Analyzing Indexes of Agile Reverse logistics Using Interpretive Structural Modeling Approach

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Abstract
With development of technology and science and continuous increase in productivity, product life cycles are shortened and customer demands are more personalized and diversified, which makes companies face with ever changing and unpredictable competitive environment. Therefore, rapid response to market competition has become one of the main focuses and the competitive advantages. Today, one of the most important issues in supply chain is reverse logistics, which includes all operations related to the reuse of products and materials. The concept of reverse logistics has received growing attention in the recent decades due to a number of factors such as Competition and marketing motives, direct economic motives and concerns with the environment. Reverse logistics has become an important source of opportunity for companies to improve visibility and profitability and lower the costs across the supply chain.Environmental issues are also increasing awareness of the importance of reverse logistics. More companies are now considering reverse logistics as a strategic activity because it can create value. Since agility becomes one of the most important tools for sustainable development of companies, achieving high agility of reverse logistics enterprises is an effective means of reducing costs and better meeting consumer needs for enterprise. Therefore, constructing high agile reverse logistics systems is very necessary. The problem of how organizations can successfully deal with unpredictable, dynamic, and constantly changing environments has been a prevailing topic both in industry and academia for the last decades. This paper introduces indexes of agile reverse logistic, and then analyses the interaction between indexes by using ISM. The results were obtained through a questionnaire from the experts. The obtained results reveal that the application level of the information system of reverse logisticsandthe time of starting reverse logistics system are two undeniable needs for the agility of reverse logistics.

Keywords
Reverse logistics, Agility, Indexes of agile reverse logistics, ISM

1. Introduction

One of the most important issues in supply chain is reverse logistics. Economic benefit, environmental concerns and legal pressure are among the main reasons which led manufacturers to integrate recovery activities into their processes [1]. Reverse logistics is the process of moving products and materials from their final destination for the purpose of recapturing value or proper disposal. It refers to the set of programs aimed at moving products in the reverse direction in the supply chain [2]. It also concerns the management of product or service after the point of sale and particularly focuses on the management of returns [3].

Ever-changing customer requirements, underlying financial requirements and competitive cost pressures require firms to rapidly adjust, redesign and adapt their processes and abilities [4]. Agility defined the ease and speed with which companies can reconfigure, redesign and re-conduct their process to respond to these needs, opportunities and threats. As such, ithas become an essential capability for business organizations [5]. Agility of reverse logistics can efficiently reduce cost and meet customer's diverse needs. So, reverse logistics companies can improve reverse logistics to implement by increasing their agility of reverse logistics [6]. There are many researches available concerning reverse logistics. For example, Youngsheng and Shouyang designed reverse distribution network for the repairing and remanufacturing options [7].Korchi and Milet introduced a framework to allow generating and assessing different reverse logistics channel structures and analyzed current reverse logistics structure and proposed alternative structures with less environmental impact and higher economic benefits[8].Abdulrahman et al. identified critical barriers in implementing reverse logistics in the chines manufacturing sector[9].Donghong et al. evaluated the agility of reverse logistics systems based on neural network [6].

In this paper, indexes of agile reverse logistics were analyzed using the interpretive structural modeling (ISM) method. This paper is organized as follows. In section 2, the indexes that affected reverse logistics are expressed. In section 3, the ISM method is presented and finally the results of this research are presented, which is followed by discussion and conclusions.

2. Indexes of agile reverse logistics

Reverse logistics includes planning, implementing and controlling an efficient, cost effective flow of raw materials, in process products, finished products from consumption to retrieval, recycle or proper disposal of the products[2].

Sumbamurthy et al. defined agilityas the ability to detect opportunities for innovation and seize those competitive market opportunities by assembling requisite assets, knowledge and relationships with speed and surprise [10]. Speed and capability of the firms and companies to use resources and respond to changes are two dimensions to define agility [11]. Donghong et al.expressed the indexes of agile reverse logistics as presented in Table 1 [6].

