A Multi-objective Programming Model for Optimization of Logistics Resources Allocation

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***Abstract* —In the face of the complex logistics task, logistics enterprise has been difficult to meet rising demand of customers. In this paper, we structure a new mode to discuss the complex logistics task allocation. A multi-objective programming model is set up based on operating costs (C), running time (T) and delivery quality (Q), with optimal resources allocation under a serial and parallel mixed complicated task by using genetic algorithm method and project management knowledge in practical application. It can increase the utilization of logistics resources and improve coordination ability and the core competitiveness in logistics industry.**

Keywords - resources allocation; multi-objective programming model; genetic algorithm

I. INTRODUCTION

With the increase of the cross-logistics and logistics integration demand, it is difficult for logistics enterprise to finish the large complex and complicated tasks by their own. In recent years, large-scale enterprise generally pursue all-inclusive model to develop. Most third party logistics enterprises construct logistics facilities and equipment on a small scale. This causes a great waste of resources and the lack of cross-industry services network. Actually, People gradually find that the future competition of resources allocation will no longer be isolated by a separate enterprise, but among enterprises.

Biqing (2005) came up with an open grid service system and provided the method of logistics resource integration frame work of the third party logistics enterprise. Lu Beisheng (2006) made a research of the feasible solution to solve the resources optimal allocation and put forward the condition of Pareto optimal solutions. He pointed out that it was reasonable to maximize profits and customer utility in equilibrium state under a perfectly competitive market environment. Most scholars made researches in the perspective of enterprise without considering actual problems of logistics task operation. Models and conclusions not fully reflected the real situation.

Therefore, it becomes the focus in this paper by integrating the logistics resources and completing complex logistics tasks in the area. A multi-objective programming model is set up based on the operating costs (C), running time (T) and delivery quality (Q), with optimal resources allocation under aserial and parallel mixed complicated task by using genetic algorithm method and project management knowledge.

II. THE OPTIMIZATION MODEL OF LOGISTICS RESOURCE CONFIGURATION

This paper is based on a single logistics task to research the resource configuration. Firstly, a single task is decomposed into several activities which are converted to the required attribute characteristics. Secondly, Match logistics activities with logistics resources characteristics and get the activities candidate set. Thirdly, a multi-objective programming model is set up. Finally, make an application and verify the model by combining with the present situation.

A. Problem Description

Due to a single enterprise with limited logistics resource, it is necessary to share different logistics resource with other enterprises to complete the task together. Therefore, according to the demand and the characteristics of the logistics, designing an optimized resources allocation scheme is important to coordinate logistics resources.

This model is based on the serial and parallel mixed complicated task to make an optimal logistics resources allocation scheme. The serial and parallel mixed logistics activity chain under a single logistics task is shown in the Fig. (1). & Fig. (2).

Theoretically, to complete a task of all combinational numbers totally are $\prod_{i=1}^{n} k_i$ kinds. Setting up a Multi-objective programming model is to evaluate all solutions and to obtain the optimal combination of logistics resources.

