A post-evaluation Research of Economical Effects for Power Grid Construction Project Based on ANP-Hesitate Linguistics

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Abstract: In electric power system reform environment, grid companies have to estimate the economic performance of power grid construction project completed with a more market-oriented perspective. Therefore, economic efficiency post-appraisal model of the power grid is proposed in this paper. In view of the problem of evaluating of economic benefits only from financial angle in existing research, lack of comprehensiveness and depth, including construction costs, financial, social and economic benefits and environmental impact costs four aspects were build as the index system with network hierarchy. On this basis, the ANP method to solve the index weight was put forward, and hesitate linguistic evaluation method for policymakers, finally cloud model assembled each index evaluation result.In the end, three power grid construction projects in liaoning province had built were used for verifying the feasibility and rationality of the model.

Introduction

At present, China's power sector reform towards market-oriented direction, grid company as a important participant in the power reform, it will face fierce competition in the electricity market. In fact, economic efficiency is the basis of power grid enterprises, major project's decision error will create a severe financial burden to grid enterprises and even bankruptcies. Correct decision-making is the premise of ensuring the long-term stable development of the grid, power grid construction projects completed will provide experiences and support for the following projects. So, evaluation from the perspective of economic efficiency for grid construction projects are necessary and useful. Economic evaluation of grid construction project is divided into previous assessment and after evaluation. Different from the previous assessment, after evaluation economic benefit is based on the life period of the real objective of financial revenue and expenditure data, and this is more in line with power grid construction projects actual operating situation. Therefore, the evaluation of economic benefit is feedback aspect of project management, which aimes at summing up experiences and lessons for future investment through the completed project to provide more scientific decision-making and management services.

The current study of grid construction project economic evaluation is very few, the common comprehensive evaluation method were correlation method, success degree evaluation, logical frame method, analytic hierarchy process(AHP) and method of DEA. Comprehensive evaluation methods above analyze the economic benefit of power grid construction project, but it is assuming that influencing factors were independent of each other, lacking of consideration of mutual influence between the factors. Actually, these factors are not independent, such as the construction

cost has influence to the financial benefits, and not directly decided financial benefits. The single financial benefit evaluation cannot reflect the construction cost level, so ignore this influence will lead to inaccurate decision results when the comprehensive evaluation of economic benefits is implemented. Accordingly, the literature[4,5] proposed ANP method based on the multilevel fuzzy comprehensive evaluation, which considering the influence of the relationship between the indexes, case analysis shows that ANP method has better decision-making comparing with AHP method.

Because of the active participation of the decision makers and the uncertainty of things,we need give attention to easy understanding and applicability of the decision making process. Compared with the quantitative description of index information, linguistic information is more easy to understand and accurate. Such as an information description of index is good, which is obviously easier understand than quantitative description as 80 points. Numerical value is not in conformity with the intuition thinking, and a data point value and even interval value may be inaccurate. In addition, due to the knowledge, experience and the differences thinking mode of the decision makers, a description of target information may be different, and these descriptions can't convince each other, but also cannot ignore, presenting the state hesitate[6]. Secondly, different decision makers have different degree for the understanding of solution(credibility). So the hesitation linguistic evaluation attaching the credibility has a good applicability. In order to reduce the loss of information in the process of transformation, this paper introduces the cloud model to transform the information of linguistic. The cloud model takes into account the fuzziness and uncertainty of information, and can reduce the amount of information loss [7].

To sum up, this paper puts forward the economic benefit evaluation model of grid construction project, which based on ANP and hesitation linguistic.

Evaluation index system

The construction and operation periods are the most closely related to the whole life cycle of power grid construction project.Based on the four aspects that the requirements of the implementation of the power grid construction project post evaluation;the setting principle and method of project economic benefit evaluation index system;combined with the actual situation of China power grid project to choice the construct cost of construction period,as well as the financial benefits of operating period,social and economic benefits and environmental impact costs of four aspects to build power grid construction project economic evaluation index system as shown in table 1 .

