



Application of Metaheuristic Models in Production Chain Risk Optimization

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ABSTRACT

With the spread of various risks and adverse events in the world, which is partly caused by the increase in economic, social and political activities, uncertainty about the future has increased. Risk is one of the basic concepts. Therefore, in this research, the risk management model has been designed using innovative models in line with optimal risk management and providing practical suggestions to reduce risk and increase investment returns. In terms of methodology and the method of data collection, it is considered a descriptive research that has been implemented post-event. In order to collect data in this research, library and document methods were used. The statistical population of this research is the active companies in the food industry accepted in the Tehran Stock Exchange, and in this regard, an example of Koroosh Food Industry Company with the symbol of Ghakoroosh in the period of 2016 to 2018 was considered. In order to analyze the data, the meta-innovative model of genetics was used using Matlab software to provide the best model for risk management. The findings showed that the range of points in the two-stage optimization mode has a wider time and cost, and the anchor resources provide us with larger numbers than the three-objective optimization mode. Besides, in some places, due to the two-stage optimization, according to the specified time and cost, the source anchor has not been obtained. In addition, due to the optimization in two separate stages, a regular trend has not been seen among the resource anchors.

Keywords: Meta-innovative models, risk management, supply chain, optimization

1. Introduction

Despite the economic conditions of the country, the existence of the stock market is more attractive to investors, because the return of this market has the highest return compared to other markets in the country in recent years (Eslami Bidgoli & Tayebi Sani, 2014). Therefore, the existence of variable investment risk has not caused investors to turn a blind eye to this volatile market, and investment in this market is still attractive (Naderi et al., 2022).

With the spread of various risks and adverse events in the world, which is partly caused by the increase in economic, social and political activities, uncertainty about the future has increased. Risk is one of the basic concepts in financial markets (Doering et al., 2019). It should be noted that the most important perception of risk is the feeling of financial loss. In other words, risk is the possibility of adverse events happening. This concept is particularly complex, and its difficulty in the measurement and monitoring stage has brought to the fore the increasing need of financial market activists to control and manage various risks (Davoodi & Sadri, 2018).

Research shows that 90% of people who invest in financial markets either do not make a profit or suffer a loss, and only 10% continue this market successfully. In order for people to be among the top ten percent, they must be familiar with the concept of risk management (Soler et al., 2017). Risk is an inherent part of the capital market, the origin of which can be from the general state of the economy to corporate events and margins. The part of the risk that is affected by the general state of the economy and affects the entire market is called systematic risk, and the rest is called unsystematic risk, diversification risk, or residual risk (Marinakis et al., 2008). The famous proverb "Don't put all your eggs in one basket" well illustrates the idea of using a stock basket to manage risk. Portfolio theory seeks to protect the portfolio against some of the risk known as unsystematic risk by diversifying the contents of the portfolio (Eslami Bidgoli & Tayebi Sani, 2014). To achieve a quantitative model for stock portfolio selection, risk must first be measured. Different indicators have been defined to measure risk so far. Considering the amount and types of risks that financial markets face, especially in recent years, when economic and currency fluctuations have had a great impact on financial markets, risk has increased and the concept and solutions of risk management have received more attention (Nateghian et al., 2022).

Naderi et al. (2022) investigated the dynamics of value at risk: the Copula-VAR approach optimized with a metaheuristic algorithm. The results of estimating the quantiles of the variable over time also indicate that the time series of the quantiles resulting

from the combined copula model shows the dynamics well due to the high time frequency compared to the MCAViaR model. The results of the Kupiec backtest also confirm the better performance of the combined copula model compared to the MCAViaR model.

Nateghian et al. (2021) in a research evaluated the investment portfolio models in mutual funds in global financial markets (with emphasis on the multi-objective metaheuristic algorithm). The research results showed that the value at risk model (historical simulation) has a higher efficient frontier compared to the value at risk (Monte Carlo simulation).

