to reveal the complex network characteristics and evolution principle of China aviation network, the relationship between the average degree and the average path length of edge vertices of China aviation network in 1988, 1994, 2001, 2008 and 2015 was studied. According to the theory and method of complex network, the network system was constructed with the city where the airport was located as the network node and the airline as the edge of the network. On the basis of the statistical data, the average degree and average path length of edge vertices of China aviation network in 1988, 1994, 2001, 2008 and 2015 were calculated. Through regression analysis, it was found that the average degree had a logarithmic relationship with the average path length of edge vertices and the two parameters of the logarithmic relationship had linear evolutionary trace.

Key words: China aviation network, complex network, average degree of edge vertices, average path length of edge vertices, logarithmic relationship, evolutionary trace.

1. Introduction

Aviation network is typical complex network with small world characters [1, 2]. The nodes of the network have multiple parameters such as degree, clustering coefficient, and path length, which can be used as the basis for studying the characteristics of nodes, but the number of edges of the network is not only far greater than the number of nodes, but also the study of edge characteristics is more difficult to start for the network without edge weights. Here, the average degree and average path length of the edge vertices were used to describe the features of the edge, and the relationship with its evolutionary trace between the average value of degree and average path length of the two vertices of each edge were used as the basis for studying the properties of the edge. This paper faces to the aviation network of China through analyzing the passenger data [3] of civil aviation airlines in year 1988, 1994, 2001, 2008 and 2015 to reveal the complex network feature. According to complex network theory, network system of airports and airlines of China was constructed with airports regarded as nodes and airline regarded as edges to study the relationship between average degree and average path length of edge vertices and its evolutionary trace of China aviation network. Based on the statistical data, the average degree and average path length of edge vertices in China aviation network in 1988, 1994, 2001, 2008 and 2015 were calculated. Using the probability statistical analysis method and regression analysis approach, it was found that the relationship between average degree and average path length of edge vertices of China aviation

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network had a logarithmic function and the two parameters of the function had linear evolution trace.

2. Nonlinear Relationship between Average Degree and Average Path Length of Edge Vertices of China Aviation Network

For network $G=(V,E)$, where $v_i \in V$ is the node of G. V is the set of nodes. E is the set of edges [4], $(v_i,v_j)\in E$. Matrix $A=(a_{i,j})_{n\times n}$ was constructed, where:

$$a_{i,j}=\begin{cases}1,(v_i,v_j)\in E\\ 0, otherwise\end{cases} \tag{1}$$

Matrix A is called adjacent matrix of network G.

The average degree of edge vertices is defined as following:

$$D_{i,j}^{EVA}=\frac{1}{2}(k_i+k_j) \tag{2}$$

In Eq. (2): k_i—the degree of node v_i; k_j—the degree of other nodes v_j; $(v_i,v_j)\in E$.

The path length matrix $L=(d_{i,j})_{n\times n}$ was gotten from adjacent matrix *A* by algorithm Floyd [4].

$$d_{i,j}=\begin{cases}\Omega_{i,j}, \text{the quantity of edges of shortest path between node } v_i \text{ and } v_j\\ 0, i=j\\ \infty,\ v_i \ and\ v_j\ was\ not\ connected\end{cases} \tag{3}$$

Since the aviation network of China was fully connected network in each year [3], so the path length matrix *L* could be simplified as the following:

$$d_{i,j}=\begin{cases}\Omega_{i,j}, \text{the quantity of edges of shortest path between node } v_i \text{ and } v_j\\ 0, i=j\end{cases} \tag{4}$$

According to the definition, the average path length $\bar{d}_i$ of node v_i to other nodes is:

$$\bar{d}_i=\frac{1}{n-1}\sum_{j=1}^{n}\Omega_{i,j} \tag{5}$$

The average path length of edge vertices is defined as following:

$$L_{i,j}^{EVA}=\frac{1}{2}(\bar{d}_i+\bar{d}_j) \tag{6}$$

In Eq. (6): $\bar{d}_i$—the average path length of node v_i; $\bar{d}_j$—the average path length of other nodes v_j; $(v_i,v_j)\in E$.

2.1 Nonlinear Relationship between Average Degree and Average Path Length of Edge Vertices of China Aviation Network in 1988

According to the data of China aviation network in 1988 [3], the adjacency matrix A_{1988} was calculated. Using algorithm Floyd, the path length matrix L_{1988} was calculated by A_{1988}. The average degree of edge vertices $D_n^{EVA}(n=1,2,3,......,265)$ of 265 edges in 1988 were gotten from A_{1988} and Eq. (2). The average path length of edge vertices $L_n^{EVA}(n=1,2,3,......,265)$ of 265 edges in 1988 were gotten from L_{1988} and Eq. (6). The scatter points between average degree and average path length of these 265 edge vertices were drawn in Fig. 1.

Let the average degree of edge vertices be x and the average path length of edge vertices be y. Let $u=\ln x$. The points in Fig. 2 were calculated by the points in Fig. 1. The correlation coefficient r of the points in Fig. 2 was calculated by Eq. (7).

$$r=\frac{L_{uy}}{\sqrt{L_{uu}L_{yy}}}=\frac{\sum_{i=1}^{n}(u_i-\bar{u})(y_i-\bar{y})}{\sqrt{\sum_{i=1}^{n}(u_i-\bar{u})^2\sum_{i=1}^{n}(y_i-\bar{y})^2}} \tag{7}$$

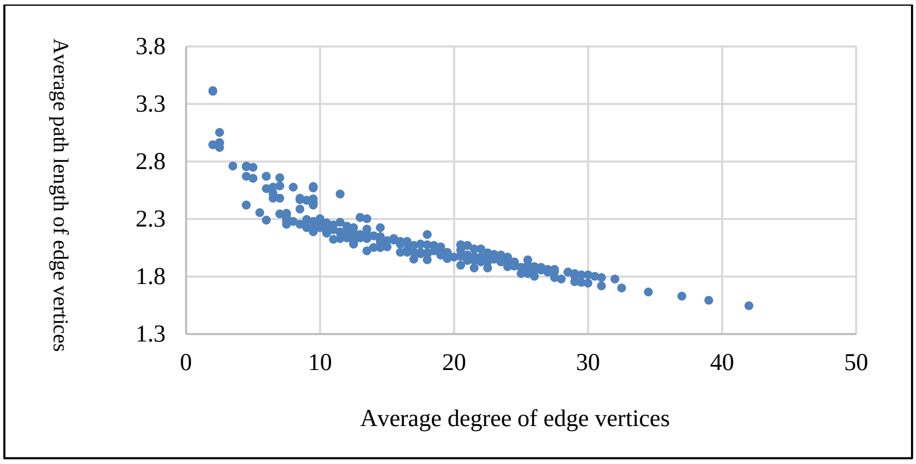

Fig. 1 Diagram of scatter points between average degree and average path length of edge vertices in 1988.

