Journal of Ecology of Health & Environment
An International Journal

http://dx.doi.org/10.18576/jehe/050101

Service Resources Matching of Reverse Supply Chain Services

Xia Xu-hui, Xiong Ying-qing, Wang Lei, Zhou Meng and Yang Yi*

School of Machinery and Automation, Wuhan University of Science and Technology, 430081, Wuhan, China.

Received: 21 Sep. 2016, Revised: 22 Nov. 2016, Accepted: 24 Nov. 2016.
Published online: 1 Jan. 2017.

Abstract: We discuss reverse supply chain which services for iron and steel industry and consider the analysis of the service resources modular and matching process of reverse supply chain for iron and steel industry. The key service resources are selected from the service set, which is required in the service activities, according to the importance lever and value. A comprehensive coupling matrix and the measurement of service resources modular degree are built by analyzing the coupling relationships of the key service resources. Then a multi-objected service resources modular and matching model is constructed, considering the degree of service resource module, the service cost and the service time. The improved non-dominated sorting genetic algorithm (NSGA-II) is used to clustering the service resources into service resource module, and matching the service resource modules by the service resource providers adaptively. The rationality and validity of the model and method were verified by the application of case and parameter sensitivity analysis.

Keywords: Supply chain management, Reverse supply chain services, Resource modularization, Resource matching, Iron and steel industry.

1 Introduction

There are a variety of residues resources in iron and steel industry. Reverse supply chain service is the effective operation and management mode of resource recovery and comprehensive utilization. As a typical complex system, the service process of the reverse supply chain service system for iron and steel industry involves lots of service activities and the service resources [1]. Multiple correlation relationship exists between the service activities and service resources between the service resources. In order to clarify the relationship, modular technology [2] is used to resolve the service activities and service resources among the service system. Service modular technology is dividing and adjusting the complex and continuous service [2]. As one of the key technologies in the complex system, Service modular technology can divide the continuity service process into discrete service activities, and also can cluster the service resources for the sub blocks from the perspective of service resource inputs. Service module was derived from the service industry, and then gradually extended to production or service organization service system. Existing research mainly focuses on the concept of service modularization [2], the divided criterion[3] and products service module system [4,5].

At present, the scholars have carried out some researches on service resources. For example, Wen put forward a task oriented service discovery algorithm in order to realize the adaptive and efficient Web service composition [6]. Tan proposed a multi-granularity resources organized adaptively and discovered mechanism based on geographic area and manufacturing resource classification tree in service environment [7]. Guo built a manufacturing resource combinatorial optimization model for manufacturing the large scale complex equipment [8]. Martins proposed a resource allocation method based on the particle swarm optimization [9]. Gao studied the service matching method using fuzzy integral which is used to measure the matching degree between cloud service resources and user needs [10]. Nie established a recommendation system of digital home service resources which combines association rules and sequential association rules, considering family service resource types and user consumption characteristics based on improved Apriori algorithm and time series data mining technology [11]. Gao proposed resource service searching method a function similar according to the task demands in the view of the service robot using distributed resource [12].

*Corresponding author e-mail: wanglei1987@wust.edu.cn

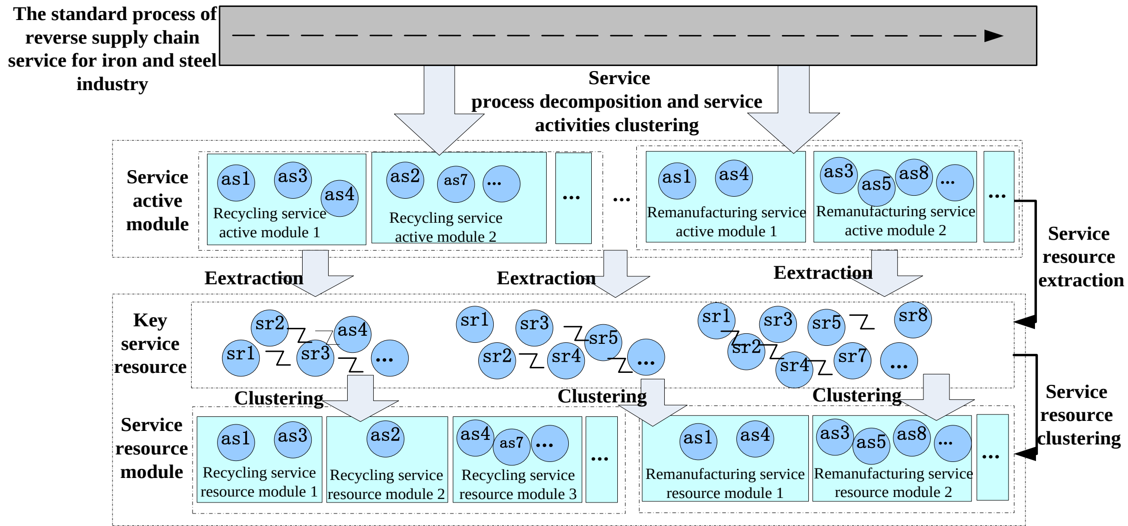

Fig. 1 The modularity process of reverse supply chain services for iron and steel industry.

