GERT Network of Cost and Risk Control of Construction Project

Yan Xue, Ding Liu(✉), and Xu Luo

Management Science and Engineering, Qingdao University of Technology, Jialing River Road, Qingdao, China
liu.ding@qut.edu.cn

Abstract. The early stage of project investment is the most optimal period for preventing project budget overruns, but the basis for evaluating the pre-project investment decision and risk management implementation strategy is unclear. This paper fills the research gap of quantitative analysis of cost risks, and precise matching of risk control strategies in the field of whole-process engineering cost management thus providing an innovative solution method for intelligent matching risk control activities and project cost overruns forecasting. Graphic Evaluation and Review Technique and Bayesian updating method were combined to develop an uncertain system analysis model of the project construction process, and Monte Carlo simulation was applied to figure out the analytical solution with different risk control methods in the project construction period. The results showed the risk transfer probability expectation and cost expectation results while adopting the optimal matching of risk control strategy in the optimal phase of the project construction process can weigh whether the risk control measures are worth implementing under the condition of limited construction period and resources combining with the risk threshold of investors. This is of practical significance for the pre-project investment decision and precise implementation of risk control during the construction process.

Keywords: whole process of project cost management · risk · GERT · Monte Carlo simulation

1 Introduction

Project cost management runs through the whole process of project construction, which is a long-term and dynamic process. Construction projects need a long construction period from the decision-making phase to the completion and delivery phase. During processes, complex and changeable risks exist in all phases of project construction. In 2013, China's Guangzhou-Hong Kong High-speed Railway project cost soared to 65 billion CNY (10.2 billion USD) due to numerous budget overruns and delays. Finally, the construction period was extended due to adverse risk control during construction, and the project overspending reached 3.4 billion CNY (540 million USD). Another example is the Su-Tong Yangtze River Highway Bridge, the contract price was estimated to be

J. Yang et al. (Eds.): ICMSEM 2022, AHE 12, pp. 646–657, 2023.
https://doi.org/10.2991/978-94-6463-038-1_61

6.45 billion CNY (1.01 million USD), while the final settlement funds were 8.6 billion CNY (1.35 billion USD). These out-of-control costs were all caused by the failure to consider risk factors comprehensively during the project estimate stage.

The whole process of cost management studies projects' cost issues from the investment decision stage, engineering design stage, and engineering construction stage to the completion evaluation stage during engineering project construction. As the construction of the project proceeds, the uncertainty of uncontrolled cost increases, and the possibility of controlling the cost decreases. The possibility of controlling cost in the investment decision-making stage is 100%, while the construction stage is only about 10% [6]. The research on quantitative description and precise control of the risks in the whole process of engineering construction contribute to reducing the cost in the early stage of a construction project, which is essential for project cost management.

2 Literature Review

Applying big data to project cost control management is an inevitable requirement for the development of industry informatization [5]. At present, the innovative research in the field of project cost mainly involves four aspects as follows.

The first category, create models to estimate and forecast project costs. Based on the Fuzzy Mamdani inference method, fuzzy relations, and compound maximum-minimum relations, a cost overrun prediction model for the construction project was established. This yielded a cost overrun probability for the most affected project0 [3]. The second category, finding the cardinal factors that affect the project cost. The key factors causing cost overrun were proposed by excavating and analysing the cost of prevenient cases of construction engineering [1]. The third category is to study the logical match between cost control strategies and the performance of engineering features. Based on the instrumentality of artificial neural networks, a structured decision support method was developed to achieve the matching of the most appropriate post-contract cost control techniques for different construction process stages [4]. Few studies have been conducted using mathematical tools for mechanism modelling and taking the whole process of construction projects as a system for project cost analysis, feedback, and control in combination with big data. The fourth category is to study the innovative application of BIM in project cost. The interactions, interrelationships, and inter-adjustments between "structure" and "innovative task" entities are studied to propose an approach to project cost and management [2].

Graphical Review Technique (GERT network) is an interdisciplinary technique of probability theory and mathematical statistics, computer simulation techniques, control theory, and management science that enables decision analysis and probabilistic processing of certain relationships. GERT network, which can be used to analyse a large number of real-world network systems, has been commonly applied to emergency material distribution path decision-making, item recycling benefit analysis, value transfer analysis of dynamic inputs in industrial chains, engineering project duration control, and complex product development, etc. [7]. Bayesian updating is a popular method for inferential statistics, and the updates of the GERT network parameters can be used to represent the causal information.