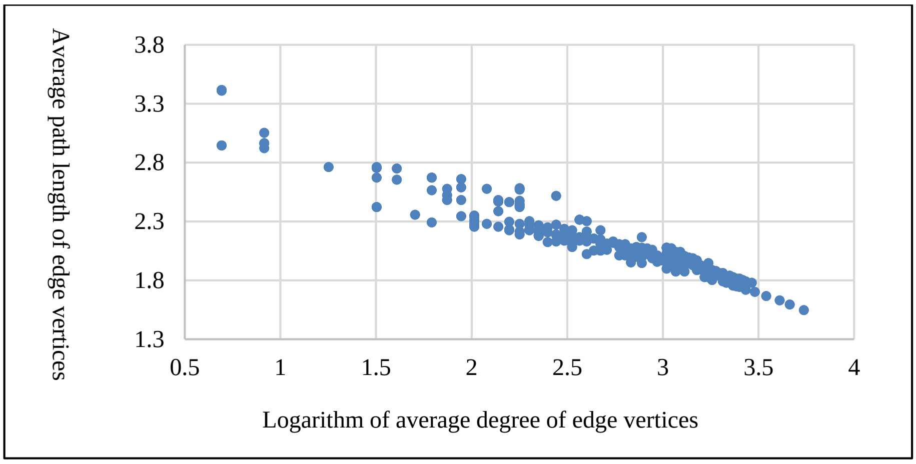

Fig. 2 Diagram of scatter points between logarithm of average degree and average path length of edge vertices in 1988.

Here, $n = 265$. The value of correlation coefficient r was calculated, $r = -0.96$. The critical value $r_{\substack{\alpha=1\% \\ f=263}} = 0.16$ was found in critical value table [5] at degree of freedom $f = 265 - 2 = 263$ and level of significant α of 1%. Since $|r| = 0.96 > 0.16 = r_{\substack{\alpha=1\% \\ f=263}}$, the scattered points in Fig. 2 had significant linear correlation. Least square method [5] was used as an approach in Eq. (8) to fit the line with points in Fig. 2.

$$\begin{cases} \hat{\beta}_0 = \bar{y} - \hat{\beta}_1 \bar{u} = 3.37 \\ \hat{\beta}_1 = \dfrac{L_{uy}}{L_{uu}} = -0.464 \end{cases} \tag{8}$$

The linear equation:

$$\hat{y} = 3.37 - 0.464u \tag{9}$$

The fitting line Eq. (9) was drawn with the sample points in Fig. 3 with good fitting effect.

To take t test [5] of Eq. (9), test hypothesis is: $H_0 : \beta_1 = 0$. When the hypothesis was true, there is:

$$\hat{\beta}_1 \sim N(0, \frac{\sigma^2}{L_{uu}}) \tag{10}$$

Here, $\hat{\beta}_1$ fluctuates near zero, statistic t is built.

$$t = \frac{\hat{\beta}_1}{\sqrt{\dfrac{\hat{\sigma}^2}{L_{uu}}}} = \frac{\hat{\beta}_1 \sqrt{L_{uu}}}{\hat{\sigma}} \tag{11}$$

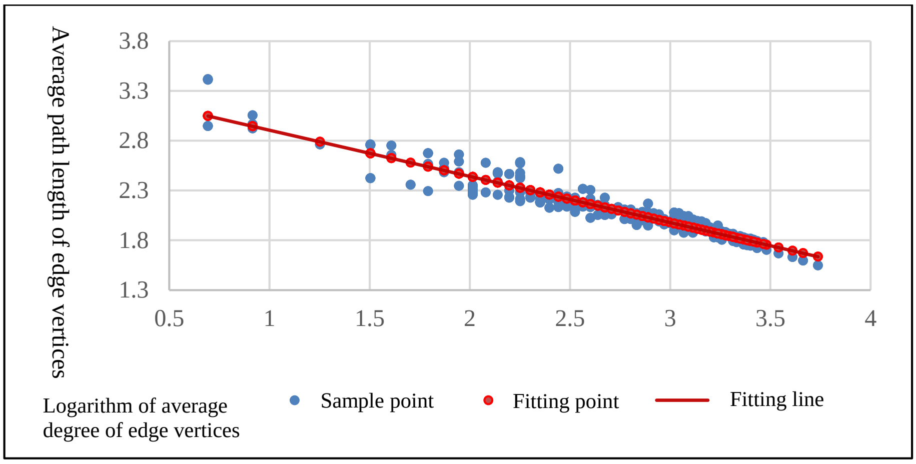

Fig. 3 Fitting linear relationship between logarithm of average degree and average path length of edge vertices in 1988.

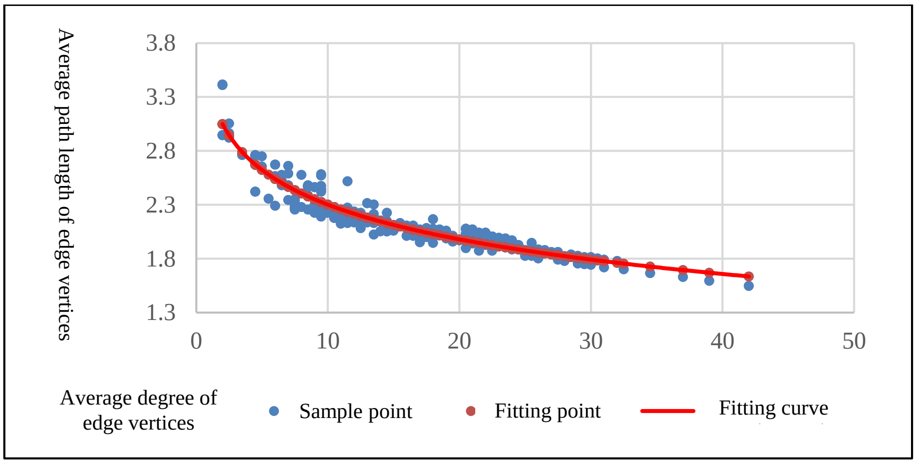

Fig. 4 Fitting nonlinear relationship between average degree and average path length of edge vertices in 1988.

where:

$$\hat{\sigma}^2 = \frac{1}{n-2}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2 \quad (12)$$

calculated by statistic data: $t = -53.7$.

To check the t distribution table [5], at significant level α of 0.01 and degree of freedom $f = n-2 = 263$, the value $t\big|_{\substack{\alpha=0.01\\ f=263}} = 2.362$. So, $|t| = 53.7 > 2.362 = t\big|_{\substack{\alpha=0.01\\ f=263}}$, null hypothesis H_0 is refused. The linear correlation of Eq. (9) is significant. The fitting curve Eq. (13) of nonlinear relationship between node degree and the nearest neighbor average degree was deduced from Eq. (9):

$$\hat{y} = 3.37 - 0.464\ln x \quad (13)$$

The points of the fitting curve Eq. (13) and the sample points were drawn in Fig. 4 with good fitting effect. It showed that the average degree of edge vertices in China aviation network in 1988 had a logarithmic relationship with the average path length of edge vertices.

2.2 Nonlinear Relationship between Average Degree and Average Path Length of Edge Vertices of China Aviation Network in 1994

According to the data of China aviation network in 1994, the adjacency matrix A_{1994} was calculated. The path length matrix L_{1994} was calculated by A_{1994}. The average degree of edge vertices D_n^{EVA} ($n = 1, 2, 3, \ldots\ldots, 589$) of 589 edges in 1994 was gotten from A_{1994} and Eq. (2). The average path length of edge vertices L_n^{EVA} ($n = 1, 2, 3, \ldots\ldots, 589$) of 589 edges in 1994 was gotten from L_{1994} and Eq. (6). The scatter points between average degree and average path length of these 589 edge vertices were drawn in Fig. 5.