Yin analyzed the cloud manufacturing resource characters [13], such as uncertainty, coarse-granularity, diversity and dynamics, established an optimization model of cloud manufacturing services resource combination for new product the development. Ma and Yang build a kind of service resource combination optimization model for the group-buying model in the cloud manufacturing environment [14], considering the group-buying factors of purchase price, purchase credibility and flexibility of the manufacturing unit. Li proposed a service resources organization method based on the hierarchical service network [15]. Li studied on the service efficiency of modular, and pointed out that the service resource modularization is conducive to improve service efficiency [16]. The above researches mainly focused on the service resources discovery mechanism, the similarity matching, the combination optimization model and so on, and many achievements were completed. However, for the number relationship of service task and service resource, many literatures were considered as one-to-one match. In the real application, there are many kinds of service resources, which finish one service task. Based on the existing research results, analyzing the classification of service resources, considering the many-to-one relationship of service activity and service resource, the characteristics of reverse supply chain service resources for iron and steel industry from the view of organizational relationships, geographic location, temporal relations and service providers are analyzed, and then a service resource comprehensive coupling matrix is constructed.

A service resources matching method on the constraints of minimizing the cost, minimizing the lead-time and maximizing the module degree is proposed. The non-dominated sorting genetic algorithm (NSGA-II) is used to solve the model, and then the parameters sensibility is analyzed. This research can offer a kind of method and thought for the study on the reverse supply chain service.

2 Materials and Methods

2.1 The process of service resources modularity

The service resources of iron and steel industry reverse supply chain includes people, equipment, information, capital and so on, which is used to realize the function of service activities in the residues resources recycling process. The service resources are the material basis of completing the service activities, and the function of service activities is realized by the related service resources which are operated cooperatively in the service system. The service resources required in the service process is mapped from the service activities which are included in the service process. When resolving the service activities into service resources, the function of the service activities and the characteristics of service resources are considered adequately. The iron and steel industry reverse supply chain service, as a product from the combination of service supply chain and service oriented manufacturing [1]. The cloud manufacturing service resources are uncertainty, coarse-grained, using online and offline binding, diversity, dynamic and demand-oriented [13]. When the service resources in the service integration system platform are organized and managed, the above characters and classification of the service resources should be fully considered.

The modularization of reverse supply chain services for iron and steel industry contains the service activity modularization and the service resource modularization. The process of service activities modularization is as follows: firstly, the personalization process of the reverse supply chain services is decomposed into some atomic service activities based on the IDEF0. The atomic service activities cannot be divided. Then the modularization criterion of the service activities is established. Finally, the atomic service activities are clustered into service activity module according to the incidence relation.

The process of service resources modularization is as follows: the service resource is resolved into single service resources. After classifying the single service resources and analyzing the coupling relationships between the single service resources, the single service resources are clustered into service resource module. In the meantime, the single service resources offered by different service resource providers can be matched by multi-objective optimization with the constraints of the service cost and service time. The modularization process of reverse supply chain services for iron and steel industry is as shown in Fig. 1.

2.2 The coupling relationship of service resources

The coupling relationship of atomic services includes organization coupling, time sequence coupling, geographical coupling and service provider coupling. The organization coupling is the degree of close connection on the organization structure. The time coupling means the time successiveness. The geographical coupling indicates that whether two single service resources executed in the adjacent geographical area. The service provider coupling indicates whether the service resources will be provided by the same service provider.

Table 1 Quantitative values of coupling relationship

Coupling Relationship	value	description
No relevance	0	No connection or similarity between the two service resources.
Weak correlated	1	The connection or similarity between the two atomic services is weak.
Moderate correlation	5	The connection or similarity between the two atomic services is moderate.
Strong correlation	9	The connection or similarity between the two atomic services is strong.

