Barriers of Reverse Logistics Implementation: A Case Study in a Car Battery Industry in Indonesia

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***Abstract*— There is a kindly new concept in logistics that related to the reusing, remanufacturing, and refurbishing of products, announced as reverse logistic (RL). While conventional or forward logistics is defined as the process of moving goods from the point of origin to the point of consumption, RL is defined contrarily. It allows the return of the products to be recycled, reworked, reused, or crushed for disposal. It has been growing out worldwide, affecting all the levels of supply chains in various industry sectors since the best RL operations would lead to higher sales revenue and reduced costs. However, regardless of its benefits, there are some barriers of the RL implementation, especially in the developing countries. The objective of this research is to identify the barriers of RL implementation in a car battery industry in Indonesia and study the interaction among those barriers to find the "the root barrier" using interpretative structural modelling. These barriers are then further analysed using MICMAC analysis to look for the priority of the strategy to manage the barriers. The finding could help the managers to generate some policies toward the RL implementation.**

***Keywords*—** *barriers, interpretative structural modelling, MICMAC analysis, reverse logistics*

1. Introduction

Reverse logistics (RL) has received a great deal of attention from operations managers to company executives. It can be defined as the 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 [1]. It is a process of reverse distribution (i.e., from the customers to the manufacturers) that causes the flow of goods and information flows in the opposite direction from the conventional forward logistics. It then allows the return of the products to be recycled, reworked, reused, or crushed for disposal.

The concept of RL has received considerable attention due to a number of factors, such as competition and marketing motives, direct economic motives, as well as concerns towards the environment. A good RL operation then would lead to higher sales revenues and reduced operational costs as well as boost the high level of customer satisfaction [2]. Other benefits that can be mentioned are efficient resource utilization and environmental protection [3], [4]. Besides, legislations and directives, as well as consumer awareness and social responsibilities towards the environment, are also the drivers for RL [5].

However, despite its benefits of implementation, there are some risky endeavours for the top management as it involves financial and operational aspects, which determine the performance of the company in the long run. The process of RL costs quite a lot; it costs up to five times greater than the cost of forward logistics [6]. In addition, the returned goods could pile up in the warehouse [7].

Interestingly, most of the prior research on the barriers of RL implementation are concentrated in developed countries, with relatively little attention being devoted to developing countries (e.g., [8], [9]). That few RL studies focused on developing countries is hardly surprising since the RL is a mandatory part of a supply chain in developed countries, yet, it is still in its infancy state in developing countries [10], [11]. This motivated us to

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look into the issues related to RL implementation in a developing country, specifically in manufacturing sectors.

The object of this research is lead acid battery manufacturers. The lead acid batteries come in many sizes and types. Most common are wet cell batteries used in cars, trucks, boats and many types of powered equipment. It is made of sheets of tin were immersed by the sulphuric acid solution. Usually the whole of the components integrated into a plastic box frame as “house of battery” made of polypropylene or polyethylene, with the average composition at a battery is about 80% of lead, about 8% of plastic, and about 12% of H_2SO_4 [12].

Lead acid batteries may be recharged after the stored energy has been used. Because of these degradation processes, batteries become unusable and are then known as used lead acid batteries (ULABs), and are waste. The ULABs are classified as hazardous waste under the Hazardous Waste Act 1989 and should not be disposed of with the regular trash. In addition, in Indonesian government regulation (in Bahasa Indonesia it is called PP) No. 18/1999 in conjunction with PP 85/1999, states that the waste of wet cell batteries included in the hazardous and toxic waste from the specific source. The disposal of ULABs can result in contamination of the environment, such as pollution of soil and groundwater caused by an electrolyte solution and heavy metals contained in the battery as Pb (or lead) that could endanger the health of humans and other living things [13]. However, the ULABs can be recycled that makes it an effective method to avoid pollution of the environment and reduce the ULABs generation in the final disposal [14]. Excitingly, in the United States, nearly 90% of the lead acid batteries are recycled, making them the most recycle products. The ULABs are recycled by separating the battery into its three main components. The polypropylene plastic is reprocessed into new battery cases. Its lead pieces are cleaned and reprocessed to be used in a new battery. The acid is either neutralized then sent through a waste water treatment plant to be cleaned or it is converted into sulphate that is used in laundry detergent.

Although the ULABs can be recycled to reduce the environmental impact, its practice is still limited in Indonesia. The proper management, i.e., the RL, is needed to enhance the effectivity of the recycling process of the ULABs. As mentioned above, the implementation of RL is not free from barriers (e.g., are lack of systems, competitive issues, financial resources, and personnel resources). The barriers not only affect the operations of RL but also influence one another. Therefore, it is essential to understand the mutual relationship among them. The identification of the “root barrier” and those which are most influenced by others, would be helpful for the management to implement the RL programs. This can be a guidance for taking a proper action to tackle barriers in RL implementation.

The objectives of the research are threefold. The first is to identify the barriers of RL implementation in a car battery industry, which produces lead acid batteries. It used literature review as well as a deep interview that employs the panel expert to discuss the barriers hindering the implementation of RL. The second is to discover the interaction among the barriers and the root barrier of the RL implementation. This can be analysed using interpretative structural modelling (ISM), which can show the interrelationships of the barriers and their levels. The last is to map the barriers in the driver-dependence diagram using MICMAC analysis.

