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Research on multi-objective trade-off of construction engineering project under the background of "Dual Carbon"

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Abstract. In construction engineering projects, contractors can decrease carbon-emission by selecting plans with equipment, labour resource allocation, materials and technology program, which form different mode. However, low-carbon construction plans may result in increased costs and delayed completion time. Environment friendly contractors need to make multi-objective trade-off in the engineering project management and determining the execution mode of each activity is a critical part to solve discrete multi-objective trade-off problem. Therefore, the paper use a multi-criteria decision method to evaluate the mode of each activity to solve the discrete time-cost-environmental impact trade-offs in construction engineering project.

Keywords: Discrete time-cost-environment impact trade-offs problem, engineering management, multi-mode, environment protection.

1. Introduction

In 2021, for the first time, China wrote the requirement of "dual carbon" into the government work report and "carbon peak" and "carbon neutral" have become important strategic goals and tasks in the 14th Five-Year Plan period [1]. In 2019 China's carbon emission in the whole process of building accounts for a large proportion of total carbon emissions according to "2021 China Building Energy Consumption and Carbon Emission Research Report [2]". It means that decreasing carbon emissions in the construction engineering project process has a significant effect on "double carbon" work and environment protection.

During construction, contractors can reduce carbon emissions by choosing plans with the best labour resource allocation, equipment, materials and technology program, which form different mode [3]. However, plans with low carbon emissions may result in increased costs and delayed completion time, and contractors need to make multi-objective trade-offs in project management. Current studies have applied and expanded a variety of algorithms to work out the problem of multi-mode and multi-objective project management [4-6], constantly emerging algorithms means that using a best algorithm to work out such problem is hard and current algorithm is hard to work out the management problem of three or four objectives. Deciding the execution mode of each activity is a critical part in discrete multi-objective problem. Therefore, Banihashem [7] introduced the multi-criteria decision method into the field of engineering project scheduling, but did not consider the impact of the environment. Therefore, this paper uses a multi-criteria decision method to evaluate the pattern of each activity and solve discrete time-cost-environment impact trade-offs by determining the optimal construction scheme.

2. Research methods

It is simple to make a project schedule if the execution mode is decided. In this paper, a multi-criteria decision method is used to determine the execution mode for activities: First, decision-maker preference and objective data of execution mode are integrated to determine the weight of three objectives of project duration, cost and environmental impact by AHP-entropy weight method. This method can effectively avoid the error caused by artificial determination of the importance of each indicator and the influence of extreme value. Then TOPSIS method is used to select the most optimal mode.

2.1. Determining the Weight

2.1.1. Subjective weight

The preferences of stakeholders involved owner, contractor and other parties can be reflected through using AHP method. Step 1: Construct the judgment matrix. Fill in the judgment matrix based on the degree of importance of experts and project decision maker for the index (project objective), among which two indexes (objective) are pairwise compared with each other, and the importance degree is assigned by 1-9. Step 2: Calculate the weight vector and does consistency check, If the test fails, go back to step1.

2.1.2. Objective weight

The entropy weight method can determine the objective weight based on the objective data of the activity execution mode and avoid determining the importance degree of each index artificially. Step 1: Dimensionalize each indicator (cost, time, environmental impact). The three indicators are all negative indicators, and the same indicator is used for standardization treatment. Step 2: Calculate the ratio of each target for each activity. Step 3: Calculate the information entropy of each target. Step 4: Calculate the weight of each target based on information entropy.

2.1.3. Combination weight

Combine the subjective weight with the objective weight in a certain proportion according to the needs of stakeholders.

2.2. Scheme Sorting

TOPSIS method is used to select the most optimal mode. Step 1: When TOPSIS method is used for evaluation, all indicators are required to change in the same direction, and all indicators (cost, construction period, environmental impact) are converted into extremely large index data. Step 2: Eliminate the dimensional influence of different data indicators (cost, construction period, environmental impact), standardize the forward matrix, and establish the correlation matrix. Step 3: Get the most optimal scheme and the worst scheme in a variety of modes. Step 4: calculate the distance between each indicator of each activity and the optimal scheme and the worst scheme respectively with the already obtained weight. Step 5: Rank alternatives. Step 6: Select the most optimal mode with maximum proximity as the execution scheme of the activity.

