Research on NEV Development Project Portfolio Optimization based on an Improved 0-1 Integer Programming Model

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Abstract: New energy vehicles (NEVs) are the future trend, and evaluating and making decisions about NEV development projects is crucial for a company's development. However, due to the many complex factors involved in NEV development projects, the current project portfolio evaluation mainly relies on expert experience prediction or the subjective judgment of corporate leaders, or traditional 0-1 integer programming model. To address the subjectivity of evaluations and the difficulty of traditional 0-1 integer programming model in handling inter-project correlations, this paper proposes an improved 0-1 integer programming model. The model considers the correlation between projects and achieves project portfolio optimization through constraint conditions. Furthermore, to further enhance solution efficiency, this paper also employs LINGO to solve the model. Finally, an empirical study is conducted using X Company's NEV development project portfolio optimization problem as an example. The results demonstrate that the model has advantages in solution efficiency and is in line with practical requirements, which can provide companies with a new approach to evaluate and optimize projects in the early stages of product planning.

Keywords: New Energy Vehicle (NEV), Development Projects, Portfolio Optimization, 0-1 Integer Programming, Project Interdependence.

1 INTRODUCTION

The adoption of carbon neutrality and carbon peaking policies in various countries has made new energy vehicles (NEVs) a focal point and a global trend[8]. As a result, selecting the most promising and feasible project portfolio from among several NEV development projects has become an urgent issue to promote the NEV industry[7], improve NEV technology, advance the transformation and upgrading of the automotive industry, and achieve sustainable development.

Currently, two primary approaches are commonly used for project portfolio selection[7]. The first approach involves prioritizing alternative projects using various evaluation methods and then allocating resources based on their priority[2]. However, this approach is not a true portfolio optimization but rather a multi-project evaluation. The second approach involves constructing a corresponding portfolio selection model by comprehensively considering all project influencing factors and enterprise resource constraints, with the help of mathematical models (e.g., integer programming models) to finally solve the project portfolio[11].

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However, these models constructed for the project portfolio optimization problem have several shortcomings. Firstly, they ignore the possibility of synergistic effects[13] between projects when setting the objective function and not considering the correlation between projects, leading to deviations between the objective function and the actual situation. Secondly, they ignore the phenomenon of enterprise resource sharing when setting up resource constraints and do not take resource relevance into account[6], resulting in model application results that do not match the actual situation.

2 NEW Approach

To address this challenge, this paper proposes a NEV development project portfolio optimization approach based on an improved 0-1 integer planning. The improved integer programming method transforms the decision problem into one with binary variables and overcomes the difficulties in handling inter-project correlations, long solution times, and unstable results that the traditional 0-1 integer programming method faces[1]. The paper validates the feasibility and effectiveness of the method through practical cases, and the research findings provide useful guidance for NEV enterprises in investment decisions and project portfolio optimization.

2.1 Basic concepts of the approach

When making project portfolio selection, decision-makers need to consider strategic objectives and comprehensive benefit maximization, not just project priority, as resource constraints, project relevance, and comprehensive benefit also need to be considered [15]. This paper establishes a multi-objective function that takes into account the highest project portfolio priority and greatest comprehensive benefit while considering interconnections and project impacts with corresponding constraints. The resulting NEV development project portfolio optimization model has the following features:

(1) Based on project priority ranking, the project portfolio with the highest sum of priority scores is used as the first objective function.

(2) To maximize corporate benefits, it is important to consider not only the benefits of individual projects, but also the overall benefits of the entire project portfolio [5]. Therefore, using the greatest comprehensive benefits as the second objective function is a reasonable approach.

(3) The optimization process tends to favor enterprise financial resources, as the company's resource capabilities have a significant impact on project implementation [3]. In reality, there are often numerous project options, but without sufficient resources, they may not be fully implemented. Therefore, enterprise resource capability is one of the key constraints for selecting projects.