2. Research Design

2.1. Barriers of reverse logistics implementation

To identify the barriers of RL implementation in a car battery industry, the literature review was performed. It was done through searching some research articles related to RL implementation (e.g., [1], [5], [8], [15]–[18]). The barriers obtained from the previous step are needed to be refined further due to the different location, condition, and situation of the research articles and object of the research. The barriers are described as follows.

(a) Lack of awareness about reverse logistics practice

Many manufacturing operations managers in Indonesia believe that RL is not a major concern for their companies. It also appears that it is unrealistic to support a large investment in setting up an infrastructure for RL. One reason which was mentioned in the interview is that they face difficulty in justifying the cost associated with RL system. The managers seem that they do not aware about the benefits which can be gained from implementing the RL. However, in some developed countries, many companies have achieved some great advantages in implementing the RL. Xerox, for example, a major manufacturer of copy machines, reported on annual savings of more than a few hundred million dollars because of remanufacturing and reuse of equipment and parts, whereas simultaneously diverting more than fifty thousand tons of material from the waste stream. If the car battery company could gather the ULABs from the point of consumption to be remanufactured, it possibly will both generate income for the firm and lead to direct benefits to the environment.

(b) Company policies

The second barrier that prevents RL from operating effectively and efficiently is the policies of the manufacturers, especially in handling product returns. Most returns are crushed, destroyed, or dumped in the garbage. It is seldom that the returns are remanufactured by the original company, recycled by other company, or reused for other purposes. A survey by [19] stated that more than one-third from more than 150 respondents who are managers with RL responsibilities believe that company policies negatively affect their RL management. In Indonesia, only a few companies implement RL due to a little—or even no—pressure from the government. Some examples of the company which operates RL practice are PT. Pertamina (Persero) for a tube of liquefied petroleum gas, PT. Tirta Investama for a gallon of mineral water, and PT. Coca-Cola Bottling Indonesia for a bottle of carbonized beverage. However, it does not happen in a car battery industry. Some companies do not aware of the chemical hazard which can be emerged from the battery if it is thrown away in the landfill. A surprising fact that raises from the interview is that some companies do not want bad images coming from the customers if they exploit reused battery.

(c) Lack of information systems and technology

One of serious the problems which are faced by the manufacturers in implementing RL is the ineffectiveness of using information systems and technology. It is corroborated by the fact that nearly zero good RL management information systems are commercially available [1]. However, the information systems is considered as major factors in the success of RL practice [20]. If a firm wants to implement RL in its operations, the firm has to build a good information system which is planned to design, identify, and handle the RL process, especially for tracing and tracking the status of products after leaving the firm. The condition in the object of the re-search is that the manufacturer only uses internal information system. It means that the materials and products information only available from suppliers to the manufacturer and to distributors, or only to tier one of supply chain entities. After leaving from the distributors, the products information cannot be traced anymore.

(d) Resistance to change to reverse logistics

The next barrier in the implementation of the RL is the resistance to change, one of a human nature. Organizational change, however, can generate scepticism and resistance in employees, making it sometimes difficult or impossible to implement organizational improvements. In a change management theory, people tend to secure their status quo: avoiding change when possible. The implementation of RL needs a radical revolution in the people’s mindset and practice when the previous system is not supported. Any management’s ability to achieve maximum benefits from the change depends on part of how effectively they create and maintain a climate that minimizes resistant behavior and encourages acceptance and support. If management does not understand, accept, and make an effort to work with resistance, it can undermine even the most well-intentioned and well-conceived change efforts. In order to facilitate a smooth transition from the old to the new, organizations must be competent in effective change management. The process of change management consists of getting off those involved and affected to accept the introduced changes as well as manage any resistance to them.

(e) Lack of appropriate performance metrics

One of the major barriers of supply chain management is a lack of appropriate performance metrics [21]. Since RL is a part of supply chain management practice, a performance measurement is also considered as a key factor in allowing the process of performance management, improvement, documentation, and so forth. If the company initiates to link its performance measurement system to the RL practice, the company will be in a better position in its struggle to achieve successful RL programs. It has to effectively synchronize all the processes, design environmentally friendly products, focus on recapturing value or proper disposal products, and establish performance measurement system that provides information as to whether the RL program meets the expectation or not.

(f) Lack of training and education

Training and education of personnel are major requirements for attaining success in any organization. Therefore, lack of qualified and competent human resources is considered as one barrier in the implementation of RL. Proper training and education regarding RL have to be conducted for the entire personnel of the company, from top management to operator level. They have to be trained from handling product returns, creating and maintaining reliable RL information system, to marketing reused or recycled products. The training also has to be designed to improve the performance and skills of the personnel.

(g) Financial constraints

The financial issue is regarded as one barrier of RL implementation since it is critical to support the workforce and infrastructure requirements of the RL programs. High-class training, as well as excellent information systems, require financial support from the company. If the company does not consider the RL programs, it then would not allocate its funds to invest in the RL implementation.