Assuming $\omega_1, \omega_2, \omega_3, \omega_4$ are the weights of the organization coupling, time sequence coupling, and service provider coupling. n is the number of service resources, Ao_{ij} means the similarity of the service resource i, j on the organization, At_{ij} means the successiveness of service resource i, j on time, Al_{ij} the degree of close connection of service resource i, j on the region, Ae_{ij} means the possibility that the service resource i, j are offered by the same service provide. The coupling matrix can be constructed, for example: $(Ao_{ij})n\times n$ means organization coupling matrix, $(At_{ij})n\times n$ is time sequence coupling matrix, $(Al_{ij})n\times n$ means geographical coupling matrix, $(Ae_{ij})n\times n$ means service provider coupling matrix.

The comprehensive coupling matrix C(i,j) can be expressed as:

$$C(i,j) = \omega_1 Ao(i,j) + \omega_2 At(i,j) + \omega_3 Al(i,j) + \omega_4 Ae(i,j) \quad (1)$$

$$\omega_1 + \omega_2 + \omega_3 + \omega_4 = 1 \quad (2)$$

Where, the range of the attribute weight is [0, 1], the strength and quantitative values of the coupling relationship are shown in table 1.

The multi-objective optimization model: The multi-objective optimization model is built based on the constraints of the service cost, service time and degree of modularity, and then the NSGA-II is used to optimize the model.

Model assumptions: (1) All the service resources correspond to the atomic services activities are demarcated according to equipment, personnel and site, or classified by the different value and importance of the service resources. The different key service resource collections are corresponding to different service function activities. (2) For the same service activities, the same service resources are distinguished form each other by time series. (3) There are I services activities, n key service resources can be extracted from them, and the key service resources are grouped together into m service resources module by clustering. (4) All the service resources belonging to the same module should be provided by the same service provider. (5) The service resources corresponding to the same atomic services activities are successively realized in serial mode. The time needed to complete the atomic services activity is equivalent to the total time of key service resources.

Model construction: The optimization objective of multi-objective optimization model includes the service modularity, service cost, and the service time.

Modularity of service resources: According to the service module loose coupling [17], a measurement of service resources module is built. The average polymerization degree of service resources module is considered as the modularity, its computation formula is as follows.

$$f_1 = (\sum_{i=n_k}^{m_k} \sum_{j=n_k}^{m_k} r_{ij}) / (m_k - n_k + 1)^2 \quad (3)$$

The average coupling degree between service resources modules is calculated as the formula (4):

$$f_2 = \frac{\sum_{i=n_k}^{m_k} (\sum_{j=1}^{n_k - 1} r_{ij} + \sum_{j=m_k+1}^{N} r_{ij})}{(m_k - n_k + 1)(N - m_k + n_k - 1)} \quad (4)$$

Service resource degree of modularity optimization function is calculated as follows.

$$Max\ M=\frac{(\sum_{k=1}^{D}f_1-\sum_{k=1}^{D}f_2)}{D} \tag{5}$$

Constraint conditions: $0<D\leq N$, i, j>0, $r_{ij}\geq 0$. M represents the modularity of the modular program. D means the service resource module number after the service resource of the single particle size clustered. n means the total number of single granularity service resources in the service process. n_k is the serial number of the first atomic service of every k module in the sequence of the clustered atomic services, m_k is the serial number of the last single granularity service resources of every k module in the sequence of the clustered single granularity service resources. r_{ij} is the value of the row i and the column j in the clustered comprehensive matrix.

Service cost of service resources: The service resource cost is composed of the use-cost of all the key service resources and the operation cost of service resource module. The use-cost of service resources includes consumed cost of service resources and the management cost of all the service resources. The optimization function of the service resource cost is shown as follows.

$$MinC_s=\sum_{i=1}^{n}Cu_i+\sum_{j=1}^{m}Co_j \tag{6}$$

Where, C_s is the all cost of service resources, Cu_i is the cost that supplier used the service resources, Co_j is the operation cost of j module.

Service time of service resources: Service time is defined as the whole time that service providers complete the reverse supply chain service process for the iron and steel industry. Assuming the services resources finished the activity parallel, the time of finished the service process is consisting of the time of realizing all the activities. Assuming Rt_{ir} is the service time of the service resource ir ($i=1,2,3,\cdots,l$) and $TotalRt$ is the total service time, the expression is as formula (7).

$$TotalRt=\sum_{ir=1}^{l}Rt_{ir} \tag{7}$$

Suppose that service activities u are classified V groups, and each group of service activities are finished parallel. Then the service time of the iv (iv=1,2,3,…,u) service resource in the v group service activity is PRt_{iv} , and it is can be expressed as formula (8).

$$PRt_{iv}=\max(Rt_{iv}) \tag{8}$$

The total service time is as formula (9).

$$TotalRt=\sum_{ir=1}^{l-u}Rt_{ir}+\sum_{iv=1}^{v}PRt_{iv} \tag{9}$$

Where 0<u<1, 0<v<1, ir=1,2,…,(1-u), iv=1,2,…,v.