Ma'danchi Zaj et al. (2021) in their study investigated the contagion and dynamics of risk between financial markets, commodity markets and digital currencies with the MGARCH model approach. Risk contagion between financial assets indicates the process of information transfer between markets. Financial markets are interconnected, information created in one market can affect other markets. Risk modeling in different markets and the relationship of these markets with each other from the perspective of financial science is an important topic for prediction. The purpose of this article is to investigate the existence of risk contagion and dynamics between commodity markets, financial markets and digital currencies using the multivariate conditional heteroscedasticity (MGARCH) method in the period of 2014-2020 with the frequency of daily data. The results of this study indicate the contagion of fluctuations between financial markets and the ratio of the dollar to the euro and Bitcoin had a significant inverse relationship with each other, but other financial assets had a direct and significant relationship in terms of returns and fluctuations with each other. Also, the stability and trend of changes in the price of oil and gold leads to the creation of an important relationship between returns and strengthening the risk transfer between the currency market, virtual money, oil and gold. Finally, the research model shows that the intensity of contagion between financial markets is different in small and large shock conditions, which indicates the existence of asymmetric effects in risk spillover between important financial markets.

Prakash and Viswanathan (2020) in a research studied the comparative study of metaheuristic optimization techniques for risk prioritization in agile software development. The results obtained are evaluated based on four key criteria features such as error rate, accuracy, reliability and execution time. The result proves that GWO performs better than four other metaheuristic optimization techniques for risk prioritization in an agile environment.

Doering et al. (2019) investigated metaheuristics for rich portfolio optimization and risk management: current status and future trends. The results showed

that in particular, these optimization methods become an alternative to the solution approach when dealing with real versions of several financial decision problems, such as rich portfolio optimization and risk management.

Malik et al. (2021) evaluated the risk of resources exposed to rainfall-induced landslides by developing metaheuristic learning algorithms. Pixel hazard zones also gradually increased from a return period of 2 to 100 years. Various natural resources, such as shrubs, created and low vegetation, were identified due to landslide hazards in hazard zones. In addition, these resources are widely exposed to landslides during return periods. Therefore, the results of the present study help planners and scientists to propose high-precision management plans for the protection of natural resources exposed to landslides.

There are different methods for risk management that can be useful in this field. Metaheuristic models are among the newest methods that seek to reduce risk in investments with an optimal view (Alizadeh et al., 2021). In this regard, considering the mentioned issues and the increase in financial risk in recent years and the necessity of risk management and optimization of investments, identifying optimal methods that have higher efficiency than other methods in risk management has become a necessity. Also, previous research in this field shows that the comparison and determination of an optimal model of metaheuristic models for risk management has not been researched in the past and there are several research gaps in this field. Therefore, in this research, the risk management model has been designed using innovative models in

line with optimal risk management and providing practical suggestions to reduce risk and increase investment returns.

Method

This research is applied in terms of purpose, which was done quantitatively. In terms of methodology and the method of data collection, it is considered a descriptive research that has been implemented post-event. In order to collect data in this research, library and document methods were used. To review the research literature, the studies conducted in this field and various library resources were used, and in the quantitative section, the required data were collected from the historical information of stocks in the Tehran Stock Exchange. The statistical population of this research is the active companies in the food industry accepted in the Tehran Stock Exchange, and in this regard, an example of Koroosh Food Industry Company with the symbol of Ghakoroosh in the period of 2016 to 2018 was considered. Therefore, the spatial domain of this research is Tehran and Koroosh Food Industry Company. In order to analyze the data, the meta-innovative model of genetics was used using Matlab software to provide the best model for risk management.

The general framework of the process of this research based on the subject and the method used to design the risk management model using innovative models in the Tehran Stock Exchange is presented in Figure 1.