Therefore, based on the urgent practical needs of matching risk control strategies and applying big data in cost management, this paper studies the impact of risk control strategies on cost increase in the whole process of construction projects through the establishment of mathematical models and computer simulations.

3 Methodology

According to the ideology of system engineering to consider the whole process of project construction as one system, this paper establishes the GERT network model of risk evolution in the whole process of engineering construction to quantify the probability of risk transfer and the increased cost of controlling risk in all procedures. Two mathematical tools, moment generating function in probability theory and signal flow diagram in cybernetics, are utilized to address stochastic problems. The impact of implementing risk control strategies is designed as a Bayesian update process of the original network parameters and it interprets the evolution of risks in each phase of the construction project. Then Monte Carlo simulation is used to calculate the expectation and objective function value of network parameters after taking different risk control activities and find the optimal control nodes for decision-makers with corresponding control strategies.

This paper fills the research gap of quantitative analysis of cost risks, and precise matching of risk control strategies in the field of whole-process engineering cost management, which is of practical significance for the pre-project investment decision and precise implementation of risk control during the construction process, thus provides an innovative solution method for intelligent matching risk control activities and project cost overruns forecasting.

4 Model Establishment

4.1 Construction of GERT Network

The construction processes of the GERT network model are as follows.

Step1 Identify input type (exclusive or, or, with) and output type (probabilistic, affirmative) for each node in the system.

Step2 Establish a general GAN network to represent the objective system in the form of a network to give people a generalized understanding.

Step3 Perform appropriate logic transformation to transform the GAN network into a GERT network. The new network is composed of "exclusive or" nodes i and j, arrow line (i, j) and network parameters (p_{ij}, c_{ij}), as shown in Fig. 1.

Due to the long construction cycle of engineering projects with large investments, there is a risk generation, transfer, and fading process in each phase of construction. As shown in Fig. 2, the basic process of engineering project construction mainly includes investment decisions, engineering design, construction process, and complete evaluation. There is a self-loop flow in the stage of preparing design documents and organizing construction, meaning that there is a revision of the design documents and reconstruction due to unqualified acceptance, while any other links do not allow the existence of a self-loop flow.

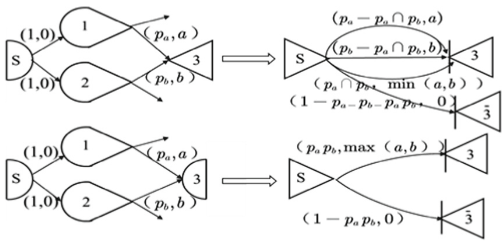


Fig. 1. Logical transformation of GAN network to GERT network

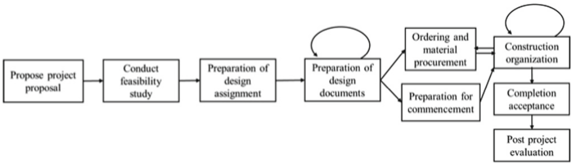


Fig. 2. Basic process of project construction

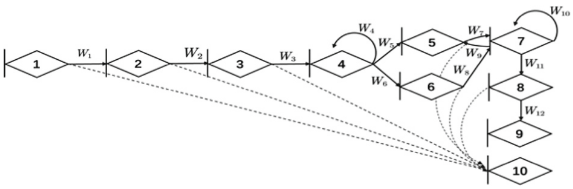


Fig. 3. GERT network model of risk evolution

Risks are random and dynamic, random from the uncertainty of unknown hazards, natural disasters, and sudden changes in policies and environment, and dynamic from the conduct of construction projects and the implementation of risk control strategies at different stages. Based on the perspective of risk origination, the GERT network model of risk evolution is established as shown in Fig. 3.

Nodes 1 to 9 correspond to the main steps of project construction in Fig. 2, while node 10 indicates the fading of risk, and the arrow line (i, j) represents the risk transfer activity between two arbitrary nodes. The network parameters on each arrow line (i, j) are specified as the risk transfer probability p_{ij} and the control cost c_{ij}. W_{ij} is a network parameter that is produced by p_{ij} and c_{ij}. Each node i has a corresponding risk control strategy recorded as W_i, and $w_i \in \Omega_i$.

