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MULTI-CRITERIA DECISION MAKING FOR REVERSE LOGISTIC CONTRACTOR SELECTION IN E-WASTE RECYCLING INDUSTRY USING POLYTOMOUS RASCH MODEL

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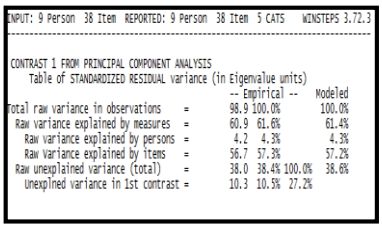
Graphical abstract



Abstract

E-waste recycling is a growing sector in the reverse supply chain and the main purpose of recycling is to recover precious materials making these recycling activities economically interesting. To increase vibrancy of this activity, third party logistic (3PLs) are used to carry out most of the logistic functions that contribute to the competitive advantages. Thus, this study attempts to ascertain the attributes that influence the selection and evaluation of 3PLs the most. Survey based approach were carried out on experts from recycling companies in Malaysia via questionnaire, the results were evaluated using rasch model analysis for evaluating and prioritizing the attributes according to the scores. Previous studies have proposed their multiple dimensions and criterias for selection on 3PLs with different types of industries and methods. The criterias play a vital role in the selection of the best on 3PLs . There are 10 criterias with 38 sub-items were identified and constructed used in screening the best reverse logistic contractor. The results shows that organisation role attribute is the most critical attributes that must be considered. The results of this study are usefull in focusing on several vital attributes for selecting the best 3PLs provider that can intensify total firm performance.

Keywords: Reverse supply chain; reverse logistic; third party logistic; rasch model; e-waste, decision making

Abstrak

Kitar semula *E-waste* merupakan sektor yang semakin berkembang didalam rantaian bekalan berbalik dan tujuan utama kitar semula adalah untuk mengembalikan semula komponen-komponen berharga yang memberi manfaat ekonomi yang menarik untuk dipelopori. Bagi meningkatkan kerancakan aktiviti ini, parti-ketiga logistik (3PLs) digunakan untuk menjalankan sebahagian besar daripada fungsi logistik berbalik yang menyumbang kelebihan berdaya-saing. Maka, kajian ini digunakan dalam mengenalpasti kriteria-kriteria yang paling mempengaruhi pemilihan dan penilaian 3PLs. Pendekatan kajian kaji selidik telah dijalankan ke atas pakar-pakar daripada syarikat-syarikat kitar semula di Malaysia melalui pengedaran soal selidik, dan hasil keputusan dianalisis menggunakan Model Rasch dalam menilai dan menyusun kriteria-kriteria tersebut mengikut skor yang diperolehi. Kajian terdahulu telah mencadangkan pelbagai dimensi dan kriteria mereka untuk pemilihan pada 3PLs dengan pelbagai jenis industri dan metodologi berbeza-beza. Kriteria tersebut memainkan peranan yang penting dalam pemilihan terbaik 3PLs. Terdapat 10 kriteria dengan 38 sub-item telah dikenalpasti dan dibangunkan dalam penilaian kontraktor logistik berbalik yang terbaik. Keputusan menunjukkan dimensi peranan organisasi adalah kriteria yang paling berpengaruh yang perlu dipertimbangkan. Keputusan kajian ini berguna dalam

memberi tumpuan kepada beberapa ciri-ciri penting untuk pemilihan pembekal 3PLs terbaik yang berupaya mempertingkatkan prestasi firma secara menyeluruh.

Kata kunci: Rantaian bekalan berbalik; logistik berbalik; parti-ketiga logistik; model rasch; *e-waste*; pembuatan keputusan.