Construction cost. Grid construction stage is the implementation of maximum workload, the investment of human, material and financial resources than any other stage, so it is the main stage of project management and control.As one of the major objectives of project management, the management level of the project cost management has the direct impact on the overall effectiveness of the power grid project.However, the traditional economic benefits post evaluation index system said that single financial efficiency indicators can be used to evaluate the internal efficiency of the power network construction project, and did not introduce a construction cost index.However, the factors that affect the ultimate benefit of enterprises are the construction cost and sales income. Therefore, the traditional financial benefit index alone can not reflect the construction cost level of the power grid construction project adequately, even not reflect Construction Cost management level of power grid construction provide, so it can not provide the basis for the similar projects construction management. So this article will introduce the construction cost index.

The massive project practice indicated that the good construction cost management level has laid the foundation of entire electrical network project overall benefit,however,the main calculation index of project construction cost in the construction period reflects the construction cost directly.So

this article selects 7 main indicators of the construction cost, such as the construction cost, the equipment purchase cost, as the second index of the construction cost.

Financial benefits. In the early stage of production operational projects, grid project has begun to make sales revenues, the start of direct financial benefit is obvious.It is the core link of the whole power grid project,and it is vital to the producing benefits of grid enterprise and the financial benefits are reflect the management level of power construction project directly in the operational period.

Grid enterprise's financial benefits can be afford in the basic form of finance.So the relevant financial benefits index reflects the power of profit level and the solvency.Therefore,This article selects the grid project financial benefit evaluation index of investment profit margin, the financial internal rate of return, net present value and other seven common evaluation index as child index of financial benefits.

Socio-economic benefits. Power grid project as large infrastructure projects to provide public goods has great socio-economic impact,and has more impact on the projects which has common effects in local economic,so the socio-economic benefits are unnegligible .

According to 《The Detailed Rules Of the post evaluation of electric power construction projects》,the power gird project's impacts on local socio-economic including employments, local national economy structure,financial revenue,and the effects on the power of improve local economy in the periods of project construction.

In this paper, Combined effects of electric power construction project on the social economy, construction of socio-economic benefits evaluation index includes 5 second index that direct employment, the creation of gross domestic product and boost the local economy, the tax amount and the second industry ratio between investments.

Environmental cost. In recent years, the government's environmental requirements of large engineering project is more and more strict, so the environmental cost of the power grid construction project is increasing constantly.Power gird project is always the large infrastructure project, and it has big effect which has the features of strong concealment and high potential cost on environment.Therefore, it is not only the cost of the environment resources which to be used and destroyed in the construction stage, but also the long-term loss of economic benefits. So this paper uses the environmental factors as an independent indicator of the economic benefit of power grid construction projects.According to<<The Detailed Rules Of the post evaluation of electric power construction projects>>, the possible factors of effects on environment including gas,water,noise and solid wastes.Because the scale of Power gird project is bigger,the nature of project covered the land is belong to the content of environment effects.Therefore, this paper constructs the 5 second indicators of environmental impact cost, which is the cost of waste disposal, electromagnetic, noise pollution, hidden land cost, transmission and emission reduction benefit and environmental coordination cost.

Table.1 evaluation index system of economic benefits of power grid construction project

First Index	Construction cost C1	Financial Benefit C2	Socio-economic benefits C3	Environmental cost C4
Secondary Index	C11	C21	C31	C41
	C12	C22	C32	C42
	C13	C23	C33	C43
	C14	C24	C34	C44
	C15	C25	C35	C45

First	Construction cost	Financial Benefit	Socio-economic benefits	Environmental cost
Index	C1	C2	C3	C4
Secondary	C16	C26	C36	C46
Index	C17	C27	C37	C47

Secondary indexes signs denots as follow:

Equipment purchase cost C12; Installment engineering cost C13; Other expenses of construction C14;Basic reserve funds C15; Loan interest C16; Price rise reserve funds C17; Investment profit rate C21; Financial internal rate of return C22; FNPV financial net present value financial net value C23; Payback period of investment C24; Loan payback period C25; Liquidity ratio C26; Quick ratio C27; Direct employment C31; Create gross C32; Boost the local economy C33; Total tax payment C34; The second industry investment proportion C35; Waste disposal cost C41; Electromagnetic, noise pollution cost C42; Hidden land cost C43;Transmission emission reduction benefits C44;

Methodology of economic benefit evaluation

Cloud model and the fuzzy linguistic set with confidence

Definition 3.1.1 A qualitative concept, C, such as fuzzy testing stress, is defined over the universe of discourse, U. If the quantitative value x belongs to U, and x is the random realization of concept C, then the certainty grade u(x) of x belonging to C is a random variable with a stable tendency:

$$\mu : U \rightarrow [0,1], \forall x \in U, x \rightarrow \mu(x)$$

Definition 3.1.2 The cloud model consists of three feature parameters: Ex, En,and He. Ex is the expectancy of the cloud model. En is the entropy of the cloud model. He is the hyper-entropy of the cloud model[8];

Definition 3.1.3 Let X be a reference set, an HLS on X is a function h that returns a subset of values in [0, 1]: $h : X \rightarrow \{[0,1]\}$.