Optimization solution: NSGA-II algorithm uses a fast non-dominated sorting mechanism, the introduction of elite policy, adopted the degree of congestion and crowding comparison operator. It is good for solving the multi-objective optimization and obtaining the Pareto set. The flow of the optimization solution based on NSGA-II is shown in Fig.2.

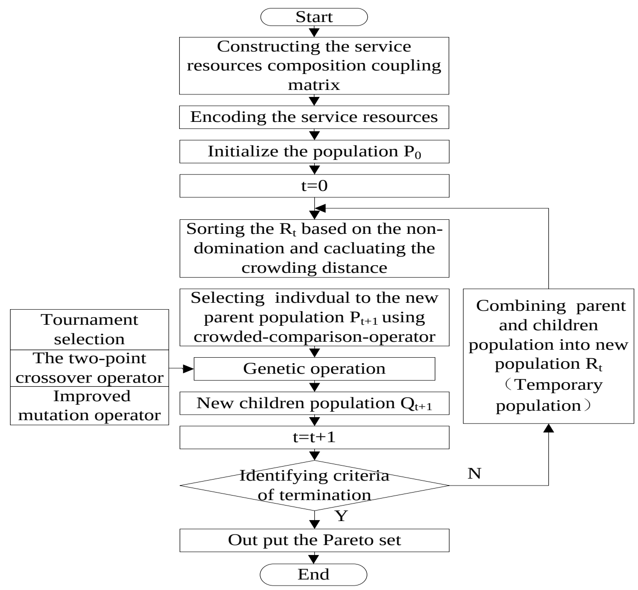

Fig.2 The flow of optimization solution

Chromosome coding: Assuming n service resources can form a n×m comprehensive coupling matrix. m is the maximum number of service resources modules. If the value of a cell in the matrix is 1， indicates that the service resource is in the corresponding cluster module. On the contrary, if the service resource is not in the corresponding cluster module, the value of the cell is 0. And in each column only one cell is presented as 1 [18].

Population initialization: for a chromosome (n×m matrix), selecting a cell from the first row to the m row in each column randomly, the value is presented as 1, and the remaining cells are 0, then a complete coding chromosome is obtained. This method can be performed repeatedly to generate different chromosomes, until get enough chromosomes.

Selection, crossover and mutation operators: Selection operator uses tournament selection method. The highest individual selected from several individuals is inherited to the next generation population.

Crossover operator uses two-point crossover method. The two parent chromosomes selected from the current population, and two integers selected in the column of the

Table 2 the atomic service for the recycling of blast furnace slag

serial number	Atomic service activities	serial number	Atomic service activities
1	Blast furnace slag over water service	8	Loading service 2
2	Loading service 1	9	Transportation service 2
3	Slag transportation service 1	10	Unloading Services 2
4	Unloading Services 1	11	Slag - glass processing services
5	Slag filtrate service	12	Slag-cement processing services
6	Slag ingredient service	13	Slag - brick processing services
7	Bulk service		

Table 3 the attributive characters of the key service resources of the blast furnace slag recycling

No.	Key service resources	Service activity No.	Timing sequence	Place of occurrence	Service provider
1	water	1	1	Iron Works	Iron Works
2	Loading equipment 1	2	2	Iron Works	Iron works or cartage company or transportation company
3	Loading staff 1	2	2	Iron Works	Iron works or cartage company or transportation company
4	Transportation Equipment 1	3	3	Iron works - slag plant	Transportation company
5	Transport personnel 1	3	3	Iron works - slag plant	Transportation company
6	Unloading equipment 1	4	4	Slag plant	Cartage company
7	Unloading staff 1	4	4	Slag plant	Cartage company
8	The filtrate equipment	5	5	Slag plant	Slag plant
9	Slag batching equipment	6	6	Slag plant	Slag plant
10	Slag detection device	6	6	Slag plant	Slag plant
11	Ingredient testing personnel	6	6	Slag plant	Slag plant
12	Packing equipment	7	7	Slag plant	Slag plant
13	Packing personnel	7	7	Slag plant	Slag plant
14	Loading equipment 2	8	8	Slag plant	Transportation company
15	Loading staff 2	8	8	Slag plant	Transportation company
16	Transportation Equipment 2	9	9	Slag plant Glass factory Cement plant Brick factory	Transportation company
17	Transport personnel 2	9	9	Slag plant Glass factory Cement plant Brick factory	Transportation company
18	Unloading staff and Equipment 2	10	10	Glass factory Cement plant Brick factory	cartage company
19	Glass processing equipment	11	11	Glass factory	Glass factory
20	Cement processing equipment	12	11	Cement plant	Cement plant
21	Brick processing equipment	13	11	Brick factory	Brick factory