1.0 INTRODUCTION

The production of electrical and electronic equipments is one of the global rapid businesses entity due to technological innovation, market acceleration and penetration, which contribute a significant impact on generation of e-waste volumes that influences the environmental obstacles [1]. E-waste has garnered a great attention because of its alarming increment as well as emerging environmental problems. It could threaten human's health and the environment if not managed properly. Therefore, the reverse logistics of e-waste is a brilliant solution to minimise its negative effects [2]. Product recovery reduces environmental effects while firms can recover precious or valuable substances by recycling the components [3].

The negative impact of e-waste can be minimised by using reverse supply chains to increase or recover useful residual waste. The reverse supply chain can be explained as a process by which a manufacturer systematically accepts previously used products or parts with the options of reuse, remanufacturing, recycling or disposal [4]. Reverse logistics is a process of planning, implementing, and controlling the efficient, cost-effective flow of raw materials, in-process inventory, finished goods, and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal [5].

The reverse supply chain presents interesting potential for cost savings related to reduce resource consumption and product reuse after the product has reached its end of life [6]. Firms held more interest in funding disposable activities such as investing resources in appropriate storing, dumping and treatment of waste, where engaging the service of third party service provider is the current approach for handling waste [7].

In the current study, clarify reverse logistics as a relatively new topic and it is in the exploration stage. A complete supply chain should include both forward logistics and reverse logistics. Forward logistics operations also influenced the reverse logistics activities and thus it plays a vital role for success implementation. Several forces drive reverse logistics, such as competition and marketing motives, direct economic motives and reverse logistics has an significant environmental dimensions as well as dimensions relating to value reclamation [8].

Reverse logistics is adopted in many types of industries which very effective to leverage in all streams of opportunities that involved in many situations for the product to be located in a reverse flow [9]. To be precise, reverse logistics in e-waste also involves material recovery since its contains precious metals. Reverse logistics networks may be done by the producer themselves but also adopted other recovery options such as the used of third party providers. Existing research recognizes the critical role played by third party enables the manufacturer to focus on their main core competencies activities such as producing goods but the producer may not have control over the costs [2].

It has been reported that most of the companies currently engaged in manufacturing and marketing of products have been establishing reverse logistics in their supply chain planning as an initiative of complying with environmental regulations as well as economic gains from the recycling activities. It is believed that successful implementation in reverse logistic programme must take into account of product recovery and product returned channel. Since it is very difficult to estimate the quantity and quality of returned products, the most suitable recovery option would be a third party reverse logistic (3PLs) provider [10].

The integration of forward and backward flows of both materials and information is essential to the success of reverse logistics implementation [11]. Sytematically managing of product return channel will enhance the customer satisfaction. Since managing returns require specialized arrangement and data tracking systems, 3PLs providers are preferred option. It is thought that by implementing 3PLs in the reverse logistic programmes, the firms improve the core competencies while reducing operation challenges [8].

To encourage sustainability efforts, firms may apply outsourcing for several reverse logistic activities to 3PLs provider. It is interesting to note that in terms of product returns management, many companies are outsourcing the reverse logistic activities to preserve the intrinsic of the returning products in the fastest way possible so that restoration can be made at the shortest time possible in order to increase customer satisfaction [12]. Firms are raising the demand of outsourcing of non-core activities due to the increasing forces of competition that necessitate them to concentrate on their core business [13].

In the past, 3PLs service offerings limited scope and insufficient number of services. However, the number of services is thriving today indicating the importance to remain in current market competitive. The increase of the services consequenced of the demands in outsourcing, that contribute to the total changes to the

3PLs role in the supply chain management. The different from traditional functions evolve from only conducting transportation services to a fully integrated, value added services and worldwide services in the customers' logistics functions which may combined services such as warehousing, inventory management, packaging, technology management and larger logistic functionality [14]. Based on the above literatures, it is quite clear that by implementing 3PLs brings advantages not solely in cost reduction but also improve the efficiency and integration of firms's operations and services.