Definition 3.1.4 Order linguistic standard $S = \{S_1, S_2, ..., S_g\}$, which has g order linguistic units. If and only if $a < b$, $Sa < Sb, a, b \in \{1, 2, ..., g\}$ .In this paper, we use 5 standards linguistic set:

$$S = \{S_{-2} very\ poor, \quad S_{-1} poor, \quad S_0 middle, \quad S_1 good, \quad S_2 very\ good\}$$

Definition 3.1.5 A hesitant linguistic set with credibility. Where l_n denotes the credibility of S_n,

$$H(x) = \{< l_1, S_1 >, < l_2, S_2 >, ..., < l_n, S_n >\}.$$

Decision makers may come from different backgrounds, and the familiarity degree of decision makers is not the same for the same decision. Therefore, the credibility of decision maker should be considered in order to make the results more reasonable and feasible.

Evaluation model implementation steps

Index weight determination based on ANP method. ANP is a kind of decision making method which is suitable for the non - independent, and it is a new practical decision-making method based on the analytic hierarchy process (AHP). It is especially suitable for the complex decision-making system with the internal dependency and feedback relationship. In this paper, the evaluation index system has an effect relationship, so the ANP method is used to determine the index weight.

According to the ANP method, the SuperDecision software is applied to calculate the relative dominance of each index and the weight of the index.

Linguistic set conversion to cloud. Assuming effective domain $U^* = [0,100], He_0 = 0.1$.In this paper, we use the golden section method in the literature to transform the linguistic set[9] .

$$Ex_0 = (U^*_{min} + U^*_{max})/2,\ Ex_{(n-1)/2} = U^*_{max},\ Ex_{-(n-1)/2} = U^*_{min},\ Ex_i = Ex_0 + 0.382i\left(\frac{U^*_{min} + U^*_{max}}{2}\right)\Big/\frac{n-3}{2},$$

$$Ex-i = Ex0 - 0.382i\left(\frac{U^*_{max} + U^*_{min}}{2}\right)\Big/\frac{n-3}{2},\ (1 \le i \le \frac{n-3}{2}); \tag{1}$$

The normal cloud of the corresponding linguistic can be expressed as follows;

$$Y_{-2} = (0.10,31,0.26), Y_{-1} = (30.9,6.37,0.16), Y_0 = (50,3.93,0.1),$$
$$Y_1 = (69.1,6.37,0.16), Y_2 = (100,10.31,0.26);$$

Integration of the hesitation linguistic set with credibility. The linguistic set of a certain index, $H(x) = \{S_1(l_1), S_2(l_2),...,S_n(l_n)\}$, according to the algorithm for a cloud generator[8] , it will be converted to normal cloud linguistic, denotes N cloud drops as follows: $(x_1, y_1), (x_2, y_2),...,(x_N, y_N)$.

A is created by N cloud drops, which value is $\hat{S}(A)$ [10].

$$\hat{S}(A) = \frac{1}{n}\sum_{n=1}^{n} x_i y_i \tag{2}$$

linguistic units in $H(x)$ can be transformed into follows: $\hat{S}_1(H),...,\hat{S}n(H)$ .Then,we get $Ag(H)$.

$$Ag(H) = \frac{1}{\sum_{i=1}^{n} l_i}\left(\sum_{i=1}^{n}(l_i * \hat{S}_i(H))\right) \tag{3}$$

Score function. Group of experts give all the secondary indexes weighted, the score function is as follows:

$$S = \sum_{i=1, j=1}^{i=m, j=n}(w_{ij} * Ag(H_{ij})) \tag{4}$$

Where S is score function, w_{ij} denotes the weight of the index X_{ij} .