Table 1. Indexes of agile reverse logistics[6]

First-level indexes	Second-level indexes	Third-level indexes
Indexes of agile reverse logistics	Time	1. the time of finding the chance of reverselogistics market 2. the time of reverse logistics flowing inthe system 3. the time of organizing the activity ofreverse logistics 4. the time of starting reverse logisticssystem
	Cost	5. the cost of reverse logistics research and development 6. the cost of remanufacturing recycleproducts and relative cost
	Robustness	7. the quality stability of remanufacturedproducts 8. the income stability of remanufacturedproducts creating 9. the satisfaction of customer to reverselogistics products 10. the environment stability of reverselogistics creating
	Production flexibility	11. the production ability of remanufacturedsystem 12. the management flexibility ofremanufactured system 13. the flexibility of delivery time
	Inter-organizational participation	14. the ability of cooperating with externalreverse logistics enterprises 15. the ability of communicating with external reverse logistics enterprises 16. the cooperation consciousness of the staff 17. the application level of informationsystem of reverse logistics
	Management relativity	18. the ability of enterprise innovation 19. the cooperation of inner enterprise 20. the satisfaction that staff feel to the workof reverse logistics

3. Interpretive Structural Modeling method

Jharkharia and Shankar defined ISM as “a well-established methodology for identifying relationship among specific items, which define a problem or an issue in a carefully designed pattern implying graphics as well as words”. This method is used for identifying relationships among specific items which define an issue [12].The ISM method is used foranalyzing the interrelationships between the variables influencing the system [13]. The researchers selected this approach because of its benefits. Direct and indirect relationships between variables and factors based on situations are revealed more accurately than individual factors taken in isolation [14].

The ISM method is described below (Adopted from Kannan et al.):

Step 1: Variables of the system are listed.

Step 2: From variables identified in step 1, a contextual relationship is established among variables to identify which pairs of variables should be examined.

Step 3: A structural self-interaction matrix (SSIM) is developed for variables, indicating pair-wise relationships among the variables of the system under consideration.

Step 4: Reachability matrix is developed from SSIM and the matrix is checked for transitivity. Transitivity of contextual relation is a basic assumption in ISM. It states that if variable A is related to B and B to C, then A is necessarily related to C.

Step 5: The reachability matrix obtained in step 4 is partitioned into different levels.

Step 6: Based on relationships stated in the reachability matrix, a directed graph is drawn and transitive links removed.

Step 7: The resultant digraph is converted into an ISM, by replacing variable nodes with statements.
Step 8: The ISM model developed in step 7 is checked for conceptual inconsistency and necessary modifications are made [15].
ISM starts with an identification of variables or factors, which are relevant to the problem or issue. Our study considered 20 indexes from available literature review. These factors are expressed in Table 1.
A questionnaire was developed after the objective of this study was explained to the experts. Then contextual relationships among indexes regarding were examined.
In step 3, a structural self-interaction matrix (SSIM) is developed for factors, including pair-wise relationships among indexes of system under consideration. Keeping in mind the contextual relationships for each index, the existence of a relation between any two indexes (i and j) and associated direction of the relation is questioned. Four symbols denote the direction of the relationship between indexes (i and j):
V: Practice i will help achieves practice j;
A: Practice j will help achieve practices i;
X: Practice i and j help achieve each other;
O: Practices i and j are unrelated.
The SSIM for indexes of agile reverse logistics is given in Table 2.

Table 2.The SSIM matrix

20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	Index
X	A	O	A	A	A	A	V	V	V	A	O	O	O	V	V	A	A	X	-	1
X	A	O	A	A	A	A	X	V	V	A	V	V	V	V	V	A	A	-		2
X	A	O	A	A	X	X	V	V	V	A	V	V	V	V	V	V	-			3
O	A	O	A	A	O	A	V	O	O	O	O	O	O	V	V	-				4
O	A	V	X	X	V	X	X	V	V	A	V	V	V	V	-					5
O	A	A	A	A	A	A	V	A	X	A	V	V	V	-						6
V	A	A	A	A	A	X	O	A	A	A	V	V	-							7
O	O	V	A	O	O	O	V	O	V	X	V	-								8
X	A	A	A	A	A	A	A	A	A	A	-									9
X	A	V	A	A	O	O	V	O	V	-										10
O	A	A	A	A	A	X	O	V	-											11
X	X	A	A	X	A	A	V	-												12
O	A	A	A	A	A	A	-													13
X	A	X	A	A	A	-														14
X	A	X	A	V	-															15
A	X	V	X	-																16
V	X	V	-																	17
A	A	-																		18
X	-																			19
-																				20