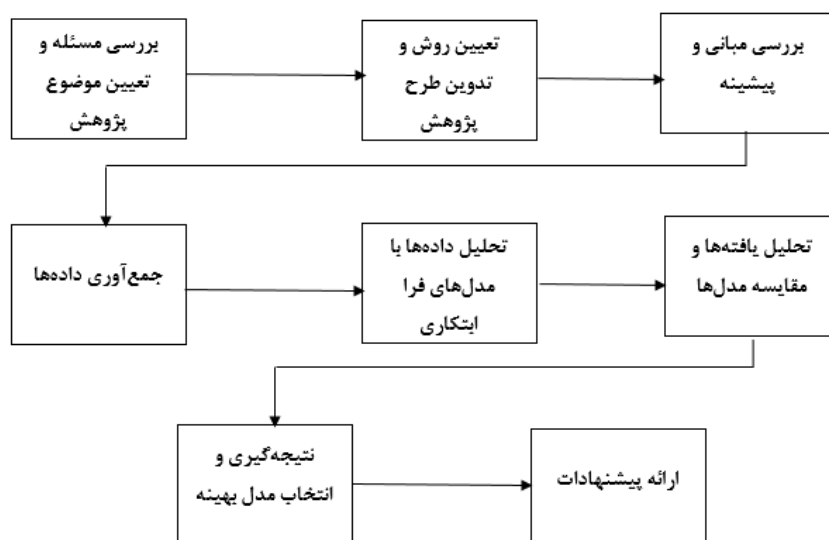


Figure 1. General research process

To model fluctuations and create a combined model; Daily index data is required
The information includes some important variables as follows:

- The index of each trading day of the relevant symbol and the index return
- Parameters related to volatility models and actualized volatility
- Parameters related to genetic algorithm
- Information criteria
- Error criteria

Findings

In order to investigate the model and the accuracy of the results, a production line with 7 activities (taken from Zheng et al.'s (2020) article) is investigated, each of which has different options of time and cost. With this difference that in this model, the cost of each activity is considered as the product of the unit cost of each resource and the number of resources consumed, so that while leveling the resources, the allocation of resources is also done based on one of the four anchors. Also, Zheng et al. (2020) solved their model as a single objective and considered both time and cost parameters as fuzzy, while in the model presented in this thesis, a membership function is assumed for both parameters and in each option selected from the discrete space, time and cost are considered fixed and non-fuzzy. The execution time of each chromosome is based on the earliest execution time of the production line based on CPM, which is the execution cost of each chromosome equal to the sum of the direct cost of

the activities and their indirect cost, which is the daily indirect cost, has been ignored. Figure 2 shows the executive network of production line activities.

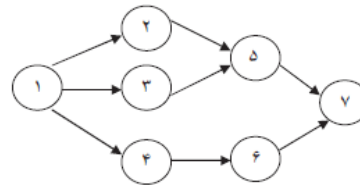


Figure 2: Executive network of production line activities

The problem is solved in one of the states (limited resources - the amount of a-cut is equal to zero for all activities) and the unit price of each of the resources is shown in Table 3:

منبع هفتم	منبع ششم	منبع پنجم	منبع چهارم	منبع سوم	منبع دوم	منبع اول
۵۰	۲۰۰	۵۰۰	۱۵۰۰	۲۰۰۰	۳۵۰۰	۴۰۰۰

In this model, the a-cut value of all activities is considered to be zero, which means that the time and cost of the activities are selected from the entire allowed range.

The results of the model in limited resources are shown in Tables 4-10. The daily resource limit (DRL) values for different resources are shown in Table 4:

R7	R6	R5	R4	R3	R2	R1
۸	۱۱	۱۰	۶	۴	۵	۸

Table 5: The results of the model in limited resources

زمان (روز)	هزینه (دلار)	M1	زمان (روز)	هزینه (دلار)	M2	زمان (روز)	هزینه (دلار)	M3	زمان (روز)	هزینه (دلار)	M4
۹۳	۱۳۲,۳۵۰	۳,۹۰۶	۹۲	۱۳۷,۳۰۰	۶۸,۷۲۶	۹۲	۱۳۵,۳۰۰	۹,۶۶۲	۹۱	۱۳۶,۸۰۰	۱۴,۹۱۲
۹۱	۱۳۶,۸۰۰	۵,۷۷۷	۹۰	۱۳۹,۵۰۰	۶۵,۹۲۰	۹۰	۱۳۹,۵۰۰	۹,۳۹۷	۸۸	۱۲۰,۸۵۰	۱۲,۰۰۶
۹۰	۱۳۶,۸۵۰	۴,۰۰۱	۸۹	۱۴۶,۱۵۰	۵۳,۲۵۵	۸۸	۱۲۸,۸۵۰	۸,۰۵۵	۸۷	۱۴۱,۲۵۰	۱۲,۳۸۷
۸۹	۱۴۶,۸۵۰	۴,۱۴۷	۸۸	۱۲۱,۲۵۰	۵۲,۸۹۲	۸۷	۱۲۹,۹۵۰	۷,۹۶۷	۸۷	۱۲۷,۷۵۰	۱۲,۸۵۴
۸۹	۱۴۵,۱۵۰	۴,۴۸۹	۸۷	۱۴۲,۸۰۰	۶۱,۳۸۴	۸۷	۱۲۷,۶۵۰	۹,۵۱۸	۸۷	۱۲۱,۰۰۰	۱۴,۰۴۱
۸۹	۱۲۱,۹۰۰	۴,۸۸۷	۸۶	۱۴۴,۷۰۰	۶۰,۰۷۸	۸۵	۱۲۲,۳۰۰	۸,۱۶۱	۸۶	۱۲۲,۱۰۰	۱۳,۴۳۹
۸۸	۱۳۷,۴۵۰	۴,۱۲۴	۸۶	۱۴۳,۹۰۰	۶۰,۵۶۹	۸۴	۱۳۷,۲۵۰	۸,۱۱۳	۸۶	۱۲۱,۷۰۰	۱۳,۷۵۸
۸۸	۱۲۴,۶۵۰	۵,۲۳۰	۸۵	۱۳۲,۹۵۰	۶۱,۲۳۴	۸۴	۱۳۵,۹۵۰	۸,۲۰۵	۸۵	۱۴۵,۴۵۰	۱۳,۱۳۹
۸۷	۱۳۳,۵۵۰	۵,۱۴۳	۸۴	۱۳۸,۴۰۰	۶۱,۸۹۶	۸۴	۱۳۵,۴۰۰	۸,۳۱۱	۸۴	۱۲۶,۳۰۰	۱۳,۳۶۴
۸۶	۱۴۸,۹۰۰	۴,۲۷۵	۸۴	۱۳۷,۲۵۰	۶۲,۰۴۵	۸۳	۱۳۸,۱۵۰	۸,۴۰۲	۸۲	۱۳۹,۸۵۰	۱۴,۵۰۲
۸۶	۱۳۱,۰۵۰	۴,۳۲۵	۸۴	۱۲۲,۴۰۰	۶۹,۸۲۰	۸۳	۱۳۲,۰۰۰	۸,۵۵۳	۸۲	۱۳۷,۴۰۰	۱۴,۶۱۱
۸۶	۱۲۱,۱۰۰	۴,۷۸۵	۸۳	۱۴۱,۹۰۰	۶۱,۰۳۲	۸۳	۱۲۸,۹۵۰	۸,۶۴۴	۸۲	۱۳۰,۰۵۰	۱۴,۶۹۴
۸۵	۱۴۱,۵۵۰	۴,۹۲۰	۸۳	۱۳۸,۱۵۰	۶۲,۵۶۰	۸۲	۱۳۰,۲۰۰	۸,۷۱۰	۸۲	۱۲۹,۱۰۰	۱۴,۷۰۵
۸۵	۱۳۸,۵۵۰	۴,۹۶۳	۸۳	۱۲۲,۳۵۰	۶۳,۷۸۹	۸۱	۱۴۴,۶۵۰	۸,۸۲۳	۸۱	۱۴۳,۲۵۰	۱۴,۸۸۹
۸۵	۱۳۷,۷۵۰	۵,۰۱۴	۸۲	۱۴۱,۴۵۰	۶۶,۵۰۳	۸۱	۱۴۰,۳۵۰	۸,۹۶۴	۸۱	۱۳۷,۲۰۰	۱۵,۶۲۳