Case analysis

Liaoning Provincial State Grid Company has built a number of grid construction projects in the 12th Five-Year Plan , to a certain extent,these power grid construction projects solved the problem of insufficient power transmission capacity. After screening, three typical transmission projects are selected as the research object, which labeled 1, 2, 3, and the voltage rating is 220Kv, the transmission line length is more than 110Km, the time limit is about 1-3 years, the entire construction year are 2011-2014.

Case evaluation. In the Project investment period,we gathered the NO.1, 2, 3 three projects of the historical financial data, and invited 10 experts to evaluate the construction cost of the three transmission projects, financial benefits,social economic benefits and environmental impact of the cost of four indicators.The evaluate degree are the linguistic standards, divided into VP (very poor), P (General), G (good) and VG (very good) five levels.Because of the different experts' experience and professional field, the expert system will give a the reliability of the different views and perspectives of the evaluation results to get a reasonable result.For example $H_{11}=\{VP (0.6), P (0.8)\}$, it shows that the expert system got two views from the first 1 indicator of the project evaluation results, that is, the credibility of the very poor is 0.6, the credibility is 0.8. The initial evaluation matrix is shown in table 2;

Table.2 Initial evaluation matrix

First index	Secondary index	Power Project 1	Power Project 2	Power Project 3
Construction Cost	C11	VP(0.1),P(0.9)	VP(0.9)	G(0.8),VG(0.2)
	C12	G(1)	M(0.6),G(0.7)	M(0.9),G(0.4)
	C13	G(0.3),VG(0.8)	M(0.8),G(0.5)	P(0.8)
	C14	P(0.2),M(0.8)	G(0.8),VG(0.6)	M(0.9),G(0.1)
	C15	G(0.4),VG(0.9)	M(0.8),G(0.6)	M(0.3),G(0.6)
	C16	G(0.8),VG(0.7)	P(0.9),M(0.6)	VP(0.7)
	C17	G(0.9)	P(1)	G(0.9),VG(0.3)
Financial Benefit	C21	M(0.4),G(0.8),VG(0.3)	G(0.8),VG(0.4)	M(0.7)
	C22	P(0.4),M(0.9)	M(1)	G(0.7),VG(0.3)
	C23	M(0.2),G(0.8)	P(0.6),M(0.6)	M(1)
	C24	M(0.3),G(0.8)	P(0.7),M(0.5)	M(0.8),G(0.2)
	C25	M(1)	M(1)	M(0.6)
	C26	G(1)	G(1)	G(0.6)
	C27	M(1)	M(1)	M(0.7)
Socio-economic Benefits	C31	P(0.3),M(0.7)	M(0.6),G(0.7)	G(1)
	C32	M(0.4),G(0.7)	G(0.5),VG(0.8)	M(0.8),G(0.3)
	C33	M(0.2),G(0.9)	P(0.6),M(0.6)	G(0.7),VG(0.1)
	C34	G(1)	P(0.4),M(0.7),G(0.2)	M(0.9),G(0.4)
	C35	M(0.3),G(0.6)	G(0.6),VG(0.8)	P(0.5),M(0.9)
Environment Cost	C41	M(0.2),G(0.6)	G(0.6),VG(0.2)	P(0.6)
	C42	G(0.8),VG(0.5)	M(0.6),G(0.2)	M(0.7),G(0.2)
	C43	G(0.5),VG(0.5)	M(0.5),G(0.8)	M(0.3),G(0.8)
	C44	G(0.3),VG(0.8)	M(1)	M(0.7)
	C45	M(0.3),G(0.5)	P(0.5),M(0.8),G(0.2)	M(0.8),G(0.2)

As stated above, the evaluation index system in Table 2 has an effect relationship, so the network structure model of the index system is constructed shown in Figure 1;