At each node in the GERT network model of risk evolution in the whole process of engineering construction, the decision-maker needs to decide whether to adopt a control strategy at this node and which one to adopt at this node. Define the positioning variable t_i as and the assignment variables as (1–2).

$$t_i = \begin{cases} 1(\text{impletement strategy at node i}) \\ 0(\text{not implement strategy at node i}) \end{cases} \tag{1}$$

When the positioning variable $t_i = 1$, it indicates that the decision-maker decides to implement a control strategy at the node i, which could be any of the set of control strategies Ω_i at that point. When the positioning variable $t_i = 0$, it indicates that the decision-maker decides not to implement any control strategy at the node i.

$$o_{wi} = \begin{cases} 1(\text{impletement strategy } w_i \text{ at node i}) \\ 0(\text{not implement strategy } w_i \text{ at node i}) \end{cases} \tag{2}$$

When the assignment variable $o_{wi} = 1$, it indicates that the decision-maker decides to implement the specific control strategy W_i at node i. In such circumstances, it is obvious that $t_i = 1$. When the assignment variable $o_{wi} = 0$, it indicates that the decision-maker decides not to implement strategy W_i at node i. If $t_i = 1$, other control strategies in Ω_i must be adopted. Otherwise, all strategies in Ω_i are not adopted.

Denote the set of actions of the decision-maker at each node as $A = \{(t_i, o_i)|i = 1,2\ldots9, w_i \in \Omega_i\}$. Due to different actions of the decision-maker, the GERT network parameters will be updated and noted as (p'_{ij}, c'_{ij}). Provided that $\sum w_i\ o_{wi} = t_i$.

Assume that there is a quantifiable correlation between the occurrence of the arrow line (i, j) and activity W_i in the network model, which is denoted by the likelihood function $p'_{wi|ij}$. Known from the Bayesian formula for discrete random variables, Bayesian updating derives a posterior probability through continuous iteration of the prior probability and the likelihood function, and a posterior probability p'_{ij} of risk transfer probability p_{ij} between nodes i and j is:

$$p'_{ij} = \sum_{w_i}\left(o_{w_i} \cdot \frac{p'_{w_i|ij} \cdot p_{ij}}{\sum_j p'_{w_i|ij} \cdot p_{ij}}\right) + (1 - t_i) \cdot p_{ij} \tag{3}$$

In (3), the likelihood function $p'_{wi|ij}$ is the conditional probability of $o_{wi} = 1$ and $t_i = 1$, conditional on the occurrence of the activity (i, j).

$$pp'_{w_i|ij} = \frac{p_{ij}}{p_{w_i}} \tag{4}$$

In (4), p_{wi} is the probability of taking the strategy W_i from the risk control strategy set Ω_i of this node.

When $t_i = 1$, it indicates that a risk control strategy is implemented at node i, $o_{wi} \neq 0$ constantly establishes, and p'_{ij} equals the value of a posterior probability which is calculated according to the Bayesian formula. When $t_i = 0$, it indicates that no risk control strategy is implemented at node i, $o_{wi} = 0$and $p'_{ij} = p_{ij}$ constantly establish.

Compared with the original cost c_{ij} caused by risk in the construction process, the a posteriori cost parameter c'_{ij} different in two aspects. One is the increased cost c_{wi} of implementing the control strategy, and the other is the reduced cost due to advanced cost management control. Therefore, there is a correlation between the cost parameters c_{ij} before adopting the risk control strategy and the increased cost c_{wi} of adopting the strategy, and it can be expressed as a function in (5).

$$L_{c_{w_i}|c_{ij}} \sim N\left(\theta_{w_i ij} \cdot c_{ij}, \tau^2_{w_i ij}\right) \tag{5}$$

According to the Bayesian updating formula of continuous random variables and probability distribution $c_{ij} \sim N(u_{ij}, \sigma_{ij}^2)$, the marginal probability distribution function of c_{wi} is presented in (6). The updated cost parameter c'_{ij} is presented in (7).

$$C \sim N\left(\theta_{w_i ij} \cdot \mu_{ij}, \tau_{w_i ij}^2 + \theta_{w_i ij}^2 \cdot \sigma_{ij}^2\right) \tag{6}$$

$$c'_{ij} \sim N\left(\varepsilon_{ij}, v_{ij}\right) \tag{7}$$

The expectation and standard deviation of the probability distribution that a posteriori parameter c'_{ij} conforms are presented in (8–9).