Let the node degree be x and the average length of node path be y. Let $u = \ln x$. The points in Fig. 6 were calculated by the points in Fig. 5. The correlation coefficient r of the points in Fig.6 was calculated by Eq. (7). Here, $n = 589$. The value of correlation coefficient r was calculated, $r = -0.92$.

The critical value $r_{\left|\substack{\alpha=1\% \\ f=587}\right.}=0.113$ was found in critical value table at degree of freedom $f = n-2 = 587$ and level of significant α of 1%. Since $|r| = 0.92 > 0.113 = r_{\left|\substack{\alpha=1\% \\ f=587}\right.}$, the scattered points in Fig. 6 had significant linear correlation. Least square method was used as an approach in Eq. (14) to fit the line with points in Fig. 6.

$$\begin{cases} \hat{\beta}_0 = \bar{y} - \hat{\beta}_1 \bar{u} = 3.08 \\ \hat{\beta}_1 = \dfrac{L_{uy}}{L_{uu}} = -0.353 \end{cases} \tag{14}$$

The linear equation:

$$\hat{y} = 3.08 - 0.353u \tag{15}$$

The fitting line Eq. (15) was drawn with the sample points in Fig. 7 with good fitting effect.

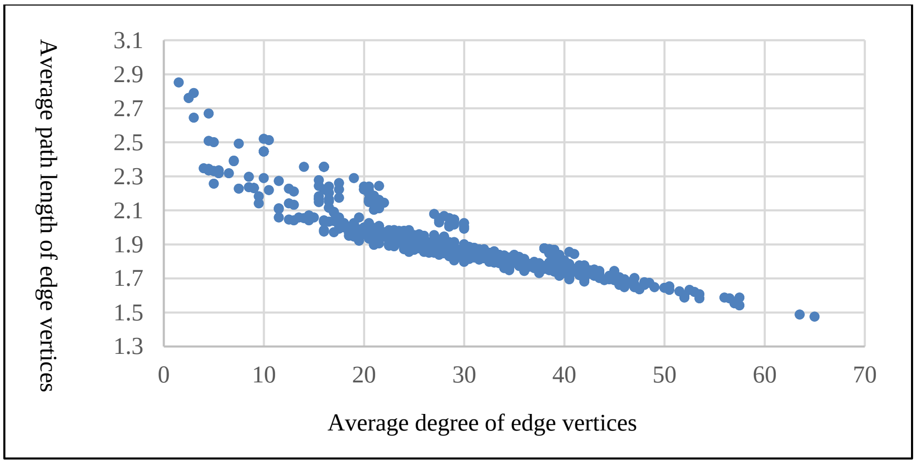

Fig. 5 Diagram of scatter points between average degree and average path length of edge vertices in 1994.

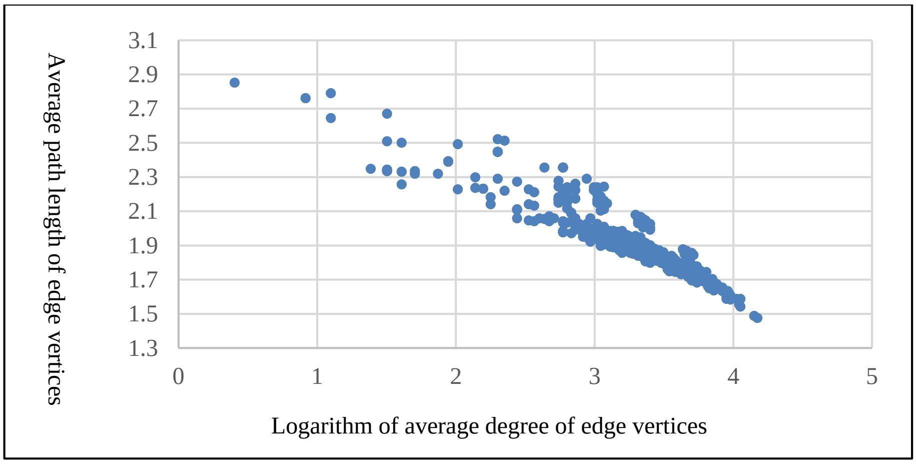

Fig. 6 Diagram of scatter points between logarithm of average degree and average path length of edge vertices in 1994.

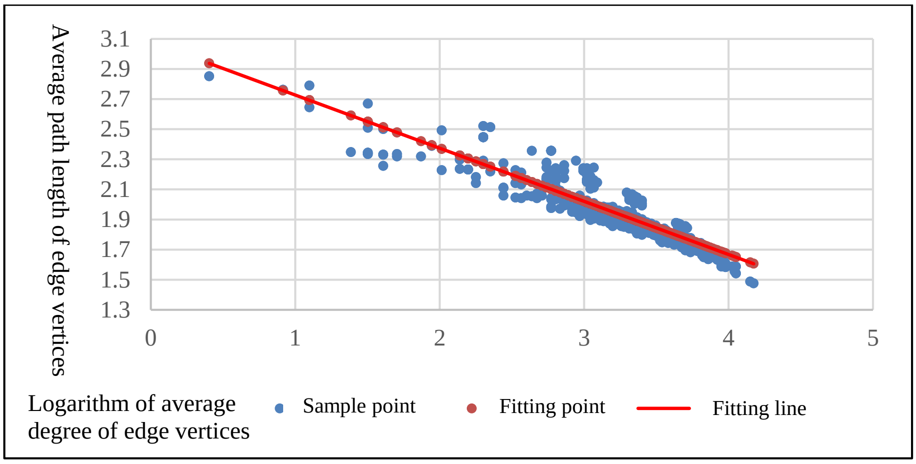

Fig. 7 Fitting linear relationship between logarithm of average degree and average path length of edge vertices in 1994.

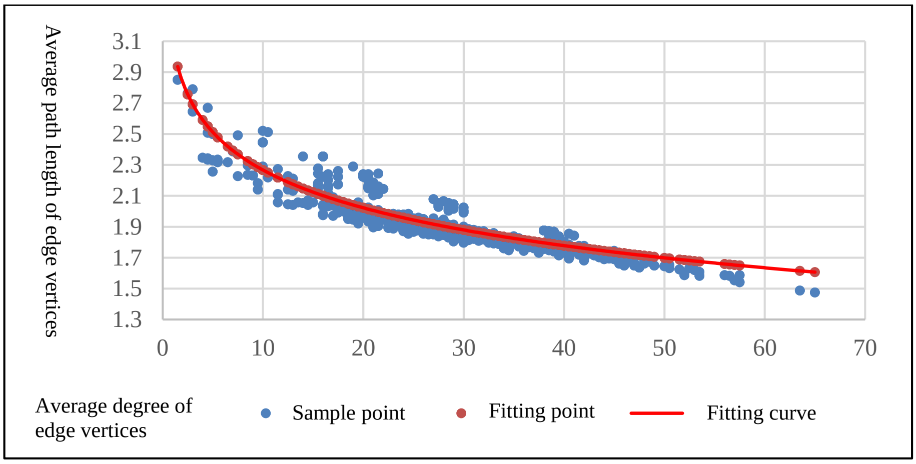

Fig. 8 Fitting nonlinear relationship between average degree and average path length of edge vertices in 1994.