(h) Lack of commitment by top management

Top management commitment is believed to be the dominant driver of corporate endeavours. In the car battery industry, lack of top management's commitment is a big challenge in implementing RL. The commitment is required to provide clear vision to the RL programs. Top management have to show that their commitment is linear with the long-term organizational goals. They have to provide strategic plans with regards to the RL programs as well as action plans to successfully implement their strategic plans.

(i) Problems with product quality

The condition or the quality of the end-of-use returned products coming from the point of consumption (i.e., the consumers) is regarded as one of the barriers in RL implementation. Comparing with forward logistics as the company can keep the uniformity of the product quality, the conditions of the products in RL are heterogeneous. This is due to numerous characteristics of returned products in RL. They can be returned be-cause they are defective or unwanted; they violate the environmental issue; or due to guarantee returns [1]. Once the returned products arrive at the collection or returns center, a decision must be made for its disposition. A gatekeeping which is the screening of defective and unwarranted returned products at the entry point into RL process is considered as the first critical factor in making the entire reverse flow manageable and profitable. Some successful companies which have performed the good gatekeeping gained many benefits from it. L.L.Bean, one of the famous retail company, accepts all of the risk associated with purchasing one of the firm's products. The concept of absorbing the risk that a product might be damaged, faulty, or simply unwanted by the customers, could attract the customers, increase sales, and at the same time cause major problems for retailers. On the other hand, a failure in returns gatekeeping can also both create significant friction between supplier and customer firms, as well as lost revenue.

(j) Lack of strategic planning

Strategic planning can be described as an organization's process of defining its strategy or direction and making decisions on allocating its resources to pursue this strategy. The role of strategic planning is very crucial in achieving the organization goals for its survival in the global market. Related to RL practice, the strategic planning is to identify the RL goals and the specification of long-term plans for managing them. Due to the rapid changes in technology and also due to changes in the behaviors of the competitors, the consumers, and the suppliers, a good strategic planning is necessitated for the RL programs.

(k) Reluctance of the support of dealers, distributors, and retailers

The last barrier in the implementation of RL in a car battery industry is that the company does not obtain any support from the distributors and retailers. The company only has a policy related to returned products with the distributors. However, there is no policy that governs the returned products from customers to the retailers; thus, the customers are free to return the products with any kind of condition. This situation may harm the retailers since there is no such kind of pricing policy and the price could be varied. If the retailers refuse to cooperate in the RL practice, then the distributors will face difficulties in collecting the products which will be submitted to the company.

2.2. Interpretative structural modelling

The ISM is a well-established methodology that can be used for identifying and summarizing relationships among specific variables. In this technique, a set of different directly- and indirectly-related elements are structured into a comprehensive systematic model. The model can picture the structure of a complex problem or issue in a designed pattern implying graphics as well as words [22]. The ISM has been widely employed in much application area, see for example [23]–[25].

The ISM starts with an identification of variables and then extends with a group problem solving technique; it also can be used individually [24]. A contextually relevant subordinate relation then is chosen. After deciding the contextual relation on the element set, a structural self-interaction matrix (SSIM) is developed based on pairwise comparison of the variables. In the next step, the SSIM is converted into a reachability matrix (RM) and its transitivity is checked. Once transitivity embedding is complete, a matrix model is obtained. Then, the partitioning of the elements and an extraction of the structural model is derived. In this approach, a systematic application of some elementary notions of graph theory is used in such a way that theoretical, conceptual, and computational advantage are exploited to explain the complex pattern of contextual relationship among a set of variables. The complete steps of ISM modelling are illustrated in Figure 1.