$$\varepsilon_{ij} = \sum_{w_i}\left(o_{w_i} \cdot \frac{\tau_{w_i ij}^2 \cdot \mu_{ij} + \sigma_{ij}^2 \cdot \theta_{w_i ij} \cdot c_{w_i}}{\tau_{w_i ij}^2 + \sigma_{ij}^2 \cdot \theta_{w_i ij}^2}\right) + (1 - t_i) \cdot \mu_{ij} \tag{8}$$

$$v_{ij} = \sum_{w_i}\left(o_{w_i} \cdot \frac{\tau_{w_i ij} \cdot \sigma_{ij}}{\sqrt{\tau_{w_i ij}^2 + \sigma_{ij}^2 \cdot \theta_{w_i ij}}}\right) + (1 - t_i) \cdot \sigma_{ij} \tag{9}$$

When $t_i = 1$, it indicates that a risk control strategy is implemented at node i, $o_{wi} \neq 0$ constantly establishes, and the expectation and standard deviation of probability distribution that a posteriori parameter c'_{ij} conforms are calculated from the Bayesian formula based on the prior cost distribution c_{ij}. When $t_i = 0$, it indicates that no risk control strategy is implemented at node i, $o_{wi} = 0$ and $c_{ij} \sim N(u_{ij}, \sigma 2\ ij)$ constantly establish.

4.2 Analytical Solution of GERT Network for Risk Evolution

According to the logic of nodes in the signal flow diagram, the solution steps of the GERT model for risk transfer in the whole process of a construction project are as follows.

Step1: Derive the moment generating function of a posteriori cost according to the probability distribution of a posteriori cost which is determined by the decision-makers action A. Because of the probability distribution $c'_{ij} \sim N(\varepsilon_{ij}, v_{ij}^2)$, the moment generating function of a posteriori cost is presented in (10).

$$M_{c'_{ij}}(A, s) = E\left(e^{sc'_{ij}}\right) = \int_{-\infty}^{+\infty} e^{s \cdot c'_{ij}} \cdot f\left(c'_{ij}\right) dc'_{ij} \tag{10}$$

In Eq. (10), A is the set of actions that can be taken at each node; E is a mathematical expectation; $f(c'_{ij})$ is the conditional probability distribution function of the activity (i, j); s is an arbitrary real number; and c'_{ij} is a posteriori cost parameter affected by the decision-makers action.

Step2: Define the equivalent transfer coefficient between two adjacent nodes and convert the original GERT network into a new one with the identical structure but only one network parameter. The equivalent transfer coefficients between two adjacent nodes in the GERT network can be described as follow.

$$W_{ij}(A, s) = p'_{ij} \cdot M_{c'_{ij}}(A, s) \tag{11}$$

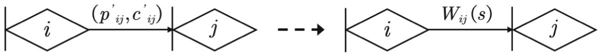


Fig. 4. Transformation of GERT network parameters between nodes

In (11), p'_{ij} is a posteriori probability of activity (i, j) realization after the decision-maker took risk control action when node i has been realized; $M_{c'_{ij}}(A, s)$ is the moment generating function of a posteriori cost c'_{ij}. The transformation of GERT network parameters by defining equivalent transfer coefficients is demonstrated in Fig. 4.

Step3 Calculate the equivalent transfer coefficient between arbitrary two nodes depending on the topological equation of the signal flow diagram. The Mason formula is given in (12), and the equivalent transfer coefficient between arbitrary two nodes is presented in (13).

$$T_{ij} = \frac{1}{\Delta}\sum\nolimits_{k=1}^{n} p_k \Delta_k \tag{12}$$

$$W_{E_{ij}}(A, s) = \frac{1}{\Delta}\sum\nolimits_{k=1}^{n} W_{ijk}(A, s)\Delta_k \tag{13}$$

In (12)–(13), Δ is the characteristic formula of the signal flow diagram; p_k is the equivalent transfer coefficient on the path from node i to node j; Δ_ks is the characteristic formula of the signal flow diagram after eliminating all nodes and arrow lines interrelated to path k; and $W_{ijk}(A, s)$ is the equivalent transfer coefficient on the path from node i to node j.