(4) In order to ensure compatibility with practical requirements, it is important to take into account the inter-project relevance and convert inter-project correlations into mathematical formulas that can be integrated into the model's construction. [4]

2.2 Assumptions of the approach

To create an effective NEV development project portfolio optimization model, appropriate assumptions must be made beforehand, given the complexity of the process and potential practical factors' impact. These assumptions include:

(1) Alternative project requirements: The decision variables in this model refer to NEV development projects that meet the enterprise's specific requirements, which include preliminary feasibility assessment, legal compliance, environmental and safety standards, and practical benefits.

(2) Alternative project scope: The model considers all NEV development projects faced by the enterprise, including ongoing projects. Ongoing projects are prioritized in the optimal project portfolio, and other projects to be developed are considered based on their impact on the enterprise's strategy, revenue potential, cost control, and risk.

(3) Resource requirements: The resources calculated in this model correspond to quantifiable tangible assets that are limited in supply and cannot be obtained externally. For ongoing projects, resource measurement is based on the uncompleted portion.

(4) Inter-project correlation constraint: The model considers the correlation of benefits between projects when calculating the combined benefits of a portfolio, leading to an increase in portfolio value [14]. When setting resource constraints, the correlation of funds is considered, leading to a decrease in the required amount of funds. Finally, there may be mutually exclusive, complementary, or dependent relationships between projects [10].

3 Mathematical Model

Based on the fundamental concepts and assumptions of the NEV development project portfolio optimization model discussed above, and in combination with NEV development project portfolio optimization theory, an optimization model is established with the dual objectives of highest priority and maximum comprehensive benefit. This model takes into account constraints such as the total investment amount of the project portfolio and inter-project correlation. The resulting NEV development project portfolio optimization model is an improved 0-1 integer programming model.

3.1 Decision variables

Let the decision variable be $x_i(i=1,2,...,n)$, and the alternative project has one, then it corresponds to a decision variable. If it is 0, it means that the project is not selected; if it is 1, it means that the decision-maker finally selects the project for the portfolio.

$$x_i = \begin{cases} 1, & \text{Project was selected} \\ 0, & \text{Project was not selected} \end{cases} \tag{1}$$

$i=1,2,...,n$.

3.2 Objective function

The 0-1 integer programming model established in constructing the priority evaluation-based NEV development project portfolio optimization model has the following two objectives.

(1) Priority objective

We can derive the corresponding priority of each NEV project based on enterprise research or hierarchical analysis, and under the conditions of resource constraints and relevant policies, we need to select the NEV project portfolio with the first sum of priority order as much as possible, so that the combined result can ensure that the preferred project is the one with high priority. To achieve this purpose, the first objective function is set as follows.

$$\max Z_1 = \sum_{i=1}^{n} E_i x_i \tag{2}$$

Where, Z_2 is the comprehensive priority of the constructed project portfolio, b_i is the priority rating value of the project, obtained by multiplying the index score value and the corresponding weight value and then summing them.

(2) Comprehensive Benefit Targets

There are usually two approaches to setting the investment benefit target. The common one is to consider the projects as independent of each other and calculate the comprehensive benefits of NEV development projects as the investment target, where the comprehensive benefits cover not only economic benefits but also environmental and social benefits. The objective function of the combined benefits when the projects are independent is as follows.

$$\max Z_2 = \sum_{i=1}^{n} b_i x_i \tag{3}$$

Where k is the benefit correlation, $k = 1, 2, ..., u$, $\sum_{k=1}^{u} b_k y_k$ is value added of portfolio benefits from benefit correlations, as assessed by the NEV Enterprise Survey, b_k is the priority rating value of the project, obtained by multiplying the index score value and the corresponding weight value and then summing them, y_k is whether the inter-project benefit correlation exists or not.

The benefit added value exists only when each project that generates a positive synergistic effect is selected into the project portfolio. This gives $y_k = \prod_{r=1}^{v} x_{r,k}$,which means the inter-project benefit correlation that arises when all v projects are selected.