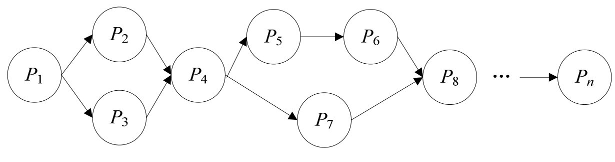

Fig.1 A Serial and Parallel Mixed Complicated Task

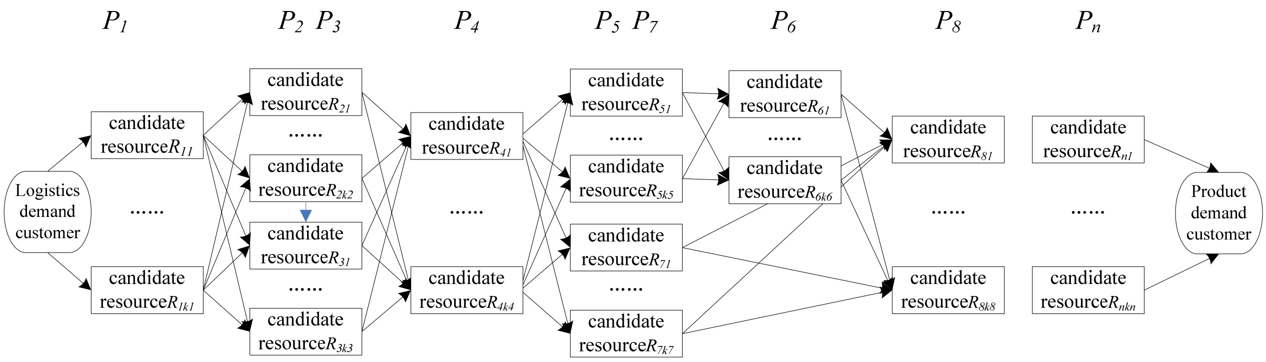

Fig.2 Logistics Resource Services Network

B. Model Establishment

1. Assumption

(1) A single task is decomposed into a series of associated logistics activities which are executed in a time sequence order.

(2) A set of candidate logistics resources can be obtained after matching each logistics activity with features. In the end, one activity can only be matched with one resource.

(3) Expressed as certain that the time and the cost are fixed when one activity matched with one resource.

(4) Expressed as known that the start point and end point of each activity is fixed. Suppose the first activity execution time is set to zero and without regard to link problem.

2. Variable Declaration

Variable definitions:

cij : Expressed as the operation costs when the logistics activity i choose the candidate logistics resource j.

cijk: Expressed as the link costs from resource k to j ,when activity i and its immediate predecessor is executed by candidate logistics resource j and k.

tij : Expressed as the running time or consuming time during execution when activity i chooses candidate logistics resource j.

tijk : Expressed as the link time from resource k to j, when i and its immediate predecessor is executed by candidate logistics resource j and k.

qij : Expressed as the quality of delivery when activity i chooses candidate logistics resource j.

Xij : Expressed as the Decision variables, Xij∈{0,1}. When Xij=1, it stands for activity i choose candidate logistics resources j. When Xij=0, it stands for activity i do not choose candidate logistics resources j.

3. Objective Function

(1) The lowest costs of operation

The lowest operation costs, which is also expressed to ensure that all logistics activities execution costs and logistics activities link costs are lowest.

That is to say, operation costs(C) = all logistics activities execution costs(C1) + all logistics activities link costs(C2).

Introduce the decision variable Xij, which stands for the matching relation between logistics activities i and the candidate logistics resource j. All logistics activities costs C1 can be expressed as:

$$C_1 = \sum_{i=1}^{n}\sum_{j=1}^{m_i} c_{ij}X_{ij} \qquad (1)$$

Introduce another decision variable X_{hk}, which stands for the matching relation between h which is the immediate predecessor of i, and the candidate logistics resource j .when X_{ij} =1 and X_{hk} =1, the link costs c_{ijk} can be meaningful. It can be expressed as:

$$C_2 = \sum_{i=1}^{n}\sum_{j=1}^{m_i}\sum_{k=1}^{m_h} c_{ijk}X_{ij}X_{hk} \qquad (2)$$

The target function of the lowest costs can be set to:

$$C = \min\left(\sum_{i=1}^{n}\sum_{j=1}^{m_i} c_{ij}X_{ij} + \sum_{i=1}^{n}\sum_{j=1}^{m_i}\sum_{k=1}^{m_h} c_{ijk}X_{ij}X_{hk}\right) \qquad (3)$$

(2) The shortest time of operation

The earliest start time of the activity i on the candidate logistics resource j consists of three parts: ①the earliest execution time when immediate predecessor is executed on the candidate logistics resource k; ②the operation time when immediate predecessor h is operated on candidate logistics resource k; ③the link time when the candidate logistics resource j is linked with the candidate logistics resource k. From the above contents, it is easy to know that the earliest start time of any logistics activity i on the candidate logistics resources j can be set to:

$$ET_i = \max\{ET_h + \sum_{k=1}^{m_h} t_{hk}X_{hk} + \sum_{j=1}^{m_i}\sum_{k=1}^{m_h} t_{ijk}X_{ij}X_{hk}\} \quad (4)$$

Due to the whole logistics task is decomposed into n parts of logistics activities, the end time of the last part of logistics activity is the whole time of the task.

$$ET_{(n+1)} = \max\{ET_n + \sum_{j=1}^{m_n} t_{nj}X_{nj}\} \quad (5)$$

n+1stands for the last node of the logistics activity network figure. n not only stands for the last link of logistics activity network figure, but the immediate predecessor of n+1. ET_n stands for the earliest start time of the last logistics activity. ET(n+1) stands for the completion time of the whole logistics task. It needs not to be executed at the last node n+1, so there is no link time and the happening of the logistics activity represents the completion of the task.