To take t test of Eq. (15), test hypothesis is: $H_0:\beta_1=0$. When the hypothesis was true, there is Eq. (10). The statistic t was calculated by Eqs. (11) and (12), $t=-54.6$. To check the t distribution table, at significant level α of 0.01 and degree of freedom $f=n-2=587$, the value $t\big|_{\substack{\alpha=0.01\\ f=587}}=2.362$. So, $|t|=54.6>2.362=t\big|_{\substack{\alpha=0.01\\ f=587}}$, null hypothesis H_0 is refused. The linear correlation of Eq. (15) is significant. The fitting curve Eq. (16) of nonlinear relationship between node degree and the path average length was deduced from Eq. (15):

$$\hat{y}=3.08-0.353\ln x \tag{16}$$

The points of the fitting curve Eq. (16) and the sample points were drawn in Fig. 8 with good fitting effect. It showed that the average degree of edge vertices in China aviation network in 1994 had a logarithmic relationship with the average path length of edge vertices.

2.3 Nonlinear Relationship between Average Degree and Average Path Length of Edge Vertices of China Aviation Network in 2001

According to the data of China aviation network in 2001, the adjacency matrix A_{2001} was calculated. The path length matrix L_{2001} was calculated by A_{2001}. The average degree of edge vertices D_n^{EVA} ($n=1,2,3,......,730$) of 730 edges in 2001 was gotten from A_{2001} and Eq. (2). The average path length of edge vertices L_n^{EVA} ($n=1,2,3,......,730$) of 730 edges in 2001 was gotten from L_{2001} and Eq. (6). The scatter points between average degree and average path length of these 730 edge vertices were drawn in Fig. 9.

Let the node degree be x and the average length of node path be y. Let $u = \ln x$. The points in Fig. 10 were calculated by the points in Fig. 9. The correlation coefficient r of the points in Fig. 10 was calculated by Eq. (7). Here, $n = 730$. The value of correlation coefficient r was calculated, $r = -0.91$. The critical value $r_{\left|\substack{\alpha=1\% \\ f=728}\right.} = 0.102$ was found in critical value table at degree of freedom $f = n - 2 = 728$ and level of significant α of 1%. Since $|r| = 0.91 > 0.102 = r_{\left|\substack{\alpha=1\% \\ f=728}\right.}$, the scattered points in Fig. 10 had significant linear correlation. Least square method was used as an approach in Eq. (17) to fit the line with points in Fig. 10.

$$\begin{cases} \hat{\beta}_0 = \bar{y} - \hat{\beta}_1 \bar{u} = 2.95 \\ \hat{\beta}_1 = \dfrac{L_{uy}}{L_{uu}} = -0.329 \end{cases} \tag{17}$$

The linear equation:

$$\hat{y} = 2.95 - 0.329u \tag{18}$$

The fitting line Eq. (18) was drawn with the sample points in Fig. 11 with good fitting effect.

To take t test of Eq. (18), test hypothesis is: $H_0 : \beta_1 = 0$. When the hypothesis was true, there is Eq. (10). The statistic t was calculated by Eqs. (11) and (12), $t = -59.5$. To check the t distribution table, at significant level α of 0.01 and degree of freedom $f = n - 2 = 128$, the value $t_{\left|\substack{\alpha=0.01 \\ f=728}\right.} = 2.362$. So, $|t| = 59.5 > 2.362 = t_{\left|\substack{\alpha=0.01 \\ f=728}\right.}$, null hypothesis H_0 is refused. The linear correlation of Eq. (18) is significant. The fitting curve Eq. (19) of nonlinear relationship between node degree and the path average length was deduced from Eq. (18):

$$\hat{y} = 2.95 - 0.329 \ln x \tag{19}$$

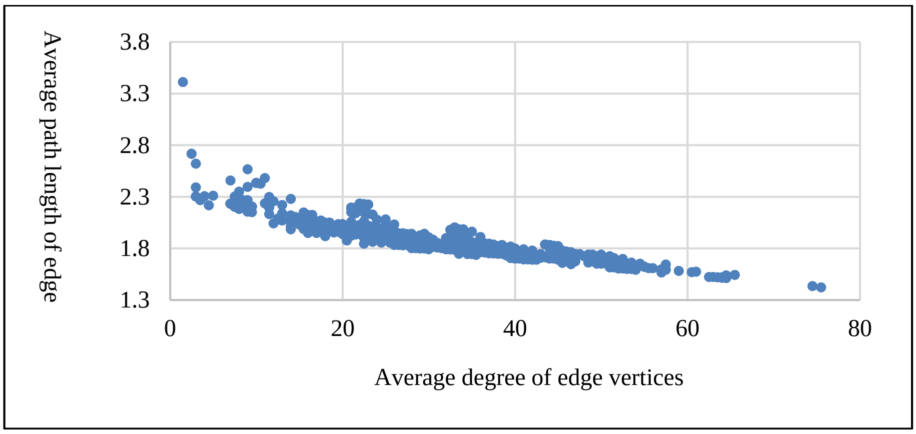

Fig. 9 Diagram of scatter points between average degree and average path length of edge vertices in 2001.

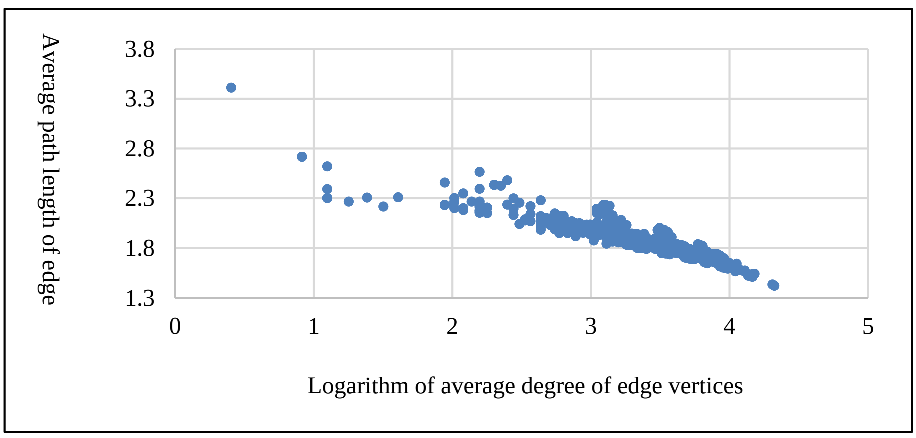

Fig. 10 Diagram of scatter points between logarithm of average degree and average path length of edge vertices in 2001.