List rings of each order in the whole process of project construction GERT network in Table 1, and calculate the equivalent transfer coefficients from node 1 to node 9 presented in (14)–(15) according to the Mason formula, for subsequent calculation of the equivalent a posterior probability and equivalent a posterior cost. As is seen in Fig. 3, there are two paths from node 1 to node 9, $\Delta_k = 1$.

$$W_{E_{19}}(s) = \frac{W_1(s)W_2(s)W_3(s)W_5(s)W_7(s)W_{11}(s)W_{12}(s)}{\Delta} + \frac{W_1(s)W_2(s)W_3(s)W_6(s)W_8(s)W_{11}(s)W_{12}(s)}{\Delta} \tag{14}$$

$$\Delta = 1 - W_4(s) - W_{10}(s) - W_7(s)W_9(s) + W_4(s)W_{10}(s) + W_4(s)W_7(s)W_9(s) \tag{15}$$

Step4: Calculate the equivalent a posteriori probability Ep'_{ij} and equivalent a posteriori cost Ec'_{ij} between arbitrary two nodes based on the corresponding equivalent transfer coefficient. As demonstrated in (16), the expectation of equivalence transfer probability is equal to the value of the equivalence transfer function at s = 0.

$$W_{E_{ij}}(A, 0) = Ep'_{ij} \cdot M_{E_{ij}}(A, 0) = Ep'_{ij}\int_{-\infty}^{+\infty} e^{s \cdot c'_{ij}} \cdot f\left(c'_{ij}\right)dc'_{ij}|_{s=0} = Ep'_{ij} \tag{16}$$

Therefore, the mathematical expectation of the equivalent posterior probability between arbitrary two nodes is:

$$Ep'_{ij} = W_{E_{ij}}(A, s)|_{s=0} \tag{17}$$

Table 1. Project overview of a city investment Fortune Plaza in Qingdao

Project	Structure type	Engineering cost	Investment amount	Scale	Location	Propose
A Fortune Plaza	Frame structure	1.4825 billion CNY (233.38 million USD)	1.9902 billion CNY (313.31 million USD)	219000 m^2 (2357296 ft^2)	Qingdao	Commercial office building

The value of the nth-order derivative of the moment generating function at s = 0 is equal to the nth-order origin moment of the random variable. The mathematical expectation of the equivalent a posteriori cost between arbitrary two nodes is presented in (18), and the objective function of minimizing the risk transfer probability and increasing cost is:

$$Ec'_{ij} = \frac{dM_{E_{ij}}(A, s)}{ds}|_{s=0} = \frac{1}{W_{E_{ij}}(A, 0)} \cdot \frac{dW_{E_{ij}}(A, s)}{ds}|_{s=0} \tag{18}$$

$$\min F = Ep'_{19} + Ec'_{19} \tag{19}$$

In (16)–(18), $M_{Eij}(A, s)$ is the moment generating function between arbitrary two nodes in the network structure, and $W_{Eij}(A, s)$ is the equivalent transfer function between arbitrary two nodes.

5 Results

5.1 Case Introduction

To validate the feasibility and reliability of the risk estimation and control activity matching model, a city investment Fortune Plaza project in Qingdao is selected as an example for calculation and conclusion analysis parameters and typical risk control strategies that can be adopted at various nodes in the construction process of the project are shown in Table 2–3. Strategy ④ refers to the simultaneous adoption of three control techniques, which indicates the difficulty level of risk control.

5.2 Monte Carlo Simulation

The values of the objective function in 2000 Monte Carlo simulations and a posteriori parameter $p'_{ij} v_{ij} \varepsilon_{ij}$ updates are recorded as the Bayesian updates to the network parameters between node 8 and node 9 as shown in Fig. 6(a) and the variation of the objective function values is shown in Fig. 6(b). When the decision-maker adopts strategy ② between node 2 → 3, strategy ④ between node 3 → 4, strategy ① between node 4 → 4, strategy ④ between node 4 → 6, strategy ② between node5 → 7, strategy ② between node 7 → 5 and strategy ③ between node 7 → 8, the minimum value of the objective function is

Table 2. GERT network parameter distribution in the whole process of Construction Engineering × 0.01

parameters	1	2	3	4	4	4	5	6	7	7	7	8
	2	3	4	4	5	6	7	7	5	7	8	9
p_{ij}	45	50	70	25	34	41	67	76	20	46	34	60
μ_{ij}	15	10	20	25	20	25	65	55	40	15	12	35
σ_{ij}	05	03	02	04	07	05	03	04	05	10	05	02