Therefore, the target function of the shortest running time can be expressed as:

$$T=\min(\max\{ET_n + \sum_{j=1}^{m_n} t_{nj}X_{nj}\}) \quad (6)$$

(3) The optimal delivery quality

It is common that the relevant requirements should be put forward when providing logistics services, such as cargo damage rate. The whole task delivery quality can be expressed as the product of the delivery quality of all activities. The target function of optimal delivery quality can be expressed as:

$$Q = \max\prod_{i=1}^{n}(\sum_{j=1}^{m_i} q_{ij}X_{ij}) \quad (7)$$

(4) The multi-objective programming model

In order to calculate the optimal value of multi-objective resources configuration, it is important to use dimensionless method to deal with each objective function. Then, build a multi-objective programming model as follows:

$$C = \min\left(\sum_{i=1}^{n}\sum_{j=1}^{m_i} c_{ij}X_{ij} + \sum_{i=1}^{n}\sum_{j=1}^{m_i}\sum_{k=1}^{m_h} c_{ijk}X_{ij}X_{hk}\right)/C_r \quad (8)$$

$$T=\min(\max\{ET_n + \sum_{j}^{m_n} t_{nj}X_{nj}\})/T_r \quad (9)$$

$$Q=\min Q_r/(\prod_{i=1}^{n}\sum_{j=1}^{m_i} q_{ij}X_{ij}) \quad (10)$$

$$\sum_{i=1}^{n}\sum_{j=1}^{m_i} c_{ij}X_{ij} + \sum_{i=1}^{n}\sum_{j=1}^{m_i}\sum_{k=1}^{m_h} c_{ijk}X_{ij}X_{hk} \le C_r \quad (11)$$

$$\max\{ET_n + \sum_{j=1}^{m_n} t_{nj}X_{nj} \le T_r\} \quad (12)$$

$$\prod_{i=1}^{n}(\sum_{j=1}^{m_i} q_{ij}X_{ij}) \ge Q_r \quad (13)$$

$$ET_i - ET_h \ge t_{hk} \quad (14)$$

$$\sum_{j=1}^{m_i} X_{ij} = 1, X_{ij} \in \{0,1\} \quad (15)$$

The Objective function (8) represents the lowest operation costs after resources configuration; The Objective function (9) represents the shorted running time after resources configuration; The Objective function (10) represents the optimal delivery quality after resources configuration; The constraint condition (11) represents the overall operation costs of logistics task is lower than customer required Cr; The constraint condition (12) represents the overall running time of logistics task is lower than customer required T_r; The constraint condition (13) represents the overall delivery quality of logistics task is higher than customer required Q_r; The constraint condition (14) represents the earliest Delta-T between adjacent activities is greater than the running time of the immediate predecessor; The constraint condition (15) is a decision variable which represents any activity i can only choose one candidate resource j to execute.

C. The Application for The Model

This paper simulate the actual scene to calculate and apply the multi-objective programming model which is constructed by the Matlab, and get the optimal configuration scheme to verify the usefulness of the model.

Assume that there are two kinds of high valued medicines (drug A and drug B) should be delivered from a pharmaceutical company in Guizhou to a hospital in Chongqing Yuzhong district. A high quality of deliver should be ensured because of its easy broken. At the same time, here are some special requirements during delivery. Firstly, a special packaging and railway container transportation should be used for along distance transportation. The detailed requirements are shown in Table I:

TABLE I. THE REQUIREMENTS OF DELIVERY

Logistics task	Weight	Service Charge	Delivery Time	Availability of Equipment
Guizhou-Chongqing	10t	30 ten thousand	3days	95%

This task is decomposed into seven related logistics activities which are executed according to a certain order shown in Fig. (3). At the same time, match each resource feature with logistics recourse and get the logistics candidate resource. Finally, conduct a computer simulation experiment by establishing the model, and make the optimal resource allocation scheme. Relevant data generated randomly by connecting with the actual situation shown in Fig. (2).