As a significant impact of demand in reverse logistic services, this study suggests a strategic approach to implement the best practice by implementing outsourcing reverse logisctic contractors to carry out a holistic logistic functions as strategies to reduce operation costs and risks. Recently, researchers have shown an increased interest in implementing 3PLs and suggested attributes for decision making selection [8][14][15]. There are a lot of dimensions that has been suggested by researchers to a specific industry. The presence of multiple attributes and the diversity of opinions needs to be refined to adapt to our objective according to e-waste industry. Thus, 10 attributes have been identified and proposed for this methodology.

A primary concern of this paper is to evaluating and selecting the best reverse logistic contractor which meet the criterias required by the company. Rasch model is used to evaluating the attributes and apply statistical analysis to investigate the impact of attributes that significantly influenced the selection of reverse logistic contractor. The most obvious finding to emerge from this method is that systematically prioritise the attributes and sub-attributes according to its score that shown in Figure 2 and Figure 4. In addition, the study also highlight the sub-attributes that should be taken into account and eliminates the sub-attributes that does not bring any impact in the next selection.

2.0 METHODOLOGY

Rasch Model is one of the method for decision making that offers advantages to analyse multiple attributes and sub-attributes and capable of transforming qualitative issues into quantitative issues representation. Thus, for this study, Rasch Model is used to construct decision making framework by analysing the attributes that most influence the selection and evaluation of 3PLs provider in reverse supply chain e-waste's recycling in Malaysia.

Table 1 Attributes and sub-attributes adopted from [8] [15] [17]

Notation	Item attributes	Sub-item attributes (Question)
OPC/OPF	Organizational Performance Criteria	Time(1), cost(2), flexibility(3), quality (4), customer satisfaction (5)
RPF	Reverse logistics process functions	Collection(6), packing (7), storage (8), sorting (9), transitional process (10), delivery (11)
E	Experience	Performance history (12)
EA	Enterprise alliance	Sharing of benefits and risks (13), enterprise culture (14)
OR	Organizational Role of Reverse Logistics	Reclaim (15), recycle (16), remanufacture (17), reuse (18), take back disposal (19)
RC	Resources Capacity	Financial capacity to invest (20) , level of advanced (21), equipment (22), network capacity (23), transport capacity (24)
QS	Quality of Service	Timeliness of service (25), personalized service (26), ability to deal with problems (27)
L	Location	familiar the area (28), geographical location (29), cultural fit (30), human resources (31)
CS	Communication Systems	EDI capacity (32), IT level (33)
LS	Logistic Services	Inventory peplenishment (34), warehouse management (35), shipment consolidation (36), carrier selection (37), direct transportation (38)

The survey questions with multiple response yielding to polytomous data. The polytomous nature of the data requires a more general form of the Rasch model. A more general Rasch model is available when data are not dichotomous and instead have multiple response options. The polytomous Rasch models also serve as the basis for other polytomous models [16].

The study uses qualitative analysis in order to gain insights of ordinal data into systematic decision making. The design of the questionnaires was based on five-point Likert scale which indicates from 'no influence' to 'highly influence'. By collecting the expert's opinion through Likert scale of the 10 attributes with regard in this study, polytomous Rasch data is simulated using the

(Winsteps) software applied to study the correlation for ordinal data because it offers more flexibility.

The 10 attributes contains with 38 sub-attributes is shown in Table 1 that is adopted from previous research [8] [15] [17].

The advantage of using these method is can be used to examine whether items measure an uni-dimensional construct, a particular aspect of both classical and modern measurement statistics. Items that show poor fit to the Rasch model might be considered for abolition [18]. Next, based on the scores obtained from the survey are analyze into the * .prn file. To measure measure the probability of respondents for polytomous scale that involve linear function for latent trait respondent as Eq.1 where *P* is the propability, *n* is responden and α_n is responden ability and β_{id} is item difficulty. The result of Rasch model is explained by the person-item variables map and causal relation diagram.