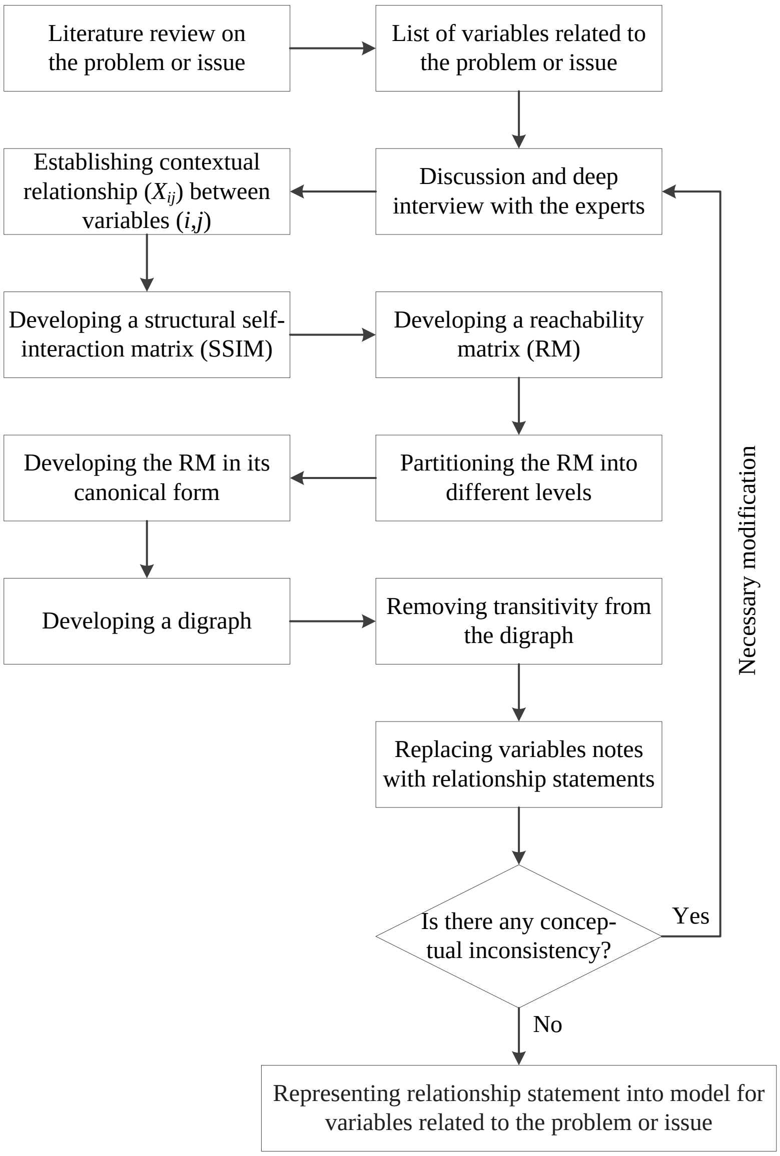

Figure 1. Flow diagram for preparing interpretative structural modelling

In this research, the eleven barriers that have been identified are then examined using the ISM methodology. A thorough investigation of the direct and indirect relationship among the barriers of RL implementation in a car battery industry can give a clearer picture of the situation than considering variables alone in isolation. The ISM can be appropriately employed as a tool under such an individual interaction state of affairs because the basis of the relationship among the variables and the overall structure can be extracted from the system under consideration [24].

2.3. MICMAC analysis

Matrice d'impacts croisés multiplication appliquée á un classement (MICMAC) or in English: cross-impact matrix multiplication applied to the classification analysis, is usually employed to analyse the driver power and dependence power of some related variables. MICMAC principle is based on multiplication of matrices to classify the key variables that drive the system in a variety of categories. Depending on their driver powers and dependence powers, the variables can be classified into four different clusters, i.e., autonomous, dependent, linkage, and independent barriers.

The first cluster includes the autonomous barriers. They are considered to have weak driver power and weak dependence. They are relatively disengaged from the system but they have few links, which may be very strong. The second consists of the dependent barriers. They have weak driver powers but strong dependence powers. The third has the linkage barriers that have strong driving powers as well as strong dependence powers. These barriers are unstable in the fact that any action on these barriers will have an effect on others and also a feedback on themselves. The fourth includes the independent barriers having strong driving powers but weak dependence powers. A variable with a very strong driving powers, or the key variables, fall into the category of independent or linkage barriers.

The MICMAC analysis has been widely used in a broader area (e.g., [5], [26]–[28]). It is usually integrated with the ISM methodology. When they are used altogether to analyse the interaction among the barriers of RL implementation in a car battery industry, it can give a better insight to the top management so that they can pro-actively deal with the barriers.

3. Result

3.1. Interpretative structural modelling hierarchy

Following is step-by-step to analyse the interaction among the barriers of RL implementation in a car battery industry in Indonesia. After the eleven barriers are identified, a deep interview with five experts (including academia and practitioners) in the field of supply chain management was conducted. They are asked to fill questionnaires which consist of some questions regarding the relationship among the barriers. For the sake of easiness, the eleven barriers are written over here as follows: (1) lack of awareness about RL practice (AWR); (2) company policies (POL); (3) lack of information systems and technology (IST); (4) resistance to change to RL (RES); (5) lack of appropriate performance metrics (PER); (6) lack of training and education (TRE); (7) financial constraints (FIN); (8) lack of commitment by top management (COM); (9) problems with product quality (QUA); (10) lack of strategic planning (PLA); (11) reluctance of the support of dealers, distributors, and retailers (DDR).

The contextual relationship among the barriers—which is then depicted in the SSIM—with respect to which pairs of barriers are examined. The relationship among barriers (*i* and *j*) is described by the four symbols of which is as follows:

- V: Barrier *i* will help to alleviate barrier *j*;
- A: Barrier *i* will be alleviated by barrier *j*;
- X: Both barriers will help to achieve each other;
- O: Both barriers are unrelated.

The following explained the use of the four symbols (i.e., V, A, X, and O) in SSIM. If the symbol for barrier 1 (AWR_i) to barrier 4 (RES_j) is V, it means that when the awareness about RL practice is increased in the firm, then the personnel in the firm are willing to change to the RL practice. When symbol A is given for the barrier 3 (IST_i) to the barrier 10 (PLA_j), this means that removal the barrier of lack of strategic planning will help alleviate barrier lack of information systems and technology. When the firm has a strategic planning regarding RL, then the firm is then willing to allocate a huge amount of money to invest in the information system and technology to support the RL practice. When barrier 2 (POL_i) to barrier 4 (RES_j) is symbolized with X. It means that when the barrier of company policies and resistance to change to RL are being removed, this will help to achieve each other. If symbol O is attributed to the barrier 6 (TRE_i) to barrier 7 (FIN_j). It means that the respondents believed that these two barriers do not correlate each other.