In Figure 1, the target and the first level index are the control factors in ANP, and the network structure of the secondary level indicators is the network layer. Based on the relationship of the elements, the elements are compared with each other, and the specific data are entered into the SD software according to the result of the comparison. Finally, the weights are calculated by the super matrix and the limit matrix. In addition, in order to get the result of two methods, this paper also lists the weights calculated by the AHP method, and the weights of the 24 secondary level indexes in this case are shown in table 3.
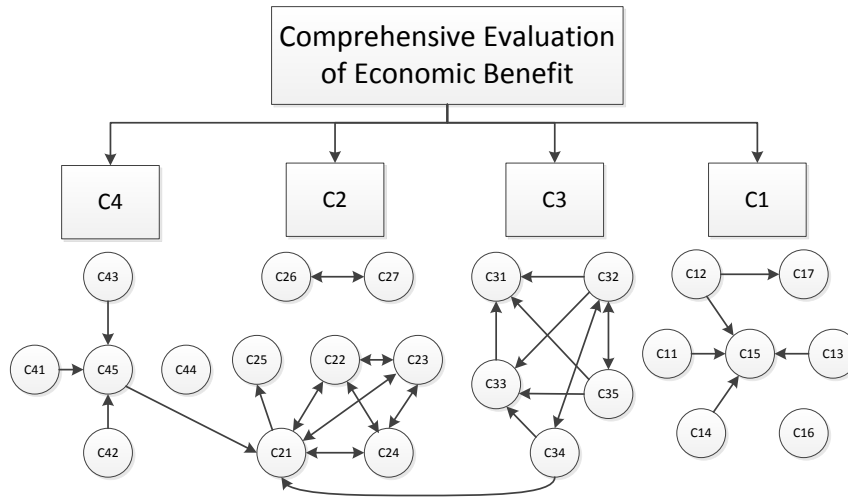

Fig. 1 Network structure model of the index system

Table.3 Weights of the secondary level indexes

Secondary Index	ANP	AHP	Secondary Index	ANP	AHP
C11	0.023	0.021	C16	0.003	0.005
C12	0.071	0.046	C17	0.004	0.002
C13	0.044	0.011	C21	0.157	0.143
C14	0.009	0.011	C22	0.210	0.072
C15	0.047	0.004	C23	0.211	0.047
C24	0.066	0.027	C34	0.027	0.023
C25	0.022	0.017	C35	0.004	0.005
C26	0.021	0.011	C41	0.002	0.002
C27	0.023	0.013	C42	0.001	0.001
C31	0.010	0.002	C43	0.003	0.002
C32	0.010	0.013	C44	0.006	0.005
C33	0.014	0.007	C45	0.012	0.015

In the process of transforming linguistic set to cloud , in order to ensure a more accurate analog cloud, this article produces 10000 cloud drops to estimate the target the cloud value. Building up all the secondary indicators, and then evaluates the result of the three power projects. The vectors $Y1$, $Y2$, $Y3$ respectively indicate the result of assembling secondary indicators of the power project No. 1, 2, 3.

$$Y1=[10.4298, 29.7578, 2.9050, 1.2413]，Y2=[7.4623, 26.7876, 2.5982, 0.8859]，$$

$$Y3=[7.8555, 29.8680, 2.7979, 0.8906]$$

According to the equation (4), results based on the ANP and AHP methods, and the results of the various power projects not considering confidence can be obtained, as shown in Table 4.

Table.4   Results of different methods

Power project	NO.1	NO.2	NO.3
ANP	44.1156 [1]	37.4919 [3]	41.1399 [2]
AHP	44.2550 [1]	41.2640 [2]	40.8396 [3]
Not considering confidence（ANP）	42.3293 [2]	38.5208 [3]	43.1679 [1]

According to the results of Table 4, considering the interaction between the indicators (ANP model), the economic benefits of power grid projects are evaluated and result as follow: project 3> project 1> project 2; Compared with ANP, the rusult of using AHP model is: project1> project 2> project 3. Leading to difference of the above scheme is the weight of some important indicators, such as the cost of equipment is a major factor in the cost of building, while this index has a direct impact on the cost of preparation cost. So weight of this index should be larger, but the weight is only 0.046, significantly less than the overall weight. Similarly, financial internal rate of return and financial net present value are also important indexes influencing other factors, the weight ratio should be larger, but only 0.072 and 0.047 when without considering the indexes influence. Therefor, the ANP method is more fully reflect the objective relationship between the indicators, and thus the weight is more reasonable.