Table 4 Comprehensive coupling matrix of the service resources

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
0	6	6	2.5	2.5	1.25	1.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	8	5	5	2.5	2.5	0	0	0	0	0	0	0.25	0.25	0.25	0.25	1.25	0	0	0
6	8	0	5	5	2.5	2.5	0	0	0	0	0	0	0.25	0.25	0.25	0.25	0	0	0	0
2.5	5	5	0	8	3.75	3.75	0.25	0.25	0.25	0.25	0.25	0.25	0.5	0.5	0.5	0.5	1.25	0	0	0
2.5	5	5	8	0	3.75	3.75	1.25	1.25	1.25	1.25	1.25	1.25	1.5	0.5	0.5	0.5	0	0	0	0
1.25	2.5	2.5	3.75	3.75	0	9	2.5	1.25	1.25	1.25	1.25	1.25	1.5	1.5	0.5	0.5	0	0	0	0
1.25	2.5	2.5	3.75	3.75	9	0	2.5	1.25	1.25	1.25	1.25	1.25	1.5	1.5	0.5	0.5	0	0	0	0
0	0	0	0.25	0.25	2.5	2.5	0	7	7	7	4.75	4.75	1.5	1.5	0.5	0.5	0	0	0	0
0	0	0	0.25	0.25	1.25	1.25	7	0	9	9	6	6	1.5	1.5	0.5	0.5	0	0	0	0
0	0	0	0.25	0.25	1.25	1.25	7	9	0	9	6	6	1.5	1.5	0.5	0.5	0	0	0	0
0	0	0	0.25	0.25	1.25	1.25	7	9	9	0	7	6	1.5	1.5	0.5	0.5	0	0	0	0
0	0	0	0.25	0.25	1.25	1.25	4.75	6	6	7	0	9	3.75	3.75	0.5	0.5	0	0	0	0
0	0	0	0.25	0.25	1.25	1.25	4.75	6	6	6	9	0	3.75	3.75	0.5	0.5	0	0	0	0
0	0.25	0.25	0.5	0.5	1.5	1.5	1.5	1.5	1.5	1.5	3.75	3.75	0	9	5	5	2.5	0	0	0
0	0.25	0.25	0.5	0.5	1.5	1.5	1.5	1.5	1.5	1.5	3.75	3.75	9	0	5	5	2.5	0	0	0
0	0.25	0.25	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1.5	5	5	0	9	5	0	0	0
0	0.25	0.25	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1.5	5	5	9	0	5	0	0	0
0	1.25	0	1.25	0	0	0	0	0	0	0	0	0	2.5	2.5	5	5	0	5	5	5
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	1.25	1.25
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	1.25	0	1.25
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	1.25	1.25	0

parent chromosomes randomly as the intersection. The column which is located on the intersection of the two chromosomes will be exchanged, and the remaining columns are unchanged.

Mutation operator is improved on the basic mutation method [19]. Two columns are selecting from a selected parent chromosome matrix randomly as a mutation point; at the mutation points, the value of row presented as “1” are changed into “0” respectively; selecting a row randomly from the remaining rows in the parent matrix, and the values in this row are changed into “1”. This will ensure that the sub-chromosomal produced by the parent mutation is not the same with the parent chromosome. The process of the improved mutation is shown as Fig.3.

Determine the max module number: There are three typical methods to determine the max module number: (1) the max module number is the geometric average of sample size [20]. (2) The max module number is between 1 and the geometric average of the sample size [21]. (3) The max module number is between the geometric average and arithmetic average of the sample size [22]. In this paper, the range of the max module number D is determined by the third method, that is $\sqrt{n} \le D \le \frac{n}{2}$, n is the number of service resources.

Modularity transformation: In the three targets of the multi-objective optimization, the modularity function should to be maximized, and the service cost and lead time should be minimized. In order to unify the form, the modularity function is needed to convert into minimizing function with the formula (10).

$$M' = M_{\max} - M \quad (10)$$

Where, M’ is the transformed modularity, M is the original modularity, M_{max} is the estimated value of the max module number.