After SSIM is formed, the next step is developing the initial RM. The symbols V, A, X, and O in SSIM are then transformed into a binary matrix. The rules for the substitution are as follows:

- If the (i,j) entry in the SSIM is V, then the (i,j) entry in the RM is 1 and the (j,i) entry is 0.
- If the (i,j) entry in the SSIM is A, then the (i,j) entry in the RM is 0 and the (j,i) entry is 1.
- If the (i,j) entry in the SSIM is X, then the (i,j) entry in the RM is 1 and the (j,i) entry also is 1.
- If the (i,j) entry in the SSIM is O, then the (i,j) entry in the RM is 0 and the (j,i) entry also is 0.

For example, when the SSIM of barrier 6 (TRE_i) and barrier 7 (FIN_j) has symbol O, then the RM turns into 0 in the cell (6,7) and 0 in the cell (7,6). The five initial RMs are then summed up to form the total RM. The threshold is set to 3 so as the total RM would be transformed into final RM, which is a binary matrix (only consists of 0 and 1). It means that if there is an element in the total RM is greater than or equal to 3, that element will be 1 in the final RM; vice versa. The final RM is presented in Table 1. The driver power and dependence power of each barrier are then calculated. The driver power of a particular barrier is the total number of barriers (including itself) which it may help achieve; while the dependence power is the total number of barriers which may help to achieve it. These driver powers and dependence powers will be useful in establishing MICMAC diagram.

Table 1. Final reachability matrix

Barriers	**AWR_j**	**POL_j**	**IST_j**	**RES_j**	**PER_j**	**TRE_j**	**FIN_j**	**COM_j**	**QUA_j**	**PLA_j**	**DDR_j**	**Driver Power**
AWR_i	1	1	1	1	1	0	0	1	0	1	1	8
POL_i	1	1	1	1	1	1	0	1	0	0	1	8
IST_i	0	0	1	1	0	0	0	0	0	0	1	3
RES_i	0	0	1	1	1	0	0	0	0	0	0	3
PER_i	0	0	0	0	1	0	0	0	0	0	0	1
TRE_i	0	0	1	1	0	1	0	0	1	0	1	5
FIN_i	0	1	1	1	0	0	1	1	0	0	1	6
COM_i	0	0	1	1	1	1	1	1	0	1	1	8
QUA_i	0	0	0	1	0	1	0	0	1	0	1	4
PLA_i	1	0	1	1	0	1	0	0	1	1	1	7
DDR_i	0	0	0	1	1	1	0	1	0	0	1	5
Dependence Power	3	3	8	10	6	6	2	5	3	3	9	

The RM is then partitioned into different levels which is described as follows. The reachability set for the specific barrier consists of the barrier itself and the other barriers, which it may help achieve. The antecedent set consists of the barrier itself and the other barriers, which may help in achieving them. The intersection set is derived for all barriers. The "top level" barrier was identified from the intersection set which contains all elements from reachability set. After identifying the "top level" barrier, it is then discarded from the other remaining barriers. The iteration is continued until the levels of each barrier are found out. The identified levels would help in building the digraph and the final model of ISM hierarchy. The barriers, along with their reachability set, antecedent set, intersection set, and the levels, are shown in Table 2.

Table 2. Level partition

Barriers	Reachability Set	Antecedent Set	Intersection Set	Level
Iteration 1				
AWR	1, 2, 3, 4, 5, 8, 10, 11	1, 2, 10	1, 2, 10	
POL	1, 2, 3, 4, 5, 6, 8, 11	1, 2, 7	1, 2	
IST	3, 4, 11	1, 2, 3, 4, 6, 7, 8, 10	3, 4	
RES	3, 4, 5	1, 2, 3, 4, 6, 7, 8, 9, 10, 11	3, 4	
PER	5	1, 2, 4, 5, 8, 11	5	I
TRE	3, 4, 6, 9, 11	2, 6, 8, 9, 10, 11	6, 9, 11	
FIN	2, 3, 4, 7, 8, 11	7, 8	7, 8	
COM	3, 4, 5, 6, 7, 8, 10, 11	1, 2, 7, 8, 11	7, 8, 11	
QUA	4, 6, 9, 11	6, 9, 10	6, 9	
PLA	1, 3, 4, 6, 9, 10, 11	1, 8, 10	1, 10	
DDR	4, 5, 6, 8, 11	1, 2, 3, 6, 7, 8, 9, 10, 11	6, 8, 11	
Iteration 2				
AWR	1, 2, 3, 4, 8, 10, 11	1, 2, 10	1, 2, 10	
POL	1, 2, 3, 4, 6, 8, 11	1, 2, 7	1, 2	
IST	3, 4, 11	1, 2, 3, 4, 6, 7, 8, 10	3, 4	
RES	3, 4	1, 2, 3, 4, 6, 7, 8, 9, 10, 11	3, 4	II
TRE	3, 4, 6, 9, 11	2, 6, 8, 9, 10, 11	6, 9, 11	
FIN	2, 3, 4, 7, 8, 11	7, 8	7, 8	
COM	3, 4, 6, 7, 8, 10, 11	1, 2, 7, 8, 11	7, 8, 11	
QUA	4, 6, 9, 11	6, 9, 10	6, 9	
PLA	1, 3, 4, 6, 9, 10, 11	1, 8, 10	1, 10	
DDR	4, 6, 8, 11	1, 2, 3, 6, 7, 8, 9, 10, 11	6, 8, 11	
Iteration 3				
AWR	1, 2, 3, 8, 10, 11	1, 2, 10	1, 2, 10	
POL	1, 2, 3, 6, 8, 11	1, 2, 7	1, 2	
IST	3, 11	1, 2, 3, 6, 7, 8, 10	3	
TRE	3, 6, 9, 11	2, 6, 8, 9, 10, 11	6, 9, 11	
FIN	2, 3, 7, 8, 11	7, 8	7, 8	
COM	3, 6, 7, 8, 10, 11	1, 2, 7, 8, 11	7, 8, 11	
QUA	6, 9, 11	6, 9, 10	6, 9	
PLA	1, 3, 6, 9, 10, 11	1, 8, 10	1, 10	
DDR	6, 8, 11	1, 2, 3, 6, 7, 8, 9, 10, 11	6, 8, 11	III