In addition, according to the results of Table 4, there are significant differences in the ranking results when considering the credibility and not considering it.The reslut not considering the credibility is: project 3> project 1> project 2. This is because the decision maker has no subjective preference, but they are from different departments, professional background and experience may be different, this would lead to different understanding of the evaluation results. For example, the evaluation results of the project 3 , the credibility of the different views is very different. G and VG class evaluation results have low reliability, if not considering the credibility project 3 would have a good performance. However, the reliability of the G and VG class evaluation in the project 1 is generally higher than that of project 3, which will lead to the overall evaluation of the project is low if not taking the credibility into account. Therefore, in the evaluation of a program, there should be a corresponding degree of credibility to express the credibility of the attributes of the decision, so that the evaluation can be more reasonable and credible.

Case sensitiveness analysis. The first level index weight of ANP method is (0.201,0.710,0.065,0.024). But in order to check whether the model used in this paper is robust, the weight of ANP is analyzed in this paper. In the first level indexes, exchange the weight of any two indexes, and the weight of the second level index is maintained. Then 6 kinds of results are obtained,which are shown in Table 5.

From table 5, the results of sensitivity analysis show that randomly change 2 fist level indicators, the number 1 power grid project is still the best, and the number 2 substation engineering performance is still relatively poor. Which indicates the ANP- hesitation linguistic model has good robustness.

Table.5 Results of sensitiveness analysis

No.	Exchange the weight	Results（No.123 Project rankr）			Rank
1	（0.201,0.710,0.065,0.024）	44.116	37.492	41.140	1>3>2（Previous Rank）
2	（0.710,0.201,0.065,0.024）	49.650	37.459	39.950	1>3>2
3	（0.201,0.710,0.024,0.065）	44.316	37.315	40.856	1>3>2
4	（0.065,0.710,0.201,0.024）	46.263	38.081	41.867	1>3>2
5	（0.024,0.710,0.065,0.201）	44.207	37.616	40.944	1>3>2
6	（0.201,0.065,0.710,0.024）	46.159	39.127	41.965	1>3>2
7	（0.201,0.024,0.065,0.710）	51.325	37.250	38.084	1>3>2

Conclusion

In order to evaluate the economic benefit of power grid project more accurately and deeply, this paper has carried on the improvement to the related research.

(1)This paper constructed the index system including the construction cost, the environmental impact cost, and proposed the influence relationship between the index.

(2)On the basis of the above, the ANP- method is used to evaluate the economic benefits of the power grid projects, and the feasibility and effectiveness of the proposed method is verified by a case study.

(3)This paper provides a new way of thinking and methods for the economic evaluation of power grid construction project, and provide empirical evidence for the construction of similar power projects in the futher decision-making management .

References

[1] Electric power planning and Design Institute. Detailed rules for the implementation of the post evaluation method for electric power construction projects[M].Beijing:2009.(In Chinese)

[2] Mingxia Xue, Yiting Mao. Evaluation Research of Socila Effects for Power Grid Construction Project Based on AHP[J], Scientific practice, 2013,05:313.(In Chinese)

[3] Yuwei Ji.Grid Construction projectpost-evaluation base on DEA[D],North China Electic Power University(Beijing),2009.

[4] Zhiyong Xu, Dongxu Zhang, Ming zeng, Yan Fan. Application of ANP-based multifuzzy conprehensive evalution methods post-evaluation for grid construction projects[J]. East China Electic Power,2009,03:488-491.

[5] Zhimeng Luo, Jianzhong Zhou,Hui Qin, Qingqing Li, Yaoyao He. Performance Assessment Model of Hydropower Enterprise based on ANP[J]. Water Power,2009,07:70-72+80.

[6] Xiaodi Liu, Jianjun Zhu, Shitao Zhang. Hesitant fuzzy decision making method with confidence levels and preference information on alternatives[J].Systerm and Engineering and Electronics,2014,07:1368-1373.

[7] Chunbing Li, Xia Feng, Zhiqiang Qi. Research on decision making of multiple criteria with risk under linguistic environment{J].Statistics and Decision, 2015,12:34-38.

[8] Changyu Liu, Deyi Li, Lili Pan. Uncertain knowledge representation based on cloud model[J]. Computer Engineering and Applications, 2004, 40(2):32-35.

[9] Hongli Wang, Yuqiang Feng. On multiple attribute group decision making with linguistic assessment information based on cloud model. Control and Decision,2005.06.017.

[10] Wang J Q, Peng L, Zhang H Y, et al. Method of multi-criteria group decision-making based on

cloud aggregation operators with linguistic information[J]. Information Sciences, 2014, 274(8):177–191.