Table 3. Typical risk control strategies of GERT network nodes

nodes	①	②	③
1	Strengthen project economic capacity assessment	Enhance the accuracy of data	Clarify the project positioning and development direction
2	Strictly implement national policies	Strengthen technical expert review	Strengthen research and fully demonstrate
3	Enhance the accuracy of budget estimates	In-depth study of building functions	Strengthen the specificity of the mission statement
4	Review design scheme	Improve design scheme	Enhance design depth
5	Broaden information channels	Review order contract	Make an annual procurement budget
6	Strengthen material quality control	Replacement of subcontractors	Improve quality and acceptance standards
7	Timely review of the periodic settlement	Reduce Visa fees	Strengthen quality management
8	Improve completion data	Strictly perform the contract	Strengthen quality management

obtained. The equivalent transfer parameter expectations of the GERT network at this moment are calculated in (20)–(21) using MATLAB 2017A. The optimal solution is obtained at the 543rd simulation, and the point is marked in Fig. 6(b) (Fig. 5).

$$Ep_{19}^{'} = W_{E_{19}}|_{s=0} = 0.216 \tag{20}$$

$$\mathrm{Ec}_{19}^{'} = \frac{\mathrm{d}\frac{\mathrm{W_{E19}}}{\mathrm{W_0}}}{\mathrm{ds}}|_{\mathrm{s}=0} = 12420.95 \tag{21}$$

The PMP (Project Management Professional) organized by PMI (Project Management Institute) aims at providing a uniform industry standard for project managers. It defines the concepts of risk appetite, risk tolerance, and risk threshold. Risk appetite

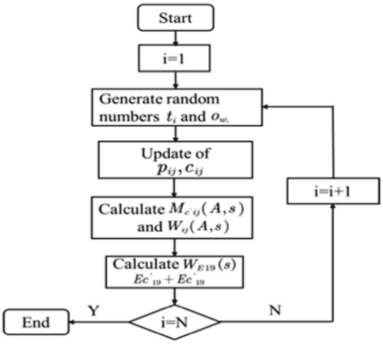
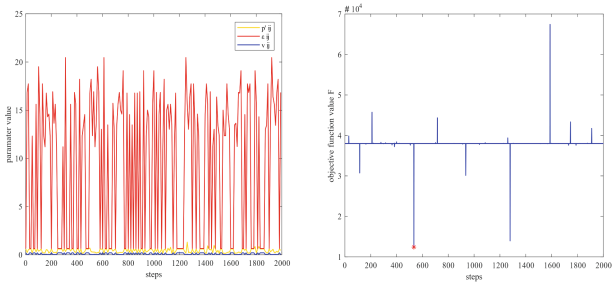


Fig. 5. Flow chart of Monte Carlo simulation

is the degree of risk that an investor allows taking to achieve goals, and investors are classified into three types depending on their risk appetite as risk-averse, risk-neutral, and risk-averse. Risk tolerance is the highest level of risk that an individual or organization can withstand, and once the risk level is exceeded the individual or organization will face bankruptcy. The risk threshold is the starting point from which risk control measures must be taken, and risks below this level are within the tolerance of the organization or individual and measures may not be acted upon. According to the Monte Carlo simulation results of the network model, the mathematical expectation of the equivalent risk transfer probability from node 1 to node 9 which represents the whole process of construction is 0.216 (<0.5), the cost expectation obtained by offsetting the increased control cost and reduced risk loss after taking risk control measures is ¥124.2095 million CNY (USD 19.5630 million). In the practical application of this model, firstly the expectation of equivalence risk transfer probability and the probability of maximum risk loss that investors are willing to bear to achieve their goal should be compared, which is reflected in whether the cost expectation after taking the optimal risk control measures exceeds the risk tolerance of investors, and it will lead to different investment decisions for investors with different risk appetite, risk tolerance, and risk threshold. And risk tolerance. Risk-averse investors are reluctant to take risks to increase returns and pay great attention to asset safety, and the risk-averse and risk-neutral types are relatively positive about risk and will not forgo investment opportunities due to the presence of risk. Then, according to the risk threshold of investors, compare the cost without implementing risk controls with the cost after implementing risk controls, and weigh whether the risk control measures are worth implementing under the condition of limited construction period and resources.