Table 2. *(Continued)*

Barriers	Reachability Set	Antecedent Set	Intersection Set	Level
Iteration 4				
AWR	1, 2, 3, 8, 10	1, 2, 10	1, 2, 10	
POL	1, 2, 3, 6, 8	1, 2, 7	1, 2	
IST	3	1, 2, 3, 6, 7, 8, 10	3	IV
TRE	3, 6, 9	2, 6, 8, 9, 10	6, 9	
FIN	2, 3, 7, 8	7, 8	7, 8	
COM	3, 6, 7, 8, 10	1, 2, 7, 8	7, 8	
QUA	6, 9	6, 9, 10	6, 9	IV
PLA	1, 3, 6, 9, 10	1, 8, 10	1, 10	
Iteration 5				
AWR	1, 2, 8, 10	1, 2, 10	1, 2, 10	
POL	1, 2, 6, 8	1, 2, 7	1, 2	
TRE	6	2, 6, 8, 10	6	V
FIN	2, 7, 8	7, 8	7, 8	
COM	6, 7, 8, 10	1, 2, 7, 8	7, 8	
PLA	1, 6, 10	1, 8, 10	1, 10	
Iteration 6				
AWR	1, 2, 8, 10	1, 2, 10	1, 2, 10	
POL	1, 2, 8	1, 2, 7	1, 2	
FIN	2, 7, 8	7, 8	7, 8	
COM	7, 8, 10	1, 2, 7, 8	7, 8	
PLA	1, 10	1, 8, 10	1, 10	VI
Iteration 7				
AWR	1, 2, 8	1, 2	1, 2	
POL	1, 2, 8	1, 2, 7	1, 2	
FIN	2, 7, 8	7, 8	7, 8	
COM	7, 8	1, 2, 7, 8	7, 8	VII
Iteration 8				
AWR	1, 2	1, 2	1, 2	VIII
POL	1, 2	1, 2, 7	1, 2	VIII
FIN	2, 7	7	7, 8	IX

Note that from Table 2 at iteration 1, since the intersection set of barrier 5 (lack of appropriate performance metrics) is same with the reachability set, thus, this barrier is assigned as Level I. For the second iteration, barrier 5 is removed from the calculation. The Level II of the barrier is found from the second iteration, which is the barrier 4 (resistance to change to RL). The barrier 11 (reluctance of the support of dealers, distributors, and retailers) is assigned as Level III. The Level IV in the ISM hierarchy consists of two barriers: barrier 3 and 9 (lack of information systems and technology; and problems with product quality). Next, Level V is assigned to the barrier 6 (lack of training and education), while Level VI is the barrier 10 (lack of strategic planning). Level VII of the barrier is appointed to the barrier 8 (lack of commitment by top management). Level VIII consists of two barriers: barrier 1 (lack of awareness about RL practice) and barrier 2 (company policies). The Level IX or the "root barrier" is assigned to the barrier 7, which is financial constraints.

Based on the iterative level partition process, the structural model is generated. If the relationship exists between the barriers *j* and *i*, an arrow points from *i* to *j* to show this connection. The resulting graph is called a digraph. The digraph for the barriers of RL implementation in a car battery industry in Indonesia is depicted in Figure 2. Note that the barrier 7 (financial constraints) is a very crucial barrier for the RL implementation as it comes as the base of the ISM hierarchy. It leads to lack of awareness about RL practice (barrier 1) and company policies (barrier 2), and so on. Contrarily, the barrier 5 (lack of appropriate performance metrics) is the RL implementation barrier on which the effectiveness of the RL implementation depends. This barrier has appeared at the top of the hierarchy.