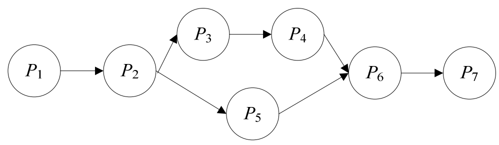

Fig.3 The Network Diagram of Logistics Activity

TABLE II. THE DETAIL INFORMATION

Logistics Activity	Activity Content	The Candidate Logistics Resources	Costs (Ten Thousand)	Time (Day)	Delivery Quality (%)
P1	From pharmaceutical companies to GY drugs warehouse center	GZMotor transport resources R11	3.5466	0.46	99.5
		GZMotor transport resources R12	3.4257	0.45	99.6
		GZMotor transport resources R13	3.6444	0.46	99.3
		GZMotor transport resources R14	3.6476	0.45	99.0
P2	Drug A encapsulation in GY warehouse center	GYwarehouse center R_{21}	1.8395	0.66	99.6
		GYwarehouse center R_{22}	1.8179	0.65	99.8
		GYwarehouse centerR_{23}	1.9726	0.67	99.6
P3	Drug A from GY warehouse center to GY railway station	GZ Motor transport resources R_{31}	2.2089	0.25	99.0
		GZ Motor transport resourcesR_{32}	2.7093	0.30	99.8
		GZ Motor transport resources R_{33}	2.2362	0.22	99.2
		GZ Motor transport resources R_{34}	2.1194	0.21	99.4
		GZ Motor transport resources R_{35}	2.6073	0.21	99.7
P4	Drug A from GY railway station to CQ north train station	Train transport resourcesR_{41}	8.4501	0.71	99.7
		Train transport resourcesR_{42}	8.4587	0.78	99.9
		Train transport resourcesR_{43}	8.6619	0.79	99.7
P5	Drug B from GYwarehouse centerto CQ north train station	GZMotor transport resources R_{51}	6.7703	1.07	99.5
		GZMotor transport resourcesR_{52}	6.3502	1.15	99.6
		GZMotor transport resources R_{53}	6.6620	1.13	99.2
		GZMotor transport resources R_{54}	6.4162	1.15	98.5
		GZMotor transport resourcesR_{55}	6.8419	1.19	99.0
P6	Drug A&B from CQ railway station hub to CQ Yuzhong district distribution center	CQ Motor transport resources R_{61}	3.8329	0.40	99.4
		CQ Motor transport resourcesR_{62}	3.2564	0.32	99.3
		CQ Motor transport resourcesR_{63}	3.6135	0.31	99.2
		CQ Motor transport resourcesR_{64}	3.5822	0.37	99.8
		CQ Motor transport resourcesR_{65}	3.5407	0.31	99.4
		CQ Motor transport resourcesR_{66}	3.8699	0.35	99.9
P7	Drug A&B from the distribution center to the hospital	CQ Motor transport resourcesR_{71}	1.6324	0.15	99.4
		CQ Motor transport resourcesR_{72}	1.6590	0.19	99.8
		CQ Motor transport resourcesR_{73}	1.5596	0.15	99.4
		CQ Motor transport resourcesR_{74}	1.9699	0.14	99.8

The link costs and link time of logistics resources are taken into account in this model. So, we can get the link costs and link time by assuming the evaluations are in the range of 5% and 8% of random data respectively according to the logistics resource operation costs and time.

TABLE III. THE LINK COSTS AND LINK TIME OF CANDIDATE LOGISTICS RESOURCES FROM P1 TO P2

	Link Costs (Ten Thousand)			Connection Time (Day)		
	R_{21}	R_{22}	R_{23}	R_{21}	R_{22}	R_{23}
R_{11}	0.1878	0.1689	0.1608	0.034	0.035	0.036
R_{12}	0.1895	0.1975	0.1664	0.034	0.037	0.036
R_{13}	0.1836	0.1719	0.1917	0.033	0.038	0.033
R_{14}	0.1884	0.1584	0.1931	0.034	0.034	0.036

TABLE IV. THE LINK COSTS AND LINK TIME OF CANDIDATE LOGISTICS RESOURCES FROM P2 TO P3

	Link Costs (Ten Thousand)					Connection Time (Day)				
	R_{31}	R_{32}	R_{33}	R_{34}	R_{35}	R_{31}	R_{32}	R_{33}	R_{34}	R_{35}
R_{21}	0.0997	0.0879	0.0971	0.0897	0.0789	0.049	0.051	0.049	0.049	0.054
R_{22}	0.0800	0.0852	0.0937	0.0956	0.0947	0.050	0.053	0.056	0.051	0.054
R_{23}	0.0830	0.0884	0.0772	0.0778	0.0784	0.054	0.051	0.053	0.049	0.055