$$\ln \frac{P_{nid}}{(d-1)P_{ni}} = \alpha_n - \beta_{id} \quad (1)$$

3.0 RESULTS AND DISCUSSION

The statistic summary of the overall results for 9 experts and 38-Item construct for Polytomous Rasch Model are presented in Figure 1. The study was conducted via questionnaire of 38 questions developed to determine the selection of sub-contractors reverse logistics or 3PLs where experts were asked to indicate the degree of influence according to 5-point Likert Scale. What is interesting in this data is that the value of Cronbach-alpha (a) indicates the minimum test score reliability and the reliability of Item, 0.90 (Item Reliability) shows the adequacy of items measured as ordinal.

```
-------------------------------------------------------------------------------
|          TOTAL                         MODEL         INFIT        OUTFIT     |
|          SCORE      COUNT    MEASURE   ERROR      MNSQ  ZSTD   MNSQ  ZSTD   |
|------------------------------------------------------------------------------|
| MEAN     139.7      38.0       1.63     .26        .99   -.1   1.00    .0   |
| S.D.       7.9        .0        .52     .00        .32   1.3    .35   1.3   |
| MAX.     146.0      38.0       2.06     .27       1.71   2.6   1.81   2.9   |
| MIN.     119.0      38.0        .26     .26        .68  -1.5    .67  -1.5   |
|------------------------------------------------------------------------------|
| REAL RMSE    .28 TRUE SD     .44  SEPARATION  1.60  Person RELIABILITY  .72 |
|MODEL RMSE    .26 TRUE SD     .45  SEPARATION  1.73  Person RELIABILITY  .75 |
| S.E. OF Person MEAN = .19                                                    |
-------------------------------------------------------------------------------
Person RAW SCORE-TO-MEASURE CORRELATION = 1.00
CRONBACH ALPHA (KR-20) Person RAW SCORE "TEST" RELIABILITY = .76

     SUMMARY OF 38 MEASURED Item
-------------------------------------------------------------------------------
|          TOTAL                         MODEL         INFIT        OUTFIT     |
|          SCORE      COUNT    MEASURE   ERROR      MNSQ  ZSTD   MNSQ  ZSTD   |
|------------------------------------------------------------------------------|
| MEAN      33.1       9.0        .00     .55       1.00    .0   1.00    .1   |
| S.D.       6.8        .0       1.92     .11        .37    .9    .37    .9   |
| MAX.      44.0       9.0       5.31    1.06       2.09   2.2   2.03   2.1   |
| MIN.      13.0       9.0      -3.98     .48        .32  -2.0    .32  -2.0   |
|------------------------------------------------------------------------------|
| REAL RMSE    .61 TRUE SD    1.82  SEPARATION  3.01  Item   RELIABILITY  .90 |
|MODEL RMSE    .56 TRUE SD    1.83  SEPARATION  3.25  Item   RELIABILITY  .91 |
| S.E. OF Item MEAN = .32                                                      |
-------------------------------------------------------------------------------
UMEAN=.0000 USCALE=1.0000
Item RAW SCORE-TO-MEASURE CORRELATION = -.99
342 DATA POINTS. LOG-LIKELIHOOD CHI-SQUARE: 619.97 with 293 d.f. p=.0000