زمان (روز)	هزینه (دلار)	M1	زمان (روز)	هزینه (دلار)	M2	زمان (روز)	هزینه (دلار)	M3	زمان (روز)	هزینه (دلار)	M4
۸۴	۱۲۳,۳۰۰	۴,۸۷۳	۸۲	۱۳۳,۰۰۰	۶۶,۹۶۰	۸۱	۱۳۴,۱۰۰	۹,۱۲۳	۸۱	۱۳۵,۹۰۰	۱۵,۹۰۸
۸۳	۱۴۱,۰۵۰	۴,۸۶۵	۸۱	۱۴۴,۱۰۰	۶۸,۲۳۱	۸۰	۱۴۲,۲۰۰	۹,۵۶۳	۸۰	۱۳۷,۸۰۰	۱۶,۵۲۳
۸۰	۱۴۸,۰۵۰	۴,۹۶۲	۸۱	۱۳۴,۳۵۰	۶۹,۳۰۲	۸۰	۱۳۹,۵۰۰	۹,۶۰۵	۸۰	۱۲۳,۶۰۰	۱۶,۹۹۷
۸۰	۱۴۴,۲۵۰	۵,۳۶۴	۸۱	۱۲۶,۷۰۰	۷۱,۴۰۹	۷۹	۱۴۲,۴۵۰	۹,۷۰۰	۷۹	۱۳۸,۹۰۰	۱۷,۵۵۶
۸۰	۱۴۳,۱۰۰	۵,۴۱۰	۸۰	۱۲۵,۶۵۰	۶۸,۲۰۴	۷۹	۱۴۰,۹۵۰	۹,۸۳۳	۷۹	۱۳۳,۰۵۰	۱۷,۹۰۸
۷۸	۱۴۵,۵۰۰	۵,۶۱۰	۷۹	۱۴۲,۶۰۰	۷۰,۹۹۸	۷۷	۱۴۶,۹۰۰	۹,۹۶۹	۷۹	۱۲۹,۸۰۰	۱۸,۸۵۳
۷۸	۱۲۹,۷۰۰	۵,۹۴۵	۷۹	۱۴۰,۳۰۰	۷۱,۶۹۸	۷۷	۱۴۴,۰۵۰	۱۰,۰۱۲	۷۹	۱۲۹,۴۰۰	۱۸,۸۶۵
۷۶	۱۴۳,۰۵۰	۶,۰۱۲	۷۸	۱۴۵,۸۰۰	۷۳,۶۷۸	۷۷	۱۴۳,۶۵۰	۱۰,۱۵۶	۷۹	۱۲۴,۷۰۰	۱۹,۹۳۳
۷۵	۱۳۲,۶۵۰	۶,۱۲۹	۷۷	۱۳۸,۸۵۰	۷۲,۰۵۹	۷۷	۱۳۹,۱۰۰	۱۰,۴۳۵	۷۶	۱۴۶,۴۵۰	۲۱,۳۰۴
۷۴	۱۵۰,۰۵۰	۶,۲۲۰	۷۴	۱۴۵,۸۰۰	۷۳,۱۱۸	۷۷	۱۳۷,۶۰۰	۱۰,۹۶۳	۷۵	۱۴۹,۷۰۰	۲۲,۴۰۳
۷۳	۱۳۱,۲۵۰	۶,۳۱۰	۷۳	۱۴۶,۳۰۰	۷۴,۶۵۰	۷۷	۱۳۱,۱۰۰	۱۱,۰۱۴	۷۴	۱۵۱,۱۵۰	۲۳,۰۰۴

In the graphs of Figure 3, the Pareto front of time-cost-resources is drawn. This front is specified in separate diagrams for each of the four resources. Considering the ability of the model, it has been investigated in two cases of limited and unlimited resources and in each of them, in four cases of a-cut=0;25;50;75, the results of a-cut=25,50,75 in the case of limited resources are in Appendix 2.