3.3 Constraints

(1) Financial constraints

Similarly, there are two approaches to considering the resource constraints after the project portfolio. In the first one, the funding constraints when the resources are independent of each other are as follows.

$$\sum_{i=1}^{n} r_i x_i \le R \tag{4}$$

Where r_i is the amount of funding required for project i, R is total amount of capital held by the enterprise.

In this paper, we adopt the second approach, which takes resource correlation into account based on the previous one, i.e., when multiple projects are selected for the portfolio at the same time, resource sharing occurs between projects [9], generating a reduced value of funds. Therefore, the improved resource constraint considering resource correlation is as follows.

$$\sum_{i=1}^{n} r_i x_i - \sum_{h=1}^{s} r_h w_h \le R \tag{5}$$

Where $\sum_{h=1}^{s} r_h w_h$ is reduced value of portfolio funding requirements arising from funding correlations, h is the nth financial correlation, r_h is value of funding reductions for funding correlations, w_h is whether the funding correlation exists.

The funding reduction value exists only if each project that generates the funding correlation is selected into the project portfolio. This gives $w_h = \prod_{q=1}^{L} x_{q,h}$, which means funding correlation that arises when all h projects opt-in.

(2) Inter-project relationship constraints

There are three types of relationships between NEV development projects: A mutually exclusive relationship means that two projects can choose only one of them, and the constraint can be expressed as follows.

$$x_i + x_j \le 1 \tag{6}$$

A complementary relationship means that either both are selected or both are not selected, and the constraint can be expressed as follows.

$$x_i - x_j = 0 \tag{7}$$

Dependent relationship means the relationship of dependency that exists for the project, such as project j depends on project i. The constraint can be expressed as follows.

$$x_i - x_j \ge 0 \tag{8}$$

$i, j = 1, 2, ..., n$.

3.4 Model Establishment

Through the above analysis, the model is established as follows.

$$
\begin{cases}
\max Z_1 = \sum_{i=1}^{n} E_i x_i \\
\max Z_2 = \sum_{i=1}^{n} \beta_i x_i + \sum_{k=1}^{u} \beta_k y_k \\
s.t. \sum_{i=1}^{n} r_i x_i - \sum_{h=1}^{s} r_h w_h \le R \\
x_i + x_j \le 1 \\
x_i - x_j = 0 \\
x_i - x_j \ge 0 \\
y_k = \prod_{r=1}^{v} x_{r,k} \\
w_h = \prod_{q=1}^{t} x_{q,h} \\
x_i, x_j, x_{r,k}, x_{q,h} \in \{0,1\} \\
i = 1,2,\ldots,n;\ j = 1,2,\ldots,n \\
k = 1,2,\ldots,u;\ r = 1,2,\ldots,v \\
h = 1,2,\ldots,s;\ q = 1,2,\ldots,t
\end{cases}
\tag{9}
$$

The project portfolio optimization model constructed in this paper with the NEV project as the research object has the following characteristics.

(1) It is a multi-objective planning model, which not only considers whether the project portfolio can maximize the comprehensive benefits but also gives the highest priority to the final project portfolio.

(2) The correlation of benefits among projects is considered. The comprehensive benefits of the portfolio are not only considered for the independent NEV projects but also the correlation between the benefits of the projects is considered in the constraints, so that the results are more consistent with the real situation.

(3) Inter-project financial correlation is considered. The amount of change in capital demand generated by resource correlation is also considered, and constraints of inter-project capital correlation are added.

3.5 Model Solving

The model is a multi-objective 0-1 integer nonlinear programming mathematical model with some constraints. The enumeration method is used to solve the model when there is a small portfolio. The process of solving the NEV development project combination model by the enumeration method [12] is shown in Figure 1.