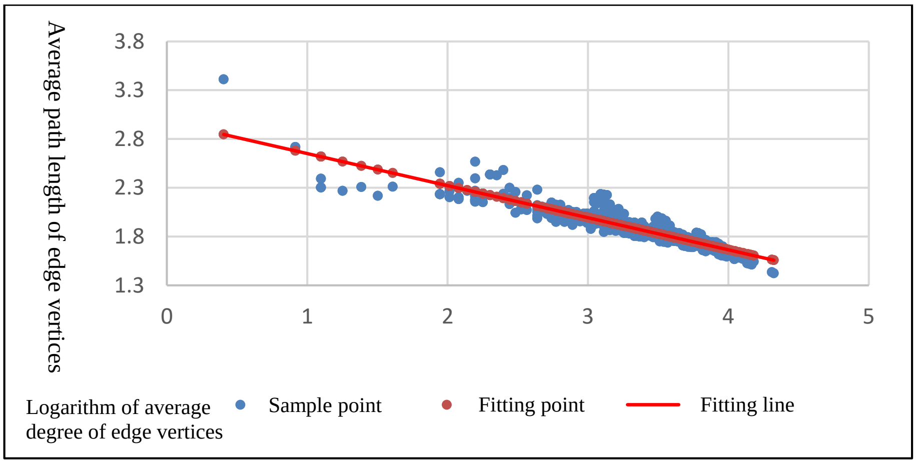

Fig. 11 Fitting linear relationship between logarithm of average degree and average path length of edge vertices in 2001.

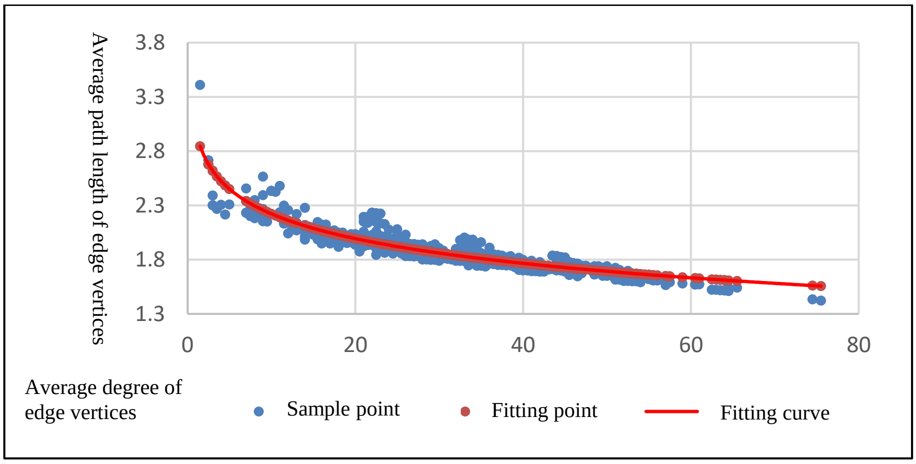

Fig. 12 Fitting nonlinear relationship between average degree and average path length of edge vertices in 2001.

The points of the fitting curve Eq. (19) and the sample points were drawn in Fig. 12 with good fitting effect. It showed that the average degree of edge vertices in China aviation network in 2001 had a logarithmic relationship with the average path length of edge vertices.

2.4 Nonlinear Relationship between Average Degree and Average Path Length of Edge Vertices of China Aviation Network in 2008

According to the data of China aviation network in 2008, the adjacency matrix A_{2008} was calculated. The path length matrix L_{2008} was calculated by A_{2008}. The average degree of edge vertices D_n^{EVA} ($n=1,2,3,......,940$) of 940 edges in 2008 was gotten from A_{2008} and Eq. (2). The average path length of edge vertices L_n^{EVA} ($n=1,2,3,......,940$) of 940 edges in 2008 was gotten from L_{2008} and Eq. (6). The scatter points between average degree and average path length of these 940 edge vertices were drawn in Fig. 13.

Let the node degree be x and the average length of node path be y. Let $u=\ln x$. The points in Fig. 14 were calculated by the points in Fig. 13. The correlation coefficient r of the points in Fig. 14 was calculated by Eq. (7). Here, $n=940$. The value of correlation coefficient r was calculated, $r=-0.91$. The critical value $r_{\left|\substack{\alpha=1\% \\ f=938}\right.}=0.084$ was found in critical value table at degree of freedom $f=n-2=938$ and level of significant α of 1%. Since $|r|=0.91>0.084=r_{\left|\substack{\alpha=1\% \\ f=938}\right.}$, the scattered points in

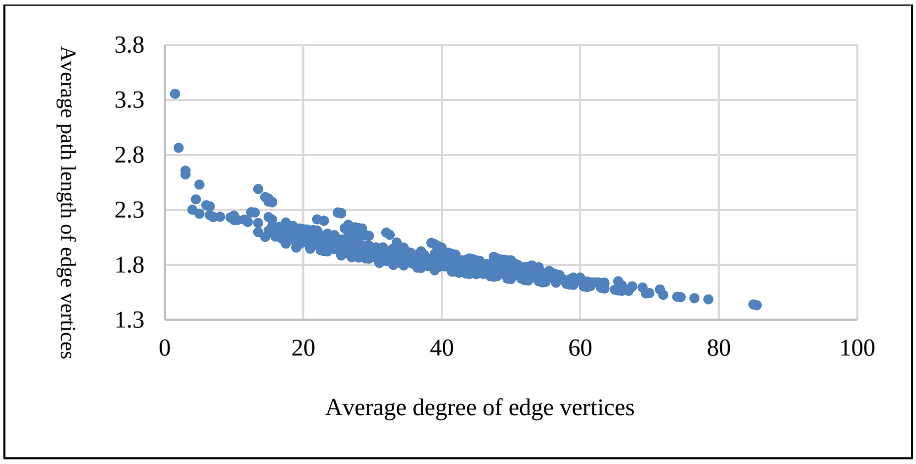

Fig. 13 Diagram of scatter points between average degree and average path length of edge vertices in 2008.

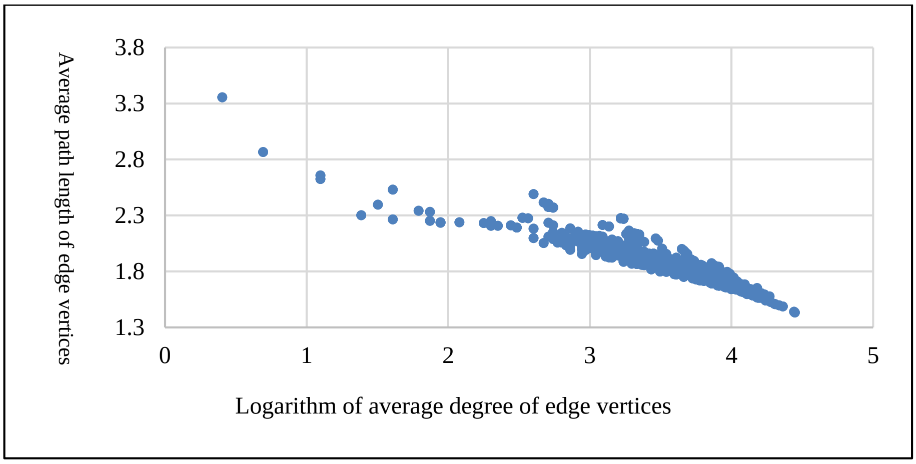

Fig. 14 Diagram of scatter points between logarithm of average degree and average path length of edge vertices in 2008.