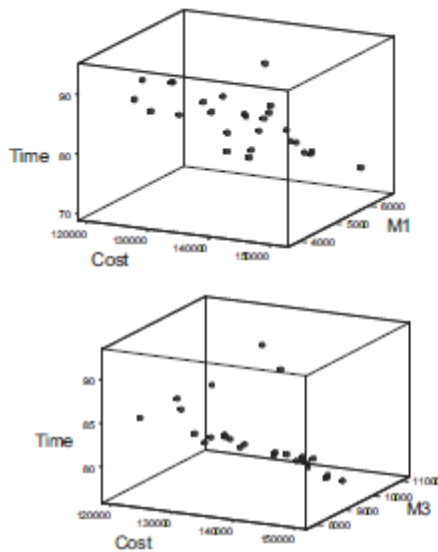


Figure 3- Pareto front of time-cost-resources for each of the four resources

Considering the investigation of case study 1 in both limited and unlimited resource modes and using the results of Table 5, it can be concluded that:

In the case of unlimited resources, the anchor of resources is a smaller number in all four cases. As explained in the third chapter, the condition of resource leveling is considered as a necessary

condition in the model. In fact, when the model tries to find the earliest start time of each of the activities that are not on the critical path by using the float of the activities, it finds a combination of activities in which each of the resource anchors is minimized. The resource usage limit is considered False.

Considering that in the first case study there are a total of only 81 options for all activities, the results obtained in the two cases of limited and unlimited resources have a significant difference.

In the case of limited resources, for a-cut equal to and greater than 85 for all activities, the model did not find any points.

Because the number of options in case study 1 is small and it is possible that the model does not find any points for a certain a-cut value and interpolation is not possible, the model increases the a-cut value to the extent that it finds a point (in the range of fewer points). It performs its search, of course, it corrects the a-cut value related to the activities in question in the output file.

Comparison of time-cost optimization (TCO) results with time-cost-resource optimization (TCRO) results

In order to make the three-objective model more practical, the problem was first solved as a two-objective time-cost, and then the minimum resource anchor was obtained for each point of the two-dimensional Pareto front. Since in this case, the optimization was done in two stages, the model did not obtain a resource anchor at some points in the limited resource mode. (The resource leveling condition was not satisfied) Some of the results obtained are shown in Table 6.

Table 6: The results of the model in two-stage optimization

زمان	هزینه (دلار)	M1	M2	M3	M4
97	123,400	#####	#####	#####	#####
96	124,800	8119	14,471	23926	56223
95	130,100	8241	14,231	#####	56243
94	131,200	8366	14,080	23920	56206
93	130,200	8427	#####	23842	56068
92	131,300	8523	14,132	23768	#####
91	133,100	8626	13850	23764	56028
90	131,900	#####	13930	23657	55953
89	132,000	8789	138862	23568	55988
87	132,200	8802	138698	23378	55699
86	133,450	8862	136771	23335	55556
85	133,800	8871	136668	23345	55368
84	134,800	8905	136273	23805	55364
83	135,200	8929	136222	23200	55359
82	135,500	#####	135579	23124	#####
81	135,600	9014	135680	23156	55302
80	136,700	9099	135796	23108	55231
79	136,000	9080	13506	23065	54889
78	137,050	9130	133677	23029	54992
77	138,200	#####	133833	23011	54895
76	140,800	9126	131400	22999	54885
75	141,900	9206	130809	22860	54818
74	145,100	9233	130936	22782	54659
73	146,350	#####	#####	#####	#####
72	148,650	#####	#####	#####	#####

The model did not get an answer in the second optimization stage for a point with a specific time and cost.

As it is clear from the comparison of tables 5 and 6, the range of points in the two-stage optimization mode has a wider range of time and cost, and the anchor resources provide us with larger numbers than the three-objective optimization mode. Besides, in some

places, due to the two-stage optimization, according to the specified time and cost, the source anchor has not been obtained. In addition, due to the optimization in two separate stages, a regular trend has not been seen among the resource anchors. In Figure 4, the time-cost points in two-objective and three-objective modes (the third diagram of anchor M1) are shown.