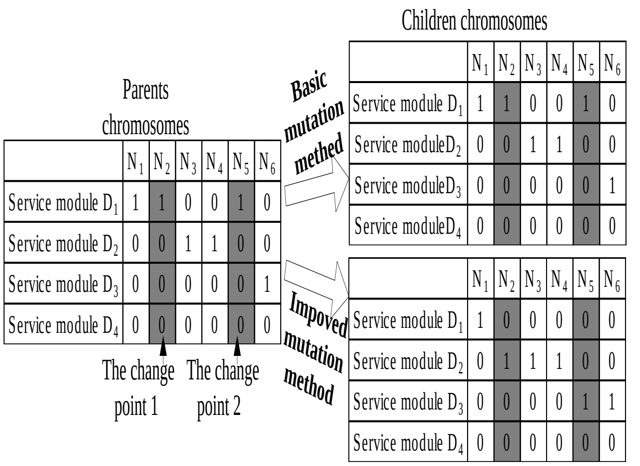

Fig.3 the process of the improved mutation

3 Results and Discussion

3.1 Case illustrating

Table 5 Information of the service resources offered by the service resources supplier

No.	Service resources module	Service activities No..	Use cost	operating cost	Service time
1	{1}	1	10	2	0.5
2	{2,3}	2	180	1	0.5
3	{4,5}	3	120	20	1
4	{6,7}	4	16	1	0.5
5	{8,9,10,11,12,13}	5,6,7	500	50	5
6	{14,15}	8	50	10	1
7	{16,17}	9	150	20	2
8	{18}	10	60	10	0.5
9	{19}	11	400	50	10
10	{20}	12	500	30	12
11	{21}	13	450	40	11
12	{1,2,3}	1,2	28	2	0.6
13	{1,2,3,4,5}	1,2,3	150	20.1	1.5
14	{1,2,3,4,5,6,7}	1,2,3,4	165	26	2.6
15	{6,7,8,9,10,11,12,13}	4,5,6,7	516	50.1	5.1
16	{8,9,10,11,12,13,14,15}	5,6,7,8	540	60	5.5
17	{6,7,8,9,10,11,12,13,14, 15}	4,5,6,7,8	550	60	5.5
18	{14,15,16,17}	8,9	190	25	2.8
19	{14,15,16,17,18}	8,9,10	280	55	2.8
20	{18,19}	10,11	450	55	10.1
21	{18,20}	10,12	550	35	12.1
22	{18,21}	10,13	500	45	11.1
23	{18,19,20,21}	10,11,12,13	1500	120	15
24	{19,20,21}	11,12,13	1500	100	12

There are 100,000 tons of blast furnace slag in an iron mill. It should be processed in a metallurgical slag business, and then transferred to the downstream firms such as cement plant, glassworks, and brick factories and so on. The atomic service extracted from the standard reprocessing of blast furnace slag process are shown in Table 2. The key service resources and theirs characteristics are shown in Table 3.

According to the Table 1 and Table 2, the coupling matrix can be constructed. Set the parameters: $\omega_i = 0.25$,i=1,2,3,4. According to the formula (1) and (2), the $C_{ij}(n\times n)$ can be shown in Table 4.

The related information of services resource module provided by service resources providers can be shown in Table 5. The number of service resource module is the service resource number in Table 2, the using cost is the cost of the unit of service resource, and service time is the time of the service activity.

3.2 Computational results

The simulation of modular and matching of service resources is achieved by using Matlab 2012b, NSGA-II algorithm parameter values are: population number of individuals p_n=100, iterations G=500 , crossover probability p_c=0.95 , mutation probability p_m=0.1 the number of resources to be clustering services n=21 the maximum number of modules clustering M=10.The above parameters are used in the program. The Pareto solution set of NSGA-II is shown in Figure 4.

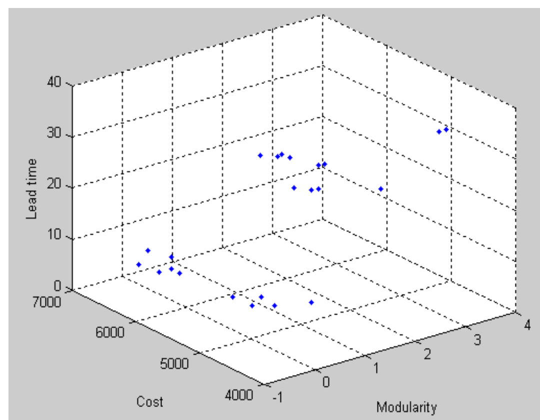

Fig.4 The Pareto set of NSGA-II

The three-dimensional coordinates are respectively corresponded to the three-optimization objectives: modularity, the cost of supply chain and lead-time, and each pointing the figure corresponds to non-dominated solutions. In optimization results, the modularity degree of is 0.5418, lead-time is 24.9, the value of the cost is 2682, and the value of chromosome encoding is shown in Table 6.