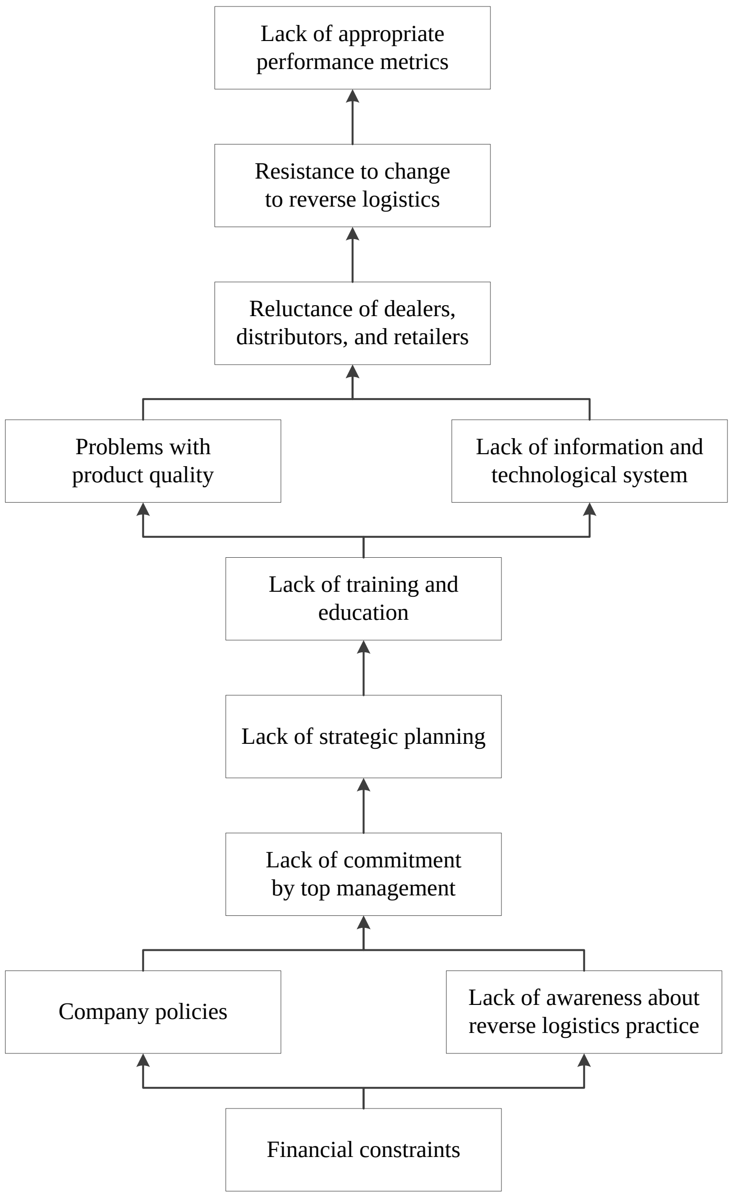

Figure 2. ISM-based model for the barriers of reverse logistics implementation

3.2. MICMAC diagram

The MICMAC analysis is used to analyse the relationship between driver power and dependence power by using MICMAC diagram. It is the two-dimensional state space where the vertical axis described the driver power while the horizontal axis described the dependence power. The barriers of RL implementation are classified into four clusters depending on their driver powers and dependence powers, i.e., autonomous barriers, dependent barriers, linkage barriers, and independent barriers. For example, as noted in Table 1, the barrier 11 (DDR) has driver power of 5 and dependence power of 9, so that this barrier is located on the horizontal axis of scale 9 and the vertical axis of scale 5. The MICMAC diagram is depicted in Figure 3.

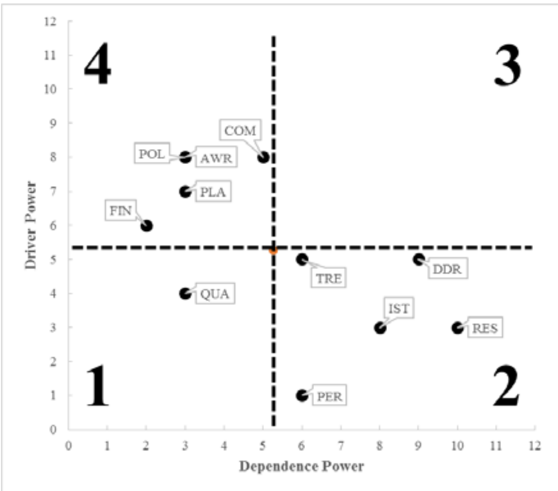

Figure 3. MICMAC diagram

Barriers that are included in the first cluster, namely autonomous cluster, have weak driving power and also weak dependence power. These barriers are relatively not related to the system and may have a little relationship so that the elements will be eliminated. Based on Figure 3, only one barrier belongs to this cluster, i.e., which means that this barrier is not associated with the system heavily.

Barriers that are categorized in the second cluster, (i.e., dependent cluster), consist of barriers that have weak driver power but strong dependence power. Based on the MICMAC diagram, it is known that the barriers which are classified in this cluster are barrier 3 (lack of information systems and technology), 4 (resistance to change to RL), 5 (lack of appropriate performance metrics), 6 (lack of training and education), and 11 (reluctance of the support of dealers, distributors, and retailers). These barriers can be explained for highly depend on the input and action of the system, which means that these barriers are not dependent barriers.