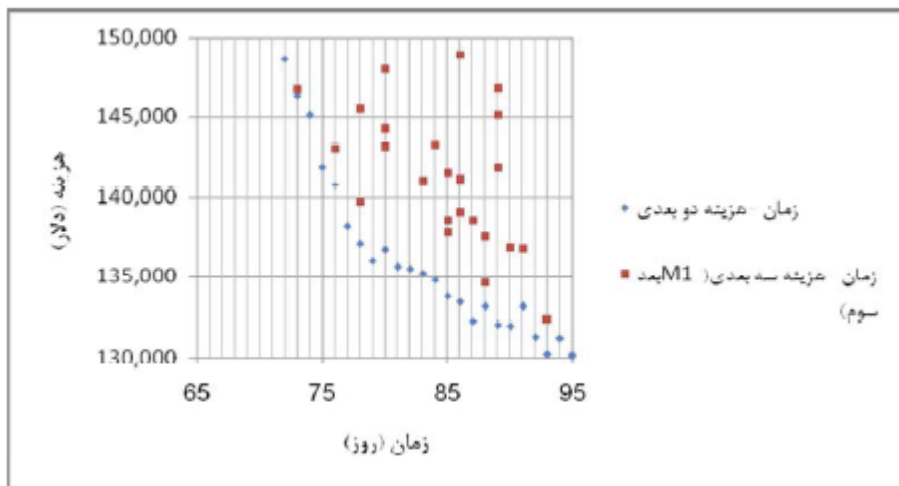


Figure 4: Comparison of two-objective and three-objective optimization results

Conclusion

This study introduces a time-cost-resource optimization model that effectively integrates a simulated approach with a genetic algorithm to allocate inter-storage warehouses across production lines. The model addresses the simultaneous optimization of time, cost, and resource allocation, providing a unified framework for improving operational efficiency in production processes.

Key Findings

Two-Stage vs. Three-Objective Model: The two-stage model, which focuses on optimizing time and cost, offers a broader range of practical solutions. In contrast, the three-objective model incorporates resource allocation, covering all the solutions from the two-stage model and providing more efficient resource outcomes.

NSGA-II Algorithm Performance: The NSGA-II algorithm was highly effective in optimizing the Pareto front, achieving quick convergence. Its elitist approach and computational efficiency made it well-suited for solving the multi-objective optimization problem at hand.

Real-World Applicability: A case study involving 63 activities and 18 resources demonstrated the practical application of the model, exploring 1990 possible configurations and validating the model's effectiveness in real-world production environments.

Practical Implications:

Optimized Resource Management: This model offers significant potential for businesses looking to optimize resource allocation. For instance, manufacturers could improve the use of raw materials, labor, and equipment, thereby reducing both time and costs across production lines.

Enhanced Decision-Making: By simulating both short-term and long-term consequences of management decisions, companies can gain deeper insights into the impact of various strategies, such as production scheduling and workforce planning, on overall performance.

Targeted Sensitivity Analysis: Organizations can identify and focus on the most influential factors affecting project outcomes, enabling them to make data-driven decisions that improve operational efficiency.

Example: A global electronics manufacturer could implement this model to optimize its supply chain and production process. By using the model to simulate different scenarios, the company could improve the timing of material procurement and resource usage, ultimately leading to reduced production costs and shorter lead times.

Future Research Directions

Cross-Industry Application: This model could be adapted to other industries such as logistics, construction, and food production, which also face complex resource allocation challenges. Testing its applicability in these sectors could broaden the impact of the model.

Exploration of Alternative Metaheuristics: Further research could explore the use of other optimization techniques, such as Particle Swarm Optimization (PSO), to compare their performance against the NSGA-II algorithm in different contexts.

Dynamic Factors Integration: Future studies could enhance the model by incorporating dynamic elements like demand fluctuations, supply chain disruptions, or inventory variability. This would make the model more adaptable to real-time changes in the production environment.

Concluding Statement

This research provides a comprehensive framework for optimizing resource management in production chains, addressing critical challenges faced by industries such as rising operational costs and supply chain disruptions. By optimizing time, cost, and resource allocation, the model offers businesses a powerful tool for improving efficiency and cost-effectiveness. Its broad applicability across industries positions it as a key strategy for companies looking to enhance operational resilience and achieve more sustainable production management practices.

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