In the next step, a reachability matrix is developed from SSIM. The SSIM format is converted into an initial reachability matrix format by transforming information from each SSIM cell into binary digits (ones or zeros). This transformation is done with the following rules [16]:

If an entry in the cell (i, j) in SSIM is V, then cell (i, j) entry becomes 1 and cell (j, i) entry becomes 0 in the initial reach-ability matrix.

If an entry in the cell (i, j) in SSIM is A, then cell (i, j) entry becomes 0 and cell (j, i) entry becomes 1 in the initial reach-ability matrix.

If an entry in the cell (i, j) in SSIM is X, then entries in both kills (i, j) and (j, i) become 1 in the initial reachability matrix.

If an entry in the cell (i, j) in SSIM is O, then entries in both the cells (i, j) and (j, i) become 0 in the initial reachability matrix.

Following these rules, the initial reachability matrix is given in Table 3.

Table 3.Initial reach ability matrix

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

The final reachability matrix for indexes, shown in Table 4, is obtained by incorporating transitivity as enumerated in Step 4 of the ISM methodology. The final reachability matrix then consists of entries from pair-wise comparisons and some inferred entries.

Table 4**.** Final reachability matrix

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

Reachability and antecedent sets for each criterion or index was obtained from the final reachability matrix [17]. The reachability set of individual index consists of the factor itself and other indexes which help to achieve it, while its antecedent set consists of the index and other indexes which might help in achieving it [18].Then, the intersection of these sets is derived from all indexes. The index for which reachability and intersection sets are the same is made the top-level variable in the

ISM hierarchy. After the identification of top-level elements, they are discarded from other remaining indexes[19].

In this paper, 20 indexes with their reachability set, antecedent set, intersection set, and levels are given in Table 5. The level partition of 25 practices was iterated in six levels.

Table 5.Level position for indexes

Index	Reachability set	Antecedent set	Intersection set	Level
1	1,2,3,5,6,7,…, 20	1,2,3,4,5,7,…,17,19,20	1,2,3,4,5,7,…,17,19,20	3
2	1,2,3,5,6,7,…, 20	1,2,3,4,5,7,…,20	1,2,3,4,5,7,…,20	2
3	1,2,3,…., 20	1,2,3,5,7,8,9,10,11,12,14,…,20	1,2,3,5,7,8,9,10,11,12,14,…,20	4
4	1,2,4,5,6,7,8,9,11,…,20	3,4,5,7,10,11,12,14,…,20	4,5,7,11,12,14,15,16,17,18,20	6
5	1,2,3,…,20	1,2,3,4,5,7,8,10,…,20	1,2,3,4,5,7,8,10,11,12,14,…,20	3
6	6,7,…16,18,20	1,…,8,10,11,…,20	6,7,8,10,11,12,14,15,18,20	2
7	1,2,3,…, 16,18,19,20	1,…,8,10,11,…,20	1,…,8,10,11,12,14,15,17,18,19,20	2
8	1,2,3,5,…,15,,18,20	1,2,3,4,5,6,7,8,10,…,20	1,2,3,5,6,7,8,10,11,12,14,15,18,20	2
9	1,2,3,9,10,12,14,15,16,18,20	1,2,…,20	1,2,3,9,10,12,14,15,16,18,19,20	1
10	1,2,3,…,20	1,2,3,5,6,7,8,10,…,20	1,2,3,5,6,7,8,9,10,12,14,15,16,17,19,20	5
11	1,2,…,11,12,13,14,16,18,19,20	1,2,3,4,5,6,7,8,10,…,20	1,…,8,11,12,13,14,16,18,19,20	2
12	1,2,3,…, 20	1,2,3,…, 20	1,2,3,…, 20	1
13	1,2,5,6,7,8,9,11,…,18,20	1,2,3,4,5,6,7,8,10,…,20	1,2,5,6,7,8,11,…,18,20	2
14	1,2,3,…,20	1,2,3,…, 20	1,2,3,…, 20	1
15	1,2,3,…,20	1,…,10,12,…,20	1,…,10,12,…,20	2
16	1,2,3,…,20	1,2,3,4,5,7,9,…,20	1,2,3,4,5,7,9,…,20	3
17	1,2,3,…,20	1,2,3,4,5,10,12,…,17,19,20	1,2,3,4,5,10,12,…,17,19,20	6
18	2,…,9,11,…,16,18,19,20	1,2,…,20	2,…,9,11,…,16,18,19,20	1
19	1,2,3,…,20	1,2,3,5,7,9,10,11,12,14,…,20	1,2,3,5,7,9,10,11,12,14,…,20	5
20	1,2,3,…,20	1,2,…,20	1,2,…,20	1