3. Case Study

3.1. Case

Taking a rural water pipeline project as a case study in reference 8 [8]. Figure 1 is the project network of eight activities and Table 1 shows different execution modes w of activities.

As a result of the discussion, experts believe that the three evaluation indexes （time，cost, environmental impact） are equally important, so the application APSSAU software calculation, get the result: Activity 2 selects execution mode 4, Activity 3 selects execution mode 1, Activity 4 selects execution mode 1, Activity 5 selects execution mode 4, Activity 6 selects execution mode 1, Activity 7 selects execution mode 4, and Activity 8 selects execution mode 4.

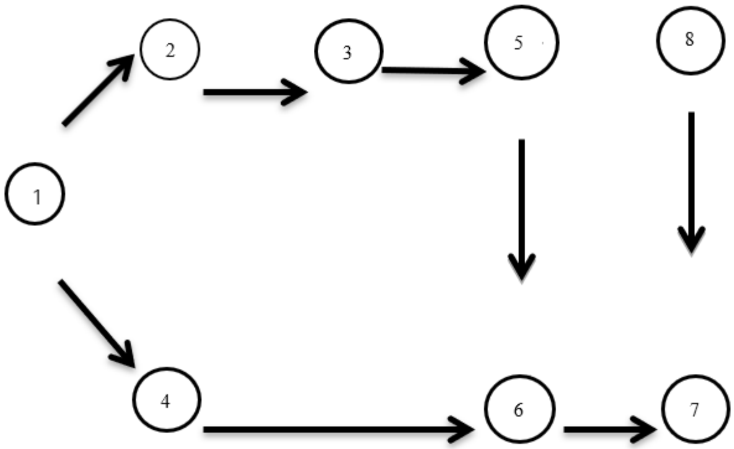

Figure1. Network plan diagram

3.2. Results and discussion

The first execution mode is adopted for each activity, this project will take 65 days and cost 4308 dollars, and the environment impact is 0.43. Compared with the original research results, even if the time for completion is delayed, the cost and environmental effect are smaller. It shows that this method has its advantages in engineering practice.

4. Conclusion

The paper uses a multi-criteria decision method to evaluate the mode of each activity to work out the discrete time-cost-environmental impact trade-offs in construction engineering project. The case result shows that the method has its advantages in engineering practice.

Table1. Execution mode data of each activity

Activity number	Project activities	Execution modes	Time	Cost	Environmental influence
1	Equipping the ingot workshop	1	2	1000	0.3
2	Canal lining and drilling	1	14	1260	0.36
		2	10	1220	0.44
		3	8	1376	0.64
		4	7	1022	0.44
		5	12	1464	0.52
		6	10	1720	0.64
		7	10	1460	0.48
3	Spin the pipes	1	25	400	0.2
		2	20	800	0.3
		3	16	896	0.4
		4	12	960	0.5
		5	22	880	0.4
		6	18	1008	0.5
		7	14	1120	0.4
4	Channel regression and levelling	1	5	160	0.5
		2	4	224	0.5
		3	3	240	0.27
		4	2	208	0.4
		5	5	280	0.47
		6	4	320	0.53
		7	3	312	0.4
5	Welding and transfer of pipes to the floor of the canal	1	5	570	0.53
		2	3	414	0.4
		3	4	488	0.45
		4	2	308	0.6
		5	4	552	0.6
		6	5	610	0.45
		7	3	462	0.6
6	Tubing and steaming operations	1	22	704	0.3
		2	20	800	0.4
		3	17	816	0.5
		4	15	840	0.6
		5	22	880	0.4
		6	19	912	0.6
		7	17	952	0.6
7	Testing	1	11	880	0.4
		2	7	112	0.5
		3	4	96	0.5
		4	2	64	0.6
		5	8	128	0.5
		6	5	120	0.6
		7	3	96	0.6
8	Channel filling	1	19	1212	0.3
		2	15	1200	0.35
		3	6	684	0.5
		4	5	650	0.5
		5	16	1280	0.3
		6	7	798	0.44
		7	6	780	0.44

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