Global Root-Mean-Square Residual (excluding extreme scores): .6171
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Figure 1 Summary Statistic of 38 Items

Table 2 Iteration, item difficulty calibration and item total correlation

Iteration	Item (*)	Measure	Model SE	Infit		Item-Total Correlation
				MNSQ	z-std	
1	*18	5.31	0.58	1.00	0.20	-0.48
2	*30	3.99	0.48	1.23	0.70	-0.33
3	*1	1.16	0.53	1.28	0.70	-0.30
4	*22	-0.44	0.51	0.44	-1.50	-0.29
5	*27	-0.18	-0.51	1.21	0.60	-0.27
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.
34	*16	-3.98	1.06	1.13	0.40	-0.15
35	*12	-3.16	0.79	0.72	-0.30	0.83
36	*20	-0.71	0.52	0.73	-0.60	0.64
37	*7	-1.54	0.55	0.68	-0.70	0.85
38	*24	-3.16	0.79	1.45	0.80	0.93

Next, this study reveal the results of the Item iteration, Item difficulty and Item total correlation in Table 2. The outcomes of this study show, all 34 items met criteria for acceptable rating scale functioning while four items failed to demonstrate acceptable item according to its fitness while the remaining 34 items demonstrated acceptable excellent item fitness. So far, 4 item or sub-attributes such as (3,7, 20, 22) have been identified as being potentially excluded from next study because does not met the criteria.

Evaluation of Item Fit is done by determine the value of Item mean square (MNSQ) where MNSQ is used in

determining the ratio of observation over expectation. This description refers to the observation that meet expectations, then the ideal MNSQ value equals to 1. MNSQ is considered out of specification when the total of Infit Mean equals to (+/-) Standard Deviation is out of this range, 1.00 + (-) 0.37= 1.37 logit (0.50). Thus, Infit MNSQ range is 0.50-1.37 logit.

The firms may use this techniques to shortlisted the sub-attributes that are more significant to the next evaluation of reverse logistic contractors. The next step followed by construct the logit scale for variables (Person and Item) with the Person maximum (max) +2.06 and minimum (min) +0.26, while Item max +5.31 and Item min -3.98. The steps was carried out to build a variables map as shown in Figure 2. In general, these results show that sub-attributes (18) for remanufacture from the attribute of Organisation Role (OR) is a sub-item that ranked highest for 3PLs selection.

Figure 2 shows a map of the variables for the selection criterion in 3PLs which Person is refer to experts who answered the survey questions and Item is the attributes that constructed in the survey question. This study focuses on the Item performance scores that perceived for main consideration in the selection of sub-contractors in e-waste recycling. In addition, these map indicates the level of difficulties of each attributes. Item that locates at the bottom considered as an easy tasks where it does not needs special attention while the item that has been increasing to the top should be given a specific emphasis in decision making in selecting the best sub-contractors in reverse logistics. The use of logit designed to classify items according to the degree of difficulty, Item a can be classified as unchallenging attributes or easy items and Item β classified as difficult or complex attributes. The measurement scale used is as follows; Person scale, 2.06 +0.26 =2.32 and Item scale, 5.31+ 3.98= 9.29 according to the case logit Person length is less than the Item.