From the final reachability matrix, a structural model is generated and given in Figure. 1. The relationship between indexes j and i is shown by an arrow pointing from i to j. The resulting graph is called a digraph. Removing transitivity as described in the ISM methodology, the digraph is finally converted into an ISM model for indexes of agile reverse logistics.

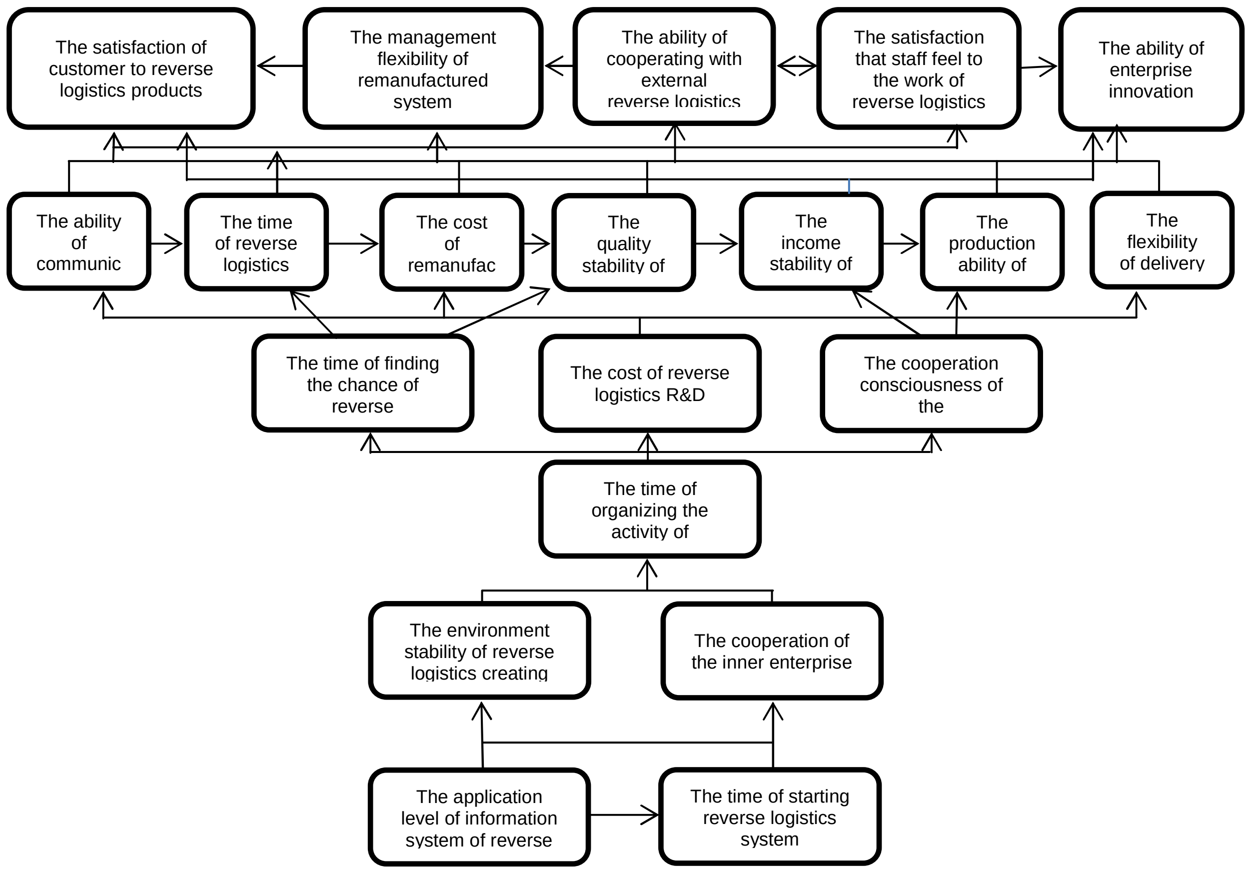

Figure 1.The ISM model

Matriced Impacts ‘croises-multipication applique’ and class-ment (cross-impact matrix multiplication applied to classification) is abbreviated as MICMAC. The MICMAC principle is based on the multiplication properties of matrices [15]. MICMAC is a graphic representation of enablers in four clusters, namely: Independent, Linkage, Autonomous, and Dependent. This is done to identify the key enablers that drive the system in various categories. Based on the driving and dependence powers, the enablers in the present case are classified into four categories as follows [15].

1. Autonomous Quadrant: This Quadrant has weak driving power and weak dependence. They are relatively disconnected from the system, with which they have few links. The links may be very strong. This is represented in Quadrant-I.
2. Dependent Quadrant: This category includes enablers which have weak driving power, but strong dependence power. They are placed in Quadrant-II.
3. Linkage Quadrant: These have strong driving power and dependence power and are placed in Quadrant-III. They are unstable and so action on them will affect others and include a feedback effect on them.
4. Independent Quadrant: These have strong driving power but weak dependence power and are represented in Quadrant-IV. It is observed that a variable with a very strong driving power, called a key variable, falls in the category of independent or linkage criteria. The driver power and dependence power of each of these indexes are shown in Figure. 2.