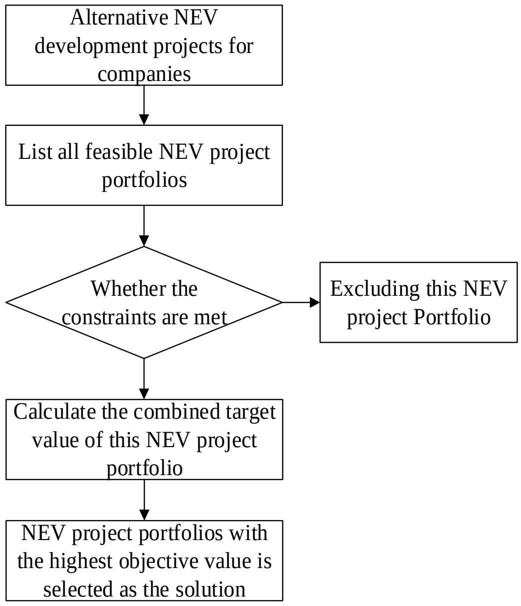

Figure 1: Enumeration method solution flow

For enumeration method, the calculation results are accurate and the solution sought is the optimal solution, but when there are many alternative projects, the number of feasible project combinations increases subsequently, which leads to a large amount of operations. Given this, the model will be solved by Lingo software to simultaneously achieve the purpose of satisfying both the solution accuracy and shortening the time [16].

4 Case Study

To verify the impact of considering the inter-project correlation on the results of the selected project portfolio, this section gives a specific case study for the above research on the NEV project portfolio optimization model. According to a survey of Company X, the data of the alternative projects are shown in table 1.

Table 1: Alternative project arithmetic data

Project Name	Priority Rating Value E_i	Comprehensive benefits b_i （RMB 100 million）	Capital requirements r_i （RMB 100million）
P1	4	7.45	4.22
P2	3	4.68	2.75
P3	3	15.56	11.82
P4	2	8.85	6.38
P5	1	3.12	1.36
Total	13	39.66	26.53

(1) Portfolio optimization model without considering inter-project correlation

The corresponding NEV project portfolio optimization model is established as follows.

$$\begin{cases} \max Z_1 = 4x_1 + 3x_2 + 3x_3 + 2x_4 + 1x_5 \\ \max Z_2 = 7.45x_1 + 4.68x_2 + 15.56x_3 \\ +8.85x_4 + 3.12x_5 \\ s.t. 4.22x_1 + 2.75x_2 + 11.82x_3 + 6.38x_4 \\ +1.36x_5 \le R \\ x_1, x_2, x_3, x_4, x_5 \in \{0,1\} \end{cases} \tag{10}$$

(2) Portfolio optimization model considering the inter-project correlation

According to data provided by Company X， the correlation parameters between the related projects, are shown in table 2.

Table 2: Correlation parameters between projects

Relevance Category	Related Projects	Correlation parameters
Benefits Related	P_2 ， P_4	$b_{2,4} = 2$
	P_4 ， P_5	$b_{4,5} = 1.2$
Funding Related	P_1 ， P_4	$r_{1,4} = -1.5$
Mutually exclusive relationships	P_2 ， P_5	$x_2 + x_5 \le 1$

According to equation (9), the model without considering the correlation between projects was established as follows.

$$\begin{cases} \max Z_1 = 4x_1 + 3x_2 + 3x_3 + 2x_4 + 1x_5 \\ \max Z_2 = 7.45x_1 + 4.68x_2 + 15.56x_3 \\ +8.85x_4 + 3.12x_5 + 2x_2x_4 + 1.2x_4x_5 \\ s.t. 4.22x_1 + 2.75x_2 + 11.82x_3 + 6.38x_4 \\ +1.36x_5 - 1.8x_1x_4 \le R \\ x_2 + x_5 \le 1 \\ x_1, x_2, x_3, x_4, x_5 \in \{0,1\} \end{cases} \tag{11}$$

(3) Portfolio optimization results and analysis

The linear weighting method was chosen to convert the dual objective function into a single objective function, and the priority objective and the comprehensive benefit objective were considered to be of equal importance, so the weighting factor was taken as 0.5.