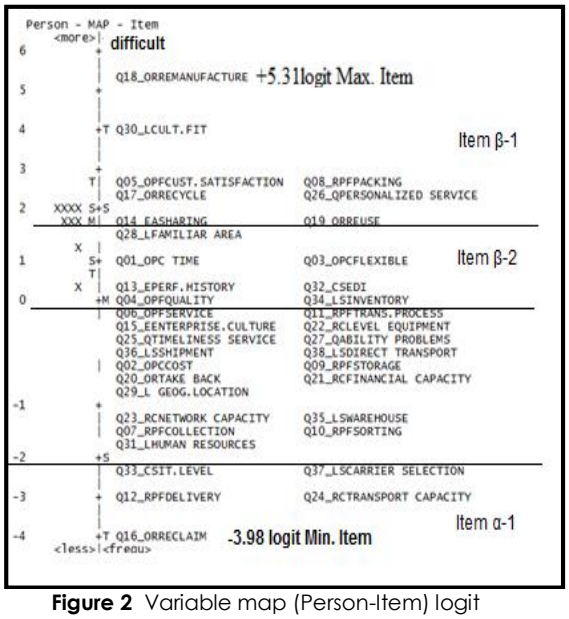

Figure 2 Variable map (Person-Item) logit

In the selection of 3PLs, as can be seen in Figure 2, reveals that a group of Item (18, 30, 5, 8, 17, and 26, 14, 19) are very complicated sub-attributes, otherwise Item 16 demonstrates an easy sub-attributes where playing unsignificant role in the selection. The most clinically relevant finding was Item 18 for remanufacture sub-attribute that representing organisation role (OR) group and Item 30 for cultural fit that representing location (L) group are the two items that showed the highest interest for selecting variables in 3PLs.

An unidimensionality is an important aspect in determining the Rasch measurement instrument development. Development of obscure instruments produce misleading aspects measured. Thus, this analysis requires a minimum score of 40% raw variance explained by measures, 60% as a good indicator measuring instruments and unexplained variance in 1st contrast does not exceed 15% of controls. Figure 3, show the standard residual variance and the results indicate in this study, 61.6% of raw variance explained by measures and 10.5% of unexplained variance in 1st contrast shows the excellent performance of the instruments study.

INPUT: 9 Person 38 Item REPORTED: 9 Person 38 Item 5 CATS WINSTEPS 3.72.3

CONTRAST 1 FROM PRINCIPAL COMPONENT ANALYSIS
Table of STANDARDIZED RESIDUAL variance (in Eigenvalue units)

		-- Empirical --		Modeled
Total raw variance in observations	=	98.9 100.0%		100.0%
Raw variance explained by measures	=	60.9 61.6%		61.4%
Raw variance explained by persons	=	4.2 4.3%		4.3%
Raw Variance explained by items	=	56.7 57.3%		57.2%
Raw unexplained variance (total)	=	38.0 38.4%	100.0%	38.6%
Unexplned variance in 1st contrast	=	10.3 10.5%	27.2%	

Figure 3 Standard residual variance (Eigenvalue unit)

This study shows that, Rasch model is able to arranged the priority of each criterions according to the score obtained. This systematic approach of decision making of selection 3PLs, identified sub-attribute of Item 18 (remanufacture) that representing organisation role (OR) group or dimension is viewed as critical attributes for the selection.

For the clear understanding of the causal relationship, each attributes according to their homogeneous group are reconstructed and formed into variaple maps (person-item) to separate and uniformly distributed the sub-attributes into their main attributes in Figure 4. This map has found that generally OR attribute dominated of overall for the most important attribute that must be considered for the selection of contractors in reverse logistics, where there are 3 sub-items showed scores above of an average logit Item. Communication System (CS) and Logistic Service (LS) attributes, the dimension of these attributes are found as easier than the dimension of OR and L. These findings may help us