TABLE V. THE LINK COSTS AND LINK TIME OF CANDIDATE LOGISTICS RESOURCES FROM P2 TO P5

	Link Costs (Ten Thousand)					Connection Time (Day)				
	R_{31}	R_{32}	R_{33}	R_{34}	R_{35}	R_{31}	R_{32}	R_{33}	R_{34}	R_{35}
R_{21}	0.1339	0.1248	0.1095	0.1248	0.1074	0.017	0.018	0.022	0.020	0.022
R_{22}	0.1027	0.1425	0.1280	0.1465	0.1348	0.019	0.018	0.016	0.021	0.019
R_{23}	0.1291	0.1408	0.1440	0.1494	0.1000	0.020	0.021	0.016	0.019	0.022

TABLE VI. THE LINK COSTS AND LINK TIME OF CANDIDATE LOGISTICS RESOURCES FROM P3 TO P4

	Link Costs (Ten Thousand)			**Connection Time (Day)**		
	R_{41}	R_{42}	R_{43}	R_{41}	R_{42}	R_{43}
R_{31}	0.4433	0.4306	0.4495	0.067	0.058	0.058
R_{32}	0.4264	0.4240	0.4401	0.057	0.056	0.063
R_{33}	0.4114	0.4249	0.4450	0.066	0.068	0.064
R_{34}	0.4287	0.4423	0.4369	0.058	0.066	0.058
R_{35}	0.4293	0.4123	0.4333	0.058	0.058	0.058

TABLE VII. THE LINK COSTS AND LINK TIME OF CANDIDATE LOGISTICS RESOURCES FROM P4 TO P6

	Link Costs (Ten Thousand)						**Connection Time (Day)**					
	R_{61}	R_{62}	R_{63}	R_{64}	R_{65}	R_{66}	R_{61}	R_{62}	R_{63}	R_{64}	R_{65}	R_{66}
R_{41}	0.3042	0.3313	0.3330	0.3365	0.3445	0.3491	0.083	0.083	0.085	0.085	0.083	0.084
R_{42}	0.3385	0.3291	0.3464	0.3290	0.3008	0.3060	0.094	0.091	0.089	0.083	0.083	0.081
R_{43}	0.3431	0.3242	0.3422	0.3105	0.3276	0.3315	0.095	0.091	0.089	0.085	0.083	0.090

TABLE VIII. THE LINK COSTS AND LINK TIME OF CANDIDATE LOGISTICS RESOURCES FROM P5 TO P6

	Link Costs (Ten Thousand)						**Connection Time (Day)**					
	R_{61}	R_{62}	R_{63}	R_{64}	R_{65}	R_{66}	R_{61}	R_{62}	R_{63}	R_{64}	R_{65}	R_{66}
R_{51}	0.1516	0.1807	0.1681	0.1525	0.1745	0.1596	0.032	0.025	0.026	0.027	0.025	0.029
R_{52}	0.1562	0.1603	0.1573	0.1595	0.1521	0.1818	0.027	0.032	0.027	0.029	0.025	0.027
R_{53}	0.1641	0.1769	0.1848	0.1750	0.1768	0.1723	0.025	0.030	0.031	0.027	0.029	0.026
R_{55}	0.1562	0.1745	0.1926	0.1937	0.1635	0.1604	0.028	0.031	0.029	0.027	0.026	0.028
R_{55}	0.1782	0.1820	0.1709	0.1603	0.1974	0.1541	0.027	0.027	0.028	0.030	0.027	0.027

TABLE IX. THE LINK COSTS AND LINK TIME OF CANDIDATE LOGISTICS RESOURCES FROM P6 TO P7

	Link Costs (Ten Thousand)				**Connection Time (Day)**			
	R_{71}	R_{72}	R_{73}	R_{74}	R_{71}	R_{72}	R_{73}	R_{74}
R_{61}	0.0776	0.0786	0.0792	0.0905	0.009	0.008	0.010	0.011
R_{62}	0.0893	0.0763	0.0983	0.0932	0.013	0.016	0.015	0.012
R_{63}	0.0934	0.0766	0.0965	0.0984	0.010	0.014	0.014	0.014
R_{64}	0.0996	0.0965	0.0946	0.0878	0.014	0.009	0.013	0.012
R_{65}	0.0794	0.0850	0.0783	0.0758	0.010	0.009	0.015	0.009
R_{66}	0.0985	0.0825	0.0824	0.0833	0.009	0.013	0.015	0.012