Taking the limit $R = 25$ as an example, according to equation (11), for the portfolio optimization model without considering the correlation between projects, write the Lingo program code as follows.

```
max=0.5*(4*x1+3*x2+3*x3+2*x4+1*x5)+0.5*(7.45*x1+4.68*x2+15.56*x3+8.85*x4+3.12*
x5);
```

4.22*x1+2.75*x2+11.82*x3+6.38*x4+1.36*x5<=25;

@bin(x1);@bin(x2);@bin(x3);@bin(x4);@bin(x5);

end

The main results are shown in figure 2.

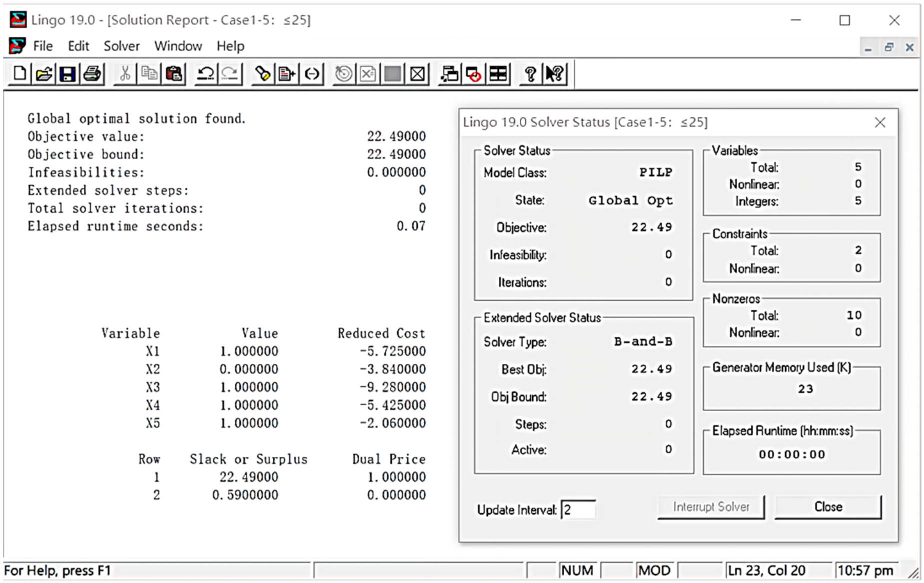

Figure 2: the results without considering the correlations

For the optimization model that takes into account inter-project correlations, the Lingo program code is written as follows.

max=0.5*(4*x1+3*x2+3*x3+2*x4+1*x5)+0.5*(7.45*x1+4.68*x2+15.56*x3+8.85*x4+3.12*x5+2*x2*x4+1.2*x4*x5);

4.22*x1+2.75*x2+11.82*x3+6.38*x4+1.36*x5-1.8*x1*x4<=25;

x2+x5<=1;

@bin(x1);@bin(x2);@bin(x3);@bin(x4);@bin(x5);

end

The main results as shown in figure 3.