6 Discussion

The control of risk is not implemented at each node indicates no Bayesian update of the GERT network parameters is performed. The expectation of equivalent risk transfer probability Ep_{19} and equivalent risk transfer cost Ec_{19} from node 1 to node 9 are calculated by (14)–(15) and (16)–(17) after replacing p'_{ij} and c'_{ij} with p_{ij} and c_{ij} using parameters in Table 3. In this circumstance, the equivalence transfer probability Ep_{19} is



(a) (b)

Fig. 6. (a) Bayesian updating of parameters (b) Optical solution of objective function

0.33 and the equivalence transfer cost Ec_{19} is 6.237 hundred million CNY (98 million USD). According to the project profile in Table 1, the actual cost overrun of the case project is 5.077 hundred million CNY (80 million USD), and the model accuracy is calculated:

$$\text{Accuracy} = (1 - \frac{\text{predictive value} - \text{actual value}}{\text{predictive value}}) \times 100\% = 81.4\%$$

The project cost overrun without any risk control measures is 43.4%, the decision-maker has to manage the risk strictly and take control. After adopting the risk control strategies obtained from the Monte Carlo simulation 2000 times, the project cost overrun decreased to 8.37%. The risk control is considered effective and successful if the level of residual or subordinated risk is reduced to below the risk threshold, and conversely, the risk response is considered a failure. Investors with different risk appetites, risk tolerance, and risk thresholds will take different actions for this purpose. In the prophase investment stage of the project, the calculated optimal control nodes and the control strategies can realize the effectiveness of risk control in each stage of engineering construction in the whole process of cost management. Combining the cost overruns calculated by this model based on big data without risk controls with the project cost calculated by traditional quotas can improve the accuracy of project cost prediction and guide investment decision-making.

7 Conclusion

With the competition in the construction industry is becoming increasingly fierce, project cost management must be controlled by informational and scientific ways to satisfy the demands of the latest development in the construction industry [20]. This paper quantifies the cost increase caused by uncertainties in the whole process of project construction and predicts the cost overruns to derive the key nodes and strategies of risk controls from the vertical perspective of the whole process of engineering construction.

The whole process of project cost management is dynamic, only by understanding the characteristics of risks in each stage and formulating corresponding control strategies can the cost be effectively reduced. In the paper, the parameters of the GERT network are set as transfer probability and cost, and the dynamic and stochastic nature of risk transfer is demonstrated by the Bayesian method, as a method to calculate the dynamic evolution of risk quantitatively, and we solve the optimal solution of the objective function with the minimum mathematical expectation of risk transfer probability and cost in the whole process of cost management, based on big data and Monte Carlo simulation. Developed from the mechanism of risk generation, the model is not restricted by data features. Further study directions include: establishing a large database of engineering information to study more elaborate risk control in the engineering construction process; considering the use and maintenance cost after completion from the perspective of the whole life cycle of the construction project in the long term.

References

1. Amusan, L.M., Afolabi; A., Ojelabi, R., Omuh, I. and Okagbue, H.I. (2018). "Data exploration on factors that influences construction cost and time performance on construction project sites." Data in Brief, Vol.17, No.4, pp.1320-1325.
2. Liu, H., Skibniewski, M.J., Ju, Q.Q., Li; J.J. and Jiang, H.B. (2021), "BIM-enabled construction innovation through collaboration: a mixed-methods systematic review." Engineering Construction and Architectural Management, Vol.28, No.6, pp.1541-1560
3. Plebankiewicz, E. (2018). "Model of Predicting Cost Overrun in Construction Projects." Sustainability, Vol.10, No.12, pp.4387-4387
4. Temitope, O., Awuzie, B. and Ayokunle, O.O. (2020) "An Artificial Neural Network Approach to Predicting Most Applicable Post-Contract Cost Controlling Techniques in Construction Projects." Applied Sciences, Vol.10, No.15, pp.101
5. Yan, S.Y. (2021) "Application Research of Big Data Technology in Engineering Cost." Journal of Physics: Conference Series, Vol.1852, No.4, pp. 042003
6. Zhao, P., Liu G.C., Zhou, T.T., Zhang X. and Luo, S.Q (2021) "Intelligent matching method of engineering cost control strategy under big data environment." Engineering Journal of Wuhan University, Vol. 53, No. 12, pp.1-7
7. Zhou, L., Xie, J.P., Gu, X.Y., Lin, Y., Ieromonachou, P. and Zhang, X.L. (2016) "Forecasting return of used products for remanufacturing using Graphical Evaluation and GERT." International Journal of Production Economics, Vol.181, No.11, pp.315-324