to understand on particular attributes that should be emphasize and the firms that engaged in e-waste recycling managed to pick the best 3PLs based on the current needs.

Based on the Figure 4, it shows 10 item categories that represents main attributes in selecting the best reverse logistics contractor which involves OPC (Organizational Performance Criteria), RPF (Reverse Logistics Process Functions), E (Experience), EA (Enterprise Alliance), OR (Organizational Role of Reverse Logistics), RC (Resources Capacity), QS (Quality of Service), L (Location), CS (Communication Systems) and LS (Logistic Services). From the previous study for 3PLs evaluation in different types of industries shows a different results. In the case studies of plastic recycling industries, RPF and RC are the most significant attributes [8] while in the tire recycling, the results shows OPC is a very significant attribute in selecting the 3PLs [15]. Although, the results of 3PLs selection in recycling an e-waste differ from some published studies [8] [15], where OR group is found as the most importance attributes in the selection of 3PLs. These results are likely to be related to the current needs of the specific industries itself. Therefore, it can be concluded that, the selection of 3PLs is strongly believe depends on the type of the industries.

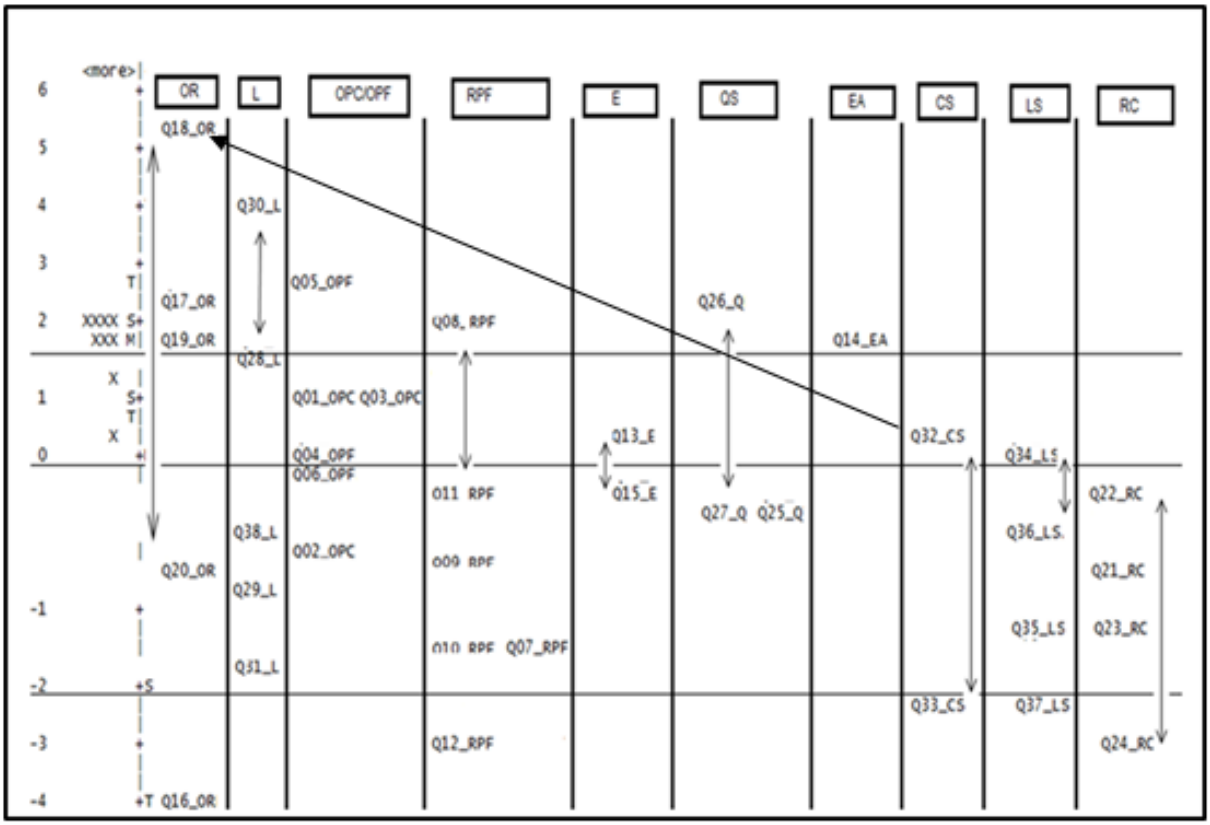

Figure 4 Reconstructed variable Person-item map

4.0 CONCLUSION

This study set out to determine the critical attributes to select reverse logistic contractor in e-waste industry in Malaysia perspectives. The findings of this research provide insights for systematic decision making approach by using Rasch Model Measurement. The results of this investigation show that sub-attributes of Remanufacture from Organisation Role (OR) attribute and cultural fit that representing location (L) attribute are the two items that showed the highest interest for selecting variables in 3PLs. As a broad perspective, the findings of this study suggest that in the framework of decision making, firm needs to initially emphasize more on OR attribute because its dominated of overall for the most important attribute that shown in reconstructed variable Person-item map. In order to improve compentency and efficiency for retrieving economic benefits from e-waste recycling, firms are realize to incorporated reverse logistic with third party logistic that offer significant impact to increase logistic operations, product return channel distributions, and customer satisfaction. Thus, this study helps the top management for making decision systematically and respond to the current needs for 3PLs provider. Finally, a key strength of the present study was easy to implements and review the finding of expert's opinions accurately and consicely.

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