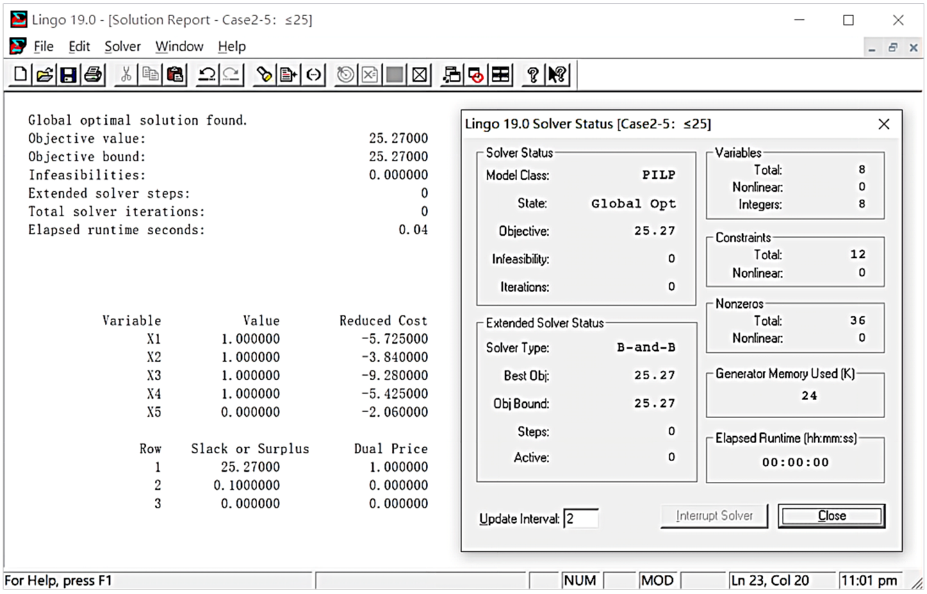

Figure 3: the results considering the correlations

Similarly, for different funding limits R, the project portfolio optimizations without and considering inter-project correlations are derived by Lingo software as follows.

Table 3 Portfolio optimization Results for Different Funding Limits

Funding Limit R (RMB 100 million)	Optimization model without considering the inter-project correlation			Optimization model considering the inter-project correlation		
	Project Portfolio	Priority Value	Benefits (RMB 100 million)	Project Portfolio	Priority Value	Benefits (RMB 100 million)
5	P1	4	7.45	P1	4	7.45
10	P1 P2 P5	8	15.25	P1 P4	6	16.3
15	P1 P2 P4	9	20.98	P1 P2 P4	9	22.98
20	P1 P3 P5	8	26.13	P3 P4 P5	6	28.73
25	P1 P3 P4 P5	10	34.98	P1 P2 P3 P4	12	38.54

Table 3 illustrates that increasing the funding limit leads to the optimization of more projects for the NEV project portfolio. The priority and comprehensive benefits of the portfolio optimization model, both with and without inter-project correlation, are higher under a given funding limit, which aligns with the logical reasoning of NEV investment.

Notably, there are significant differences between the portfolio optimization results with and without inter-project correlation under varying funding limit conditions. When there is a certain capital constraint, the portfolio with inter-project correlation is typically superior to the portfolio without inter-project correlation, emphasizing the importance of considering inter-project correlation in NEV investment decisions. Furthermore, selecting projects for the NEV portfolio based on prioritization alone differs from the actual optimal optimization under different funding constraints. For instance, the optimal portfolio for $R = 10$ is P1, P2, and P5 with a priority ranking of 8. This is because although P2 has a higher priority, it has a mutually exclusive relationship with P5, so they are unsuitable for the portfolio. In contrast, P4, with the lowest priority, is identified as the optimal portfolio due to its correlation with P1, enabling better comprehensive benefits.

This study tested the model on actual projects, and demonstrated its practicality and effectiveness in meeting resource and inter-project relevance constraints.

5 Conclusion

This paper focuses on how to construct a model for selecting the optimal portfolio of NEV development projects. Starting from the basic concepts for model construction, the assumptions for building the model are set, and then specific analysis is conducted on decision variables, objective functions, constraints, and model solutions. Based on this, a NEV development project portfolio optimization model based on 0-1 integer programming is established, and the effectiveness of the model and the necessity of considering the interdependence between projects are verified through a case study.

Based on the research above, it is recommended that NEV companies should avoid independently considering each candidate project and only focusing on the priority or benefit objectives of individual projects during project investment decision-making. Instead, companies should balance the investment benefits of NEV development projects with the interdependence between projects based on their actual situation. This model provides a new approach for evaluating project portfolio optimization for companies and serves as a reference for decision-making.

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