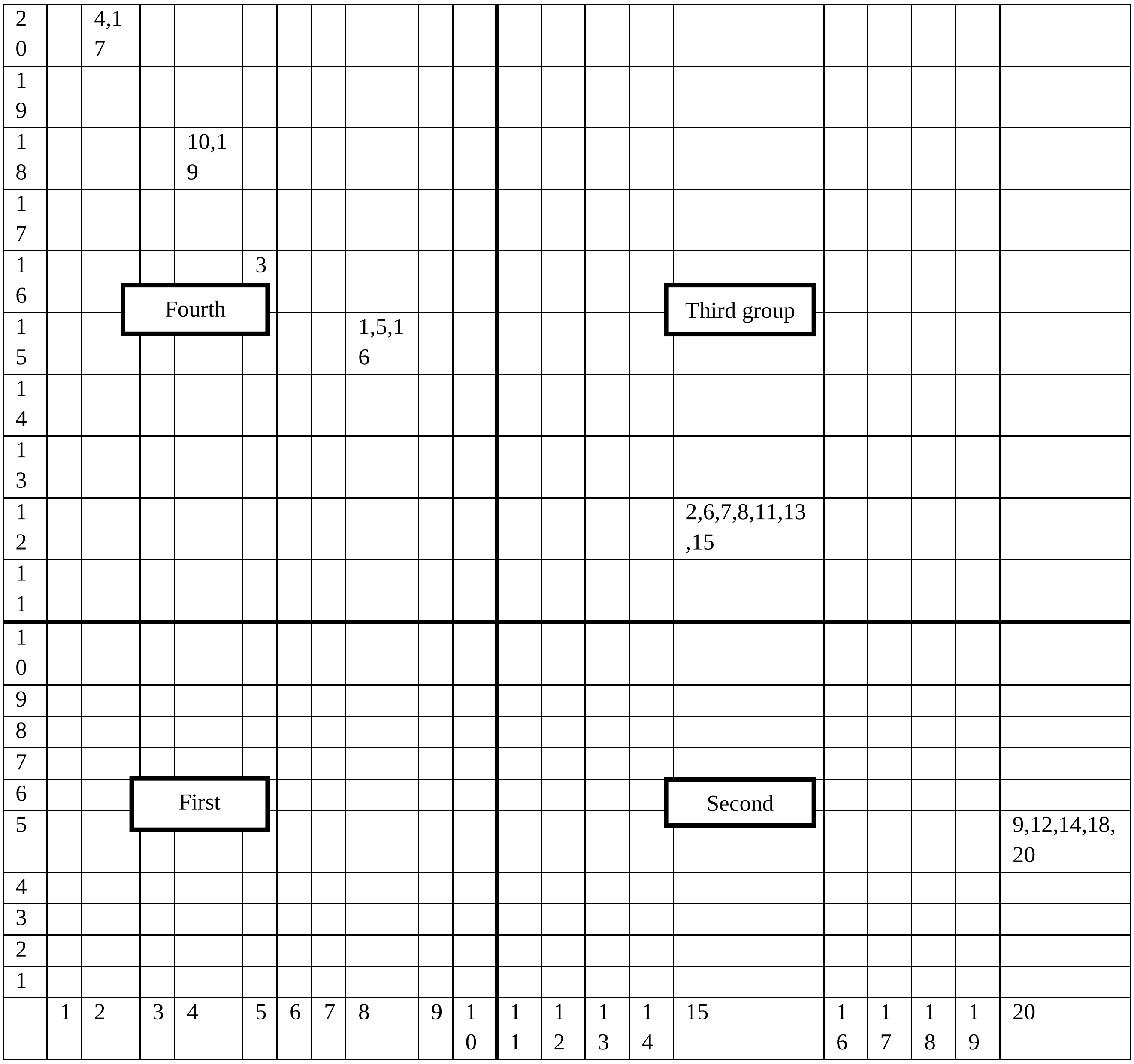

Figure 2. Driving power and dependence power diagram

4. Results and discussion

Reverse logistics refers to the activities involved in product returns, source reduction, conservation, recycling, substitution, disposal, refurbishment, reuse, remanufacturing and repair. Agility is the ability to detect opportunities for innovation and seize competitive market opportunities by assembling requisite assets, knowledge, and relationships with speed and surprise. Due to the importance of reverse logistics and agility, the main purpose of this study is surveying agile indexes that affected reverse logistics.

Result of the ISM method shows that the application level of the information system of reverse logistics and the time of starting reverse logistics indexes are the main indexes for the agility of reverse logistics.

Furthermore, results show indexes of the time of finding the chance of reverse logistics market, the time of organizing the activity of reverse logistics, the time of starting reverse logistics system, the cost of reverse logistics research and development, the environment stability of reverse logistics creating, the cooperation consciousness of the staff, the application level of the information system of reverse logistics and the cooperation of inner enterprise have strong driving power but weak dependence power.

5. Conclusions

Indexes of the time of reverse logistics flowing in the system, the cost of remanufacturing recycle products and relative cost, the quality stability of remanufactured products,the production ability of remanufactured system, the flexibility of delivery time, the ability of communicating with external reverse logistics enterpriseshave strong driving power and dependence power. These indexes are unstable and so will affect others and include a feedback effect on them.

Indexes of the satisfaction of customer to reverse logistics products, the management flexibility of remanufactured system, the ability of cooperating with external reverse logistics enterprises, the ability of enterprise innovation, the satisfaction that staff feel to the work of reverse logistics have weak driving power, but strong dependence power.

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