Fig. 14 had significant linear correlation. Least square method was used as an approach in Eq. (20) to fit the line with points in Fig. 14.

$$\begin{cases} \hat{\beta}_0 = \bar{y} - \hat{\beta}_1 \bar{u} = 3.13 \\ \hat{\beta}_1 = \dfrac{L_{uy}}{L_{uu}} = -0.353 \end{cases} \tag{20}$$

The linear equation:

$$\hat{y} = 3.13 - 0.353u \tag{21}$$

The fitting line Eq. (21) was drawn with the sample points in Fig. 15 with good fitting effect.

To take t test of Eq. (21), test hypothesis is: $H_0: \beta_1 = 0$. When the hypothesis was true, there is Eq. (10). The statistic t was calculated by Eqs. (11) and (12), $t = -68.6$. To check the t distribution table, at significant level α of 0.01 and degree of freedom $f = n - 2 = 938$, the value $t_{\substack{\alpha=0.01 \\ f=938}} = 2.362$. So, $|t| = 68.6 > 2.362 = t_{\substack{\alpha=0.01 \\ f=938}}$, null hypothesis H_0 is refused. The linear correlation of Eq. (21) is significant. The fitting curve Eq. (22) of nonlinear relationship between node degree and the path average length was deduced from Eq. (21):

$$\hat{y} = 3.13 - 0.353 \ln x \tag{22}$$

The points of the fitting curve Eq. (22) and the sample points were drawn in Fig. 16 with good fitting effect. It showed that the average degree of edge vertices in China aviation network in 2008 had a logarithmic relationship with the average path length of edge vertices.

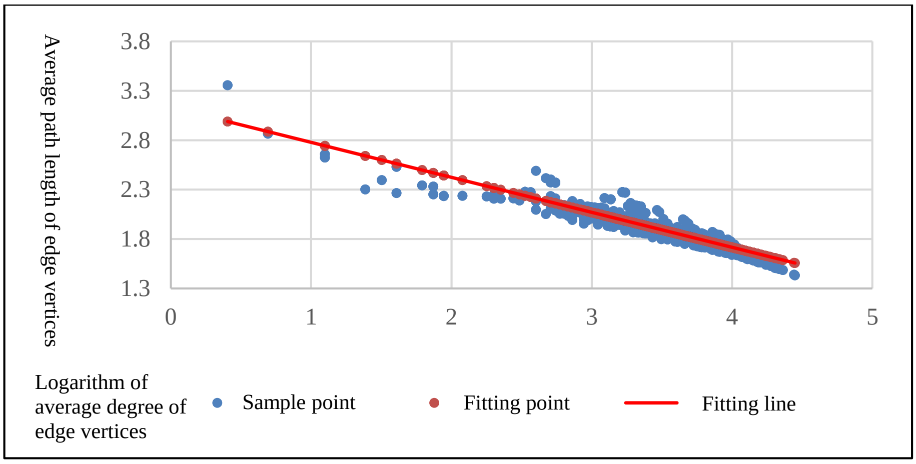

Fig. 15 Fitting linear relationship between logarithm of average degree and average path length of edge vertices in 2008.

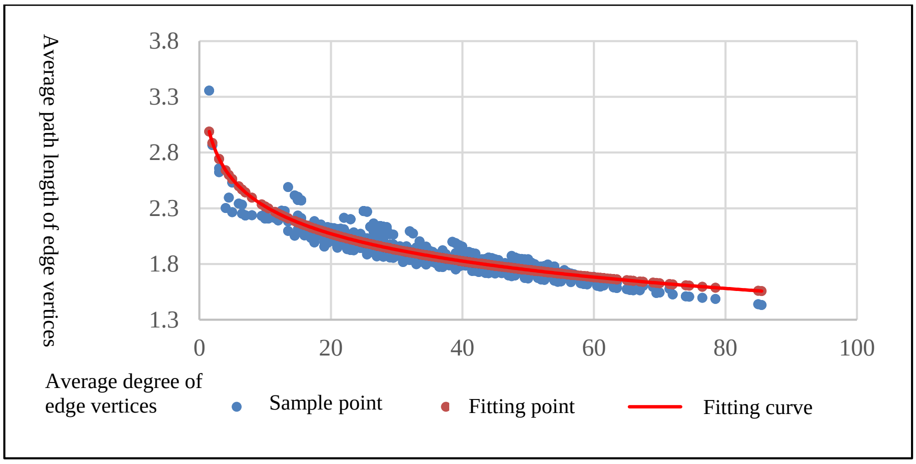

Fig. 16 Fitting nonlinear relationship between average degree and average path length of edge vertices in 2008.

2.5 Nonlinear Relationship between Average Degree and Average Path Length of Edge Vertices of China Aviation Network in 2015

According to the data of China aviation network in 2015, the adjacency matrix A_{2015} was calculated. The path length matrix L_{2015} was calculated by A_{2015}. The average degrees of edge vertices D_n^{EVA} ($n=1,2,3,......,1924$) of 1,924 edges in 2015 were gotten from A_{2015} and Eq. (2). The average path length of edge vertices L_n^{EVA} ($n=1,2,3,......,1924$) of 1,924 edges in 2015 were gotten from L_{2015} and Eq. (6). The scatter points between average degree and average path length of these 1,924 edge vertices were drawn in Fig. 17.

Let the node degree be x and the average length of node path be y. Let $u=\ln x$. The points in Fig. 18 were calculated by the points in Fig. 17. The correlation coefficient r of the points in Fig. 18 was calculated by Eq. (7). Here, $n=1924$. The value of correlation coefficient r was calculated, $r=-0.92$. The critical value $r_{\left|\substack{\alpha=1\% \\ f=1922}\right.}=0.081$ was found in critical value table at degree of freedom $f=n-2=1922$ and level of significant α of 1%.

Since $|r|=0.92>0.081=r_{\left|\substack{\alpha=1\% \\ f=1922}\right.}$, the scattered points in Fig. 18 had significant linear correlation. Least square method was used as an approach in Eq. (23) to fit the line with points in Fig. 18.

$$\begin{cases} \hat{\beta}_0 = \bar{y} - \hat{\beta}_1 \bar{u} = 2.97 \\ \hat{\beta}_1 = \dfrac{L_{uy}}{L_{uu}} = -0.298 \end{cases} \tag{23}$$

The linear equation:

$$\hat{y} = 2.97 - 0.298u \tag{24}$$

The fitting line Eq. (24) was drawn with the sample points in Fig. 19 with good fitting effect.

To take t test of Eq. (24), test hypothesis is: $H_0 : \beta_1 = 0$. When the hypothesis was true, there is Eq. (10). The statistic t was calculated by Eqs. (11) and (12), $t = -104.1$. To check the t distribution table, at significant level α of 0.01 and degree of freedom $f = n - 2 = 1922$, the value $t\big|_{\alpha=0.01, f=1922} = 2.362$. So, $|t| = 104.1 > 2.362 = t\big|_{\alpha=0.01, f=1922}$, null hypothesis H_0 is refused. The linear correlation of Eq. (24) is significant. The fitting curve Eq. (25) of nonlinear relationship between node degree and the average path length was deduced from Eq. (24):

$$\hat{y} = 2.97 - 0.298 \ln x \tag{25}$$

The points of the fitting curve Eq. (25) and the sample points were drawn in Fig. 20 with good fitting effect. It showed that the average degree of edge vertices in China aviation network in 2015 had a logarithmic relationship with the average path length of edge vertices.