III. THE MATLAB SIMULATION EXPERIMENT AND RESULT INTERPRETATION

All the data are simulated by Matlab2009, and compile the corresponding genetic algorithm code to get the solution. Set the related parameters as follows: setting the three weight coefficient are λ1=0.3,λ2= 0.3 ,λ3=0.4 , Population size is 40, iterations numbers are 150, a crossover probability is 0.6, mutation probability is 0.06, α1 is 3, α2 is 2, Omega initial penalty coefficient ω(1)=1.

The simulation results are shown in Fig.(4). It is obvious to find that the simulation results began to convergence when a computer iterated 80 times.The objective function is minimized to 0.8484, and the corresponding chromosomes are [2242253].Get the decision variable matrix elements X(1,2) = X(2,2) = X(3,4) = X(4,2) = X(5,2) = X(6,5)=X(7,3)=1 after decoding the chromosomes. Therefore, the drug delivery of the logistics resource allocation scheme can be [R12, R22, R34, R42, R52, R65, R73].

It is obvious to know that the total costs of logistics task are 286800 yuan, the total time of logistics task are 2.88 days, the delivery quality of logistics task is 97.13% under the logistics resource allocation scheme.

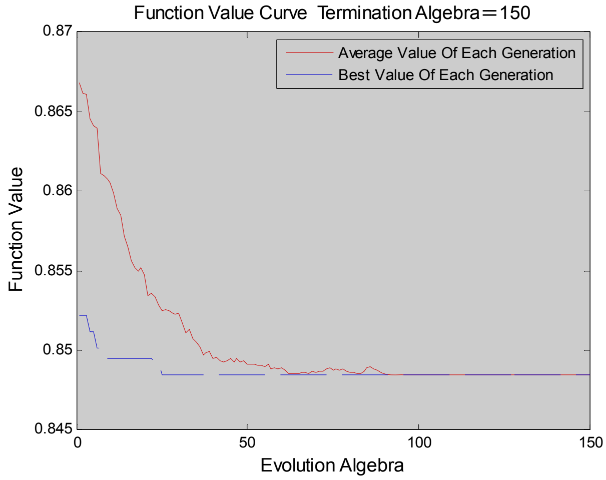

Fig.4. The Simulation Results

All three goals have met the personalized needs of customer and realize the comprehensive optimal logistics resource allocation. The scheme is shown in Table X.

Although the optimal scheme has not achieve the three goals (C,T,Q) to the optimal state ,it has maximized the overall benefit of logistics service and gets rid of the single goal optimal which is more in line with the reality.

TABLE X. THE OPTIMAL LOGISTICS RESOURCE ALLOCATION OF A&B DRUGS

The Logistics Activities	Active Contents	Selected Logistics Resources
P_1	from pharmaceutical companies to GY warehouse center	GZ motor transport resources R_{12}
P_2	encapsulation A drug in GY storage center	GY warehouse center R_{22}
P_3	A drug from GY warehouse center to GY railway station	GZ motor transport resources R_{34}
P_4	A drug from GY railway station to CQ north train station	The train transport resources R_{42}
P_5	B drug from GY storage center to CQ north train station	GZ motor transport resources R_{52}
P_6	from the railway station hub to CQ Yuzhong district distribution center	CQ motor transport resources R_{65}
P_7	A&B drugs from the distribution center to the hospital in Yuzhong district	CQ motor transport resources R_{73}

It has verified the usefulness of multi-objective programming model and has shown that it plays a practical role in logistics resources optimization allocation.

IV. CONCLUSION

In this paper, there are three innovations: (1) we established the logistics shortest running time model which is different from other scholar ideas to summate times, but to product times (execution time, running time and link time) with the idea of project management. (2) we considered a individual case under a serial and parallel mixed complicated task to allocate the resource. (3) we put forward a optimal allocation scheme under a actual scene. But in the construction of the model, it takes direct consideration of link time instead of multi-tasks and occupancy of resources. And we adopted the expert scoring method to score the weights which exerts a certain influence on the optimal resource allocation scheme.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflicts of interest.

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