As can be seen in the Table 6, six service modules are generated, that is M_1={1,2,3}, M_2={6,7}, M_3={18,19,20,21}, M_4={4,5}, M_5={8,9,10,11,12,13}, M_6={14,15,16,17}. The element of the other four lines is 0, indicating that the module is empty. These service resource modules are respectively described as follows: service resource module 1 comprises water, loading equipment 1and loading personnel 1; service resource module 2 comprises

Table 6: the dyeing coding of the clustering optimization results

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0

transport equipment 1and transport personnel 1; service resource module 3 includes unloading equipment 1and unloading personnel 1; service resource module 4 comprises filtrate equipment, slag batching equipment, ingredients testing personnel, packing equipment and packing personnel; service resource module 5 comprises loading equipment 2, loading personnel 2, transport equipment 2 and transport personnel 2; service resources module 6 comprises the unloading personnel and equipment, glass processing equipment, cement processing equipment and kiln processing equipment; and the remaining four service resource module contain no service resource.

3.3 Algorithm analysis

Iterations which can the impact the results of the NSGA-II are the main considerations in parametric analysis. Parameter settings of NSGA-II algorithm in programming are: population size is 100, the largest hereditary algebra is 500, crossover probability is 0.95, mutation probability is 0.1, and the maximum number of modules is set to 10. The number of iterations is set as 5.50 and 500, respectively, the solution sets of NSGA-II are shown in Table 7.

Table 7 Pareto set while the iteration number is 5, 50, and 500

No.	Objective function			The modular solution of service resources
	Modula-rity	Cost	Lead time	
1	3.6813	2711	41	{1,3,18}{2,8,9,10}{4}{5}{7, 15}{12,13}{14,16,19} {20,21}{6}
2	0.6621	3487	31	{6,7}{15,21}{4,5}{8,9,10,11} {1,2,3}{12,13,14}{16,17}{18,19,20,21}
3	0.5413	2682	24.9	{4,5}{1,2,3}{14,15,16,17}{18,19,20,21}{6, 7}{8,9,10,11, 12,13}

When the iteration is set as 5 or 50, the dissatisfied service resource modular and matching solutions are presented. When the iteration is 500, many satisfactory service resource modular matching solutions are presented, as shown in Table 8.

According to Table 9, the three solutions of the modular program, cost and lead time optimization have different performance. The cost of the solution 1 are smaller than the solution 2 and the solution 3, but the modularity of scheme 3 is the smallest; the lead time of the solution 2 are smaller than the other two solutions, but the module degree and the cost are larger than the other two solutions; the modularity of scheme 3 is larger than the other two solutions, but the lead-time is the biggest. In practical engineering, the design personnel can select the appropriate service resource matching solution according to the customer's actual service needs and preferences, such as the lead-time.

Table 8 the different Pareto sets while the iteration number is 500

No.	Objective function			The modular solution of service resources
	Modul-arity	Cost	Lead time	
1	0.2134	2627.1	22	{1,2,3,4,5}{6,7}{16,17,18}{8,9,10,11,12,13,14, 15} {19,20,21}
2	0.2698	2672	21.9	{14,15,16,17,18}{8,9,10,11} {12,13}{4,5}{6, 7} {19,20,21}{1,2,3}
3	0.5413	2682	24.9	{1,2,3}{6,7}{18,19,20,21} {4,5}{8,9,10,11, 12,13} {14,15,16,17}

Acknowledgments

The authors gratefully acknowledge financial support from the National Natural Science Foundation of China (No. 71471143), Hubei Key Laboratory for Efficient Utilization and Agglomeration of Metallurgic Mineral Resources(No. 2016zy013), and Hubei Province Key Laboratory of Systems Science in Metallurgical Process(Wuhan University of Science and Technology) (No. Y201501).

References

[1] Wang L., X.H. XIA, Y.Q. Xiong, J.W. Liu, and M. Zhou: Reverse supply chain service process model for the iron and steel industry. Chin. J. Eng., 37, 812 – 821(2015).

[2] Stremersch S., A. M. Weiss, B.G.C. Dellaert and R.T. Frambach: Buying modular systems in technology-intensive markets. Journal of Marketing Research J. Mal. Res., 40, 335-350(2003).

[3] Li B.H: Analysis of the service modular efficiency. Shanghai Manag. Sci., 32, 59-63(2010).