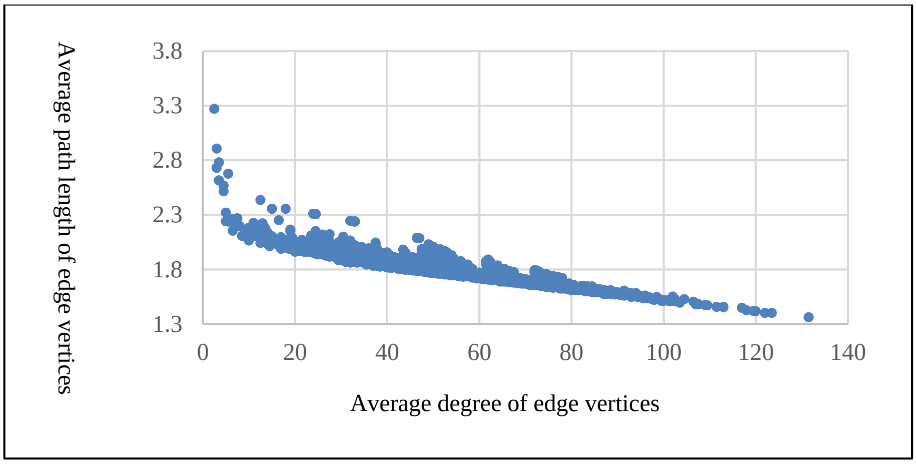

Fig. 17 Diagram of relationship between scatter points between average degree and average path length of edge vertices in 2015.

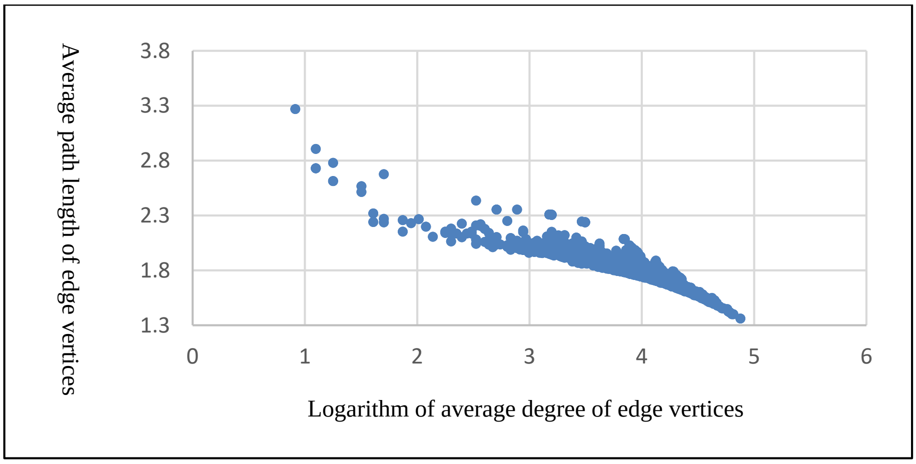

Fig. 18 Diagram of relationship between logarithm of average degree and average path length of edge vertices in 2015.

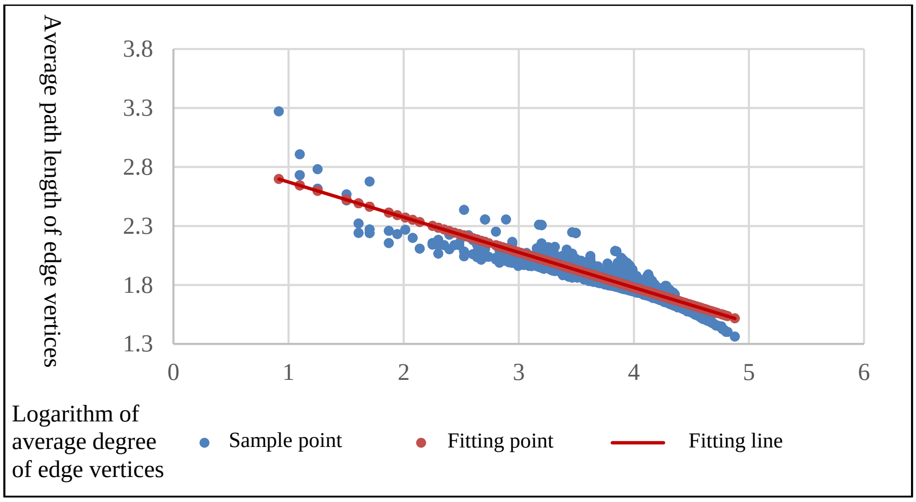

Fig. 19 Fitting linear relationship between logarithm of average degree and average path length of edge vertices in 2015.

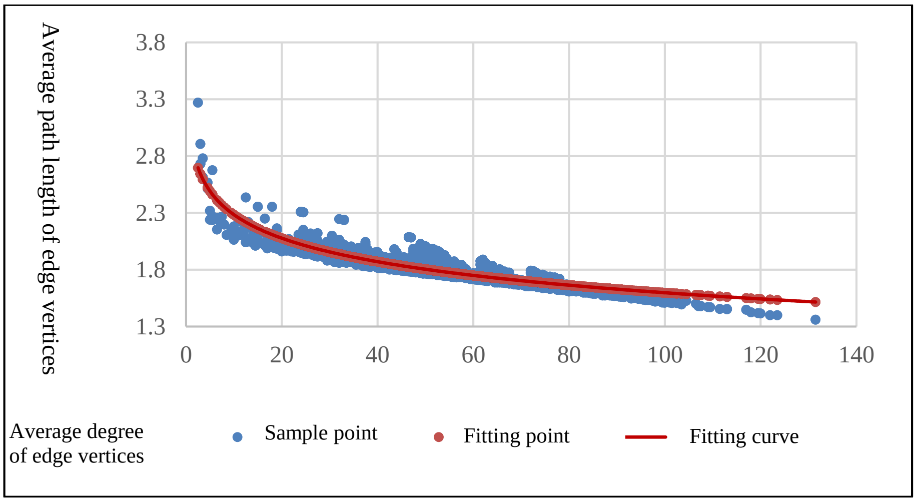

Fig. 20 Fitting nonlinear relationship between average degree and average path length of edge vertices in 2015.

3. Evolution of Relationship between Average Degree and Average Path Length of Edge Vertices of China Aviation Network

3.1 Logarithmic Relationship Evolution between Average Degree and Average Path Length of Edge Vertices of China Aviation Network

The fitting curve Eq. (13), Eq. (16), Eq. (19), Eq. (22) and Eq. (25) of relationship between average degree and the average path length of edge vertices of China aviation network in 1988, 1994, 2001, 2008 and 2015 were drawn in Fig. 21.

In Fig. 21, from 1988 to 2015, the relationship curves between the average degree and the average path length of edge vertices were arranged from bottom to top, and the front part intersected and the rear part diverged. With the increasing of the average degree of edge vertices, the average path length of edge vertices decreased rapidly and then slowly.