[4] Dong M. and L.Y. Su: Ontology-based product-service system configuration of mass customization. Comput. Integra. Manuf. Sys., 17, 653-661(2011).

[5] Wang P.P., X.G. Ming, Z.Y. Wu, M.K. Zheng and Z.T. Xu.

Research on industrial product–service configuration driven by value demands based on ontology modeling. Comput. Ind., 65, 247-257(2014).

[6] Wen J.H., Z. Jiang, L.Y. Tu and P. He: Task-oriented web service discovery algorithm using semantic similarity for adaptive service composition. J. Southeast Univ., 25, 468-472(2009).

[7] Tan W., X. Liu and Q.G. Xu: Adaptive organization and discovery of multi-granularity manufacturing resource in service environment. Comput. Integra. Manuf. Sys., 20, 2283-2296(2014).

[8] Guo S.S., B.G. Du, P. Zhao, X.R. Huang and Y.B. Li: Manufacturing resource combinatorial optimization for large complex equipment in group manufacturing: A cluster-based genetic algorithm. Mech. Atronics., 31: 105-115(2015).

[9] Martins M.S.R., S.C. Fuchs, L.U. Pando, R. Lüders and M.R. Delgado: PSO with path relinking for resource allocation using simulation optimization. Comput. Ind. Eng., 65, 322-330(2013).

[10] Gao X., Z.W. Liang and G.Z Xu: Service resource selection mechanism based on functional match. Chin. J. Sci. Instrum., 33, 2647 - 2653 (2012).

[11] Nie G.H., H.J. You and J. Meng: Recommendation system of digital home service resources based on association relationships. J. Wuhan Univ. Technol., 35, 445-447(2013).

[12] Gao Y.C., Y.X. Feng, J.R. Tan, H. Zheng，Z. Wei and X.H. An: research on coupled mapping and service matching technology of cloud manufacturing based on fuzzy integral. J. Comput.-aided design comput. Graph., 24, 290-298(2012).

[13] Yin C., Y. Zhang and T. Zhong: Optimization model of cloud manufacturing services resource combination for new product development. Comput. Integra. Manuf. Sys., 18, 1368-1378 (2012).

[14] Ma S.G. and J.H. Yang, Cloud manufacturing service resource combination optimization model and algorithm under group buying mode. J. Comput. Appl., 35, 2147-2152(2015).

[15] Li D.S: Research on the key issues of instant construction service supply chain in electronic commerce service platform. Shandong University (2012).

[16] Li H., Y.J. Ji, X.J. Gu, G.N. Qi and R.Z. Tang: Module partition process model and method of integrated service product. Comput. Ind., 63, 298-308 (2012).

[17] Zhao Y., X.Q. Yi and X. S. Luo: Research on a dynamic resource organization method task-oriented for the loosely could system. J. Syst. Eng. Electron., 36, 1328-1333(2014).

[18] Liu E., L. Changjun, Y. Liuting, L. Song, W. Mingchang and W. Di: Research on the optimal energy consumption of oil pipeline. J. Environ. Biol., 36, 703-711 (2015).

[19] Tang D.B., X.M. Qian and J.G. Liu: Product design and development based on the DSM, Beijing, China (2009).

[20] Tseng H.E, C.C. Chang and J.D. Li: Modular design to support green life-cycle engineering. Expert. Syst. Appl., 34, 2524-2537(2008).

[21] Kreng V.B. and T.P. Lee: Modular product design with grouping genetic algorithm-a case study. Comput. Ind. Eng., 46, 443-460(2004).

[22] Tian Xia. Life Cycle Oriented Modular Design Using Group Genetic Algorithm. Shanghai: Shanghai Jiao Tong University(2009).

Xia Xu-hui was born in 1966. He is a professor and Ph.D supervisor in Wuhan University of Science and Technology. His main research interests include manufacturing systems engineering, supply chain management, optimization and decision with application in manufacturing industry.

Xiong Ying-qing was born in 1984. She is a Ph.D candidate in Wuhan University of Science & Technology. Her main research interests is reverse supply chain management.

Wang Lei was born in 1987. She is an engineer and Ph.D candidate in Wuhan University of Science & Technology. Her main research interests include manufacturing/ remanufacturing systems engineering, reverse supply chain management, knowledge management and engineering.

Zhou Meng was born in 1990.He is a master degree candidate at Wuhan University of Scienceand Technology. His main research interests include manufacturing systems engineering, optimization and decision with application in manufacturing industry.

Yang Yi was born in 1992. He is a master degree candidate in Wuhan University of Science and Technology. His main research interests include remanufacturing systems engineering.