3.2 Parameter Evolution of Logarithmic Relationship between Average Degree and Average Path Length of Edge Vertices of China Aviation Network

The two parameters in fitting curve equation were taken as one point. Then the parameters in five fitting curve equations could consist five points: (3.37, -0.464), (3.08, -0.353), (2.95, -0.329), (3.13, -0.353), (2.97, -0.298). These five points were drawn in Fig. 22. The correlation coefficient r of the points in Fig. 22 was calculated, $r = -0.964$. Here, $n = 5$. The critical value $r_{\left|\substack{\alpha=1\% \\ f=3}\right.}=0.959$ was found in critical value table at degree of freedom $f=n-2=3$ and level of significant α of 1%. Since $|r|=0.964>0.959=r_{\left|\substack{\alpha=1\% \\ f=3}\right.}$, the scattered points in Fig. 22 had significant linear correlation. Least square method was used as an approach in Eq. (26) to fit the line with points in Fig. 22.

$$\begin{cases} \hat{\beta}_0=\bar{y}-\hat{\beta}_1\bar{x}=0.75 \\ \hat{\beta}_1=\dfrac{L_{xy}}{L_{xx}}=-0.358 \end{cases} \tag{26}$$

The linear equation:

$$\hat{y}=0.75-0.358x \tag{27}$$

The fitting line Eq. (27) was drawn with the sample points in Fig. 23 with good fitting effect.

To take t test of Eq. (26), test hypothesis is: $H_0:\beta_1=0$. When the hypothesis was true, there is Eq. (10). The statistic t was calculated by Eqs. (11) and (12), $t=-6.35$. To check the t distribution table at significant level α of 0.01 and degree of freedom $f=n-2=3$, the value $t_{\left|\substack{\alpha=0.01 \\ f=3}\right.}=4.541$. So, $|t|=6.35>4.541=t_{\left|\substack{\alpha=0.01 \\ f=3}\right.}$, null hypothesis H_0 is refused. The linear correlation of Eq. (27) is significant.

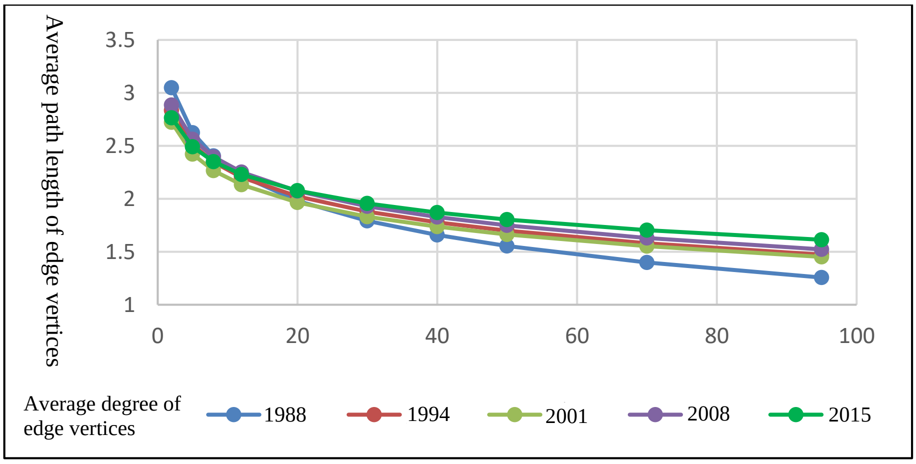

Fig. 21 Evolution diagram of logarithmic relationship between average degree and average path length of edge vertices of China aviation network.

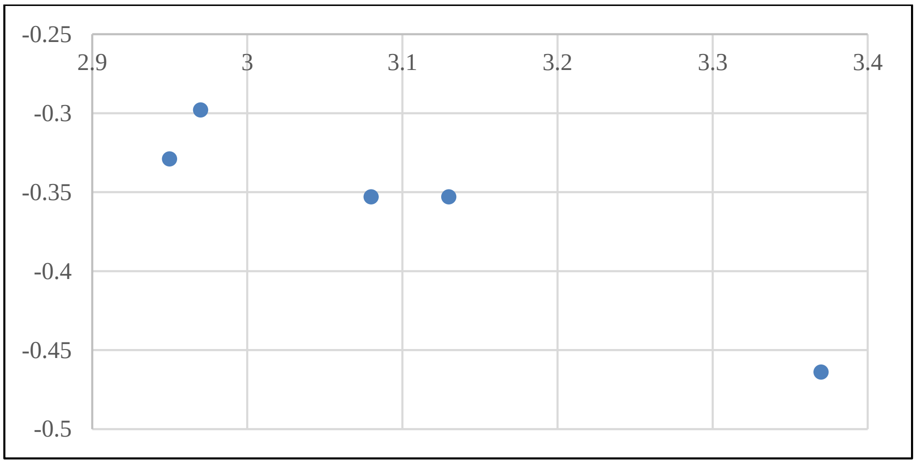

Fig. 22 Diagram of relationship between the two parameters of logarithmic curves.

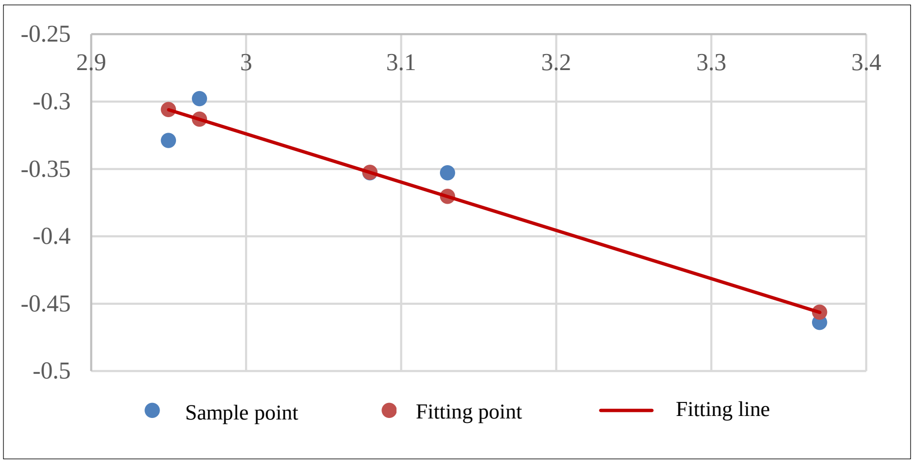

Fig. 23 Fitting linear relationship between the two parameters of logarithmic curves.

4. Conclusion

In order to reveal the complex network characteristics and evolution principle of China aviation network, the relationship between the average degree and the average path length of edge vertices of China aviation network in 1988, 1994, 2001, 2008 and 2015 were studied. According to the statistical data, it was found that the relationship between average degree and average path length of edge vertices of China aviation network had a logarithmic function and the two parameters of the function had linear evolution trace. From 1988 to 2015, the relationship curves between the average degree and average path length of edge vertices were arranged from bottom to top, and the front part intersected and the rear part diverged. With the increasing of the average degree of edge vertices, the average path length of edge vertices decreased rapidly and then slowly. The two parameters of the logarithmic relationship of these five curves had linear evolutionary trace through regression analysis.

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