Barriers belong to the third cluster or linkage clusters are barriers for having strong driver power and strong dependence power. These barriers should be examined carefully because of the relationship between barriers is not stable. Any action that against these barriers will have an effect on other barriers as well as be a feedback on the barriers themselves. Based on the results of MICMAC diagram, there is no barrier in the third cluster.

Barriers belong to the fourth cluster (i.e., independent cluster), have strong driver power but weak dependence power. It is observed that the barrier with the driver power is a very strong so-called key barrier; enter into the category of an independent cluster or linkage clusters. Based on the MICMAC diagram, it is known that the barriers belong to this cluster are the barrier 1 (lack of awareness about RL practice), 2 (company policies), 7 (financial constraints), 8 (lack of commitment by top management), and 10 (lack of strategic planning). The improvements can be focused on these barriers.

4. Finding and discussion

While the documented benefits of RL are impressive, its implementation needs to be performed carefully since there are barriers that could hinder it. Those barriers must be taken into consideration as challenges by the top management and policy makers to be faced and solved in order to perform the practice of RL effective- and efficiently. In this paper, the eleven barriers are identified (see Section 2 for the detail); then the ISM was conducted to investigate the interaction among the barriers as well as to identify the “root barrier”.

The digraph as a result of the ISM revealed the barrier 7, i.e., financial constraint, as the root barrier (see Figure 2). As a consequence, the company must be able to eliminate this financial barrier by allocating sufficient financial resource for implementing the RL. This finding is not so surprising since in the developing countries, the practice of RL is viewed as a cost for the companies. If the company does not consider the RL as its priority, the cost associating with the RL practice will disrupt the company’s balance. Supporting the RL implementation financially may boost the company's awareness and policy toward RL.

The low awareness for putting RL into company's practice as well as the absence of company's supports which is integrated into its policy may affect the lack of commitment by the top management to implement the RL. If the company's vision, missions, and goals are intended to bolster the RL implementation, the commitment of the top management is supposed to be in line with those. However, the effect could go conversely due to lack of company's policy (or even no policy) and lack of awareness about the benefits gained from applying the RL.

To successfully implement the RL in the company, the role of company's strategic planning is vital. It can be regarded as how the company identifies the goals and establishes the long-term planning for managing its activities. Incorporating the RL practice into company's strategic policy without the personnel's dedication would be impractical. It means that the commitment has to be initiated first and then it has to be reinforced by the top management. If the top management do not have a big willingness in carrying out the RL due to personnel's denial toward the RL implementation, then the strategic planning about RL will not be successfully realized.

The strategic planning is a multifaceted activity that integrates various processes and requires a careful planning and scheme to be run effectively. Since incorporating the RL implementation into strategic planning is preceded by the commitment of both employees and top management, thus, all of the elements in the company do agree to implement the RL. The next step that has to be conducted by the company is providing training and education about the RL. Training must be performed throughout all of the company's personnel, from top management to company's staffs. They have to be given an appropriate training to handle product returns, apply the technology and information system used in RL implementation, as well as to deal with the process of reusing and recycling the products.

The knowledge and ability of the employees about the RL implementation after being given the training would affect the RL's information and technological system and the quality of the products. The well-trained employees would be able to design an excellent RL's information system. This information system must be capable identifying and handling the process of RL, particularly for tracing and tracking the status of the returned products. The company has to be well informed about the "position" of not only the products, but also the returned products in the supply chain, whether the products have reached the customers, at the gatekeepers, or have been sent back to the company. Similarly, the trained employees also have already known what to do with the returned products especially at the gatekeeping that have very different qualities in favour. As has been mentioned in Section 2, the conditions of the returned products vary; they can be returned due to the defects, violating the environmental issue, or guarantee returns. A gatekeeper must make a crucial decision about the disposition of the returned products, whether the products have to be disassembled, directly sent back to the headquarters, or specially treated due to already exposed to pollution.

The awareness of the other entities in the supply chain, such as dealers and distributors toward RL implementation is believed to be affected by those two, i.e., the lack of RL's information system and product quality. The good RL's information system could track and trace the status and position of the products after leaving the company, i.e., at the distributors, at the dealers, or when they contacted the customers. This condition would force the distributors and the dealers to join in the RL practice. Moreover, the company could cooperate with those entities to install the gatekeeping system at the entry point of the RL practice as a screening process for the returned products that have varying qualities as having been aforementioned.

When all the entities in the supply chain join and work together to implement the RL, hence, the barrier of resistance to change to RL could be managed. The last, to complete the RL practice, the implementation must be measured in order to assess its performance. The RL implementation must be evaluated periodically; the policy and strategy can be adjusted if necessary.

The MICMAC diagram was then utilized to analyse the relationship between driver power and dependence power of each barrier. Those eleven barriers are classified into four clusters depending on their driver powers and dependence powers (see

Figure 3). Strategic issues such as financial constraint, company policy, and lack of awareness about RL practice have the high value of driver powers. It is the priority of the company in order to deal with the barriers since these barriers have the ability to affect and influence other barriers. It also means that the company is suggested not to put a big effort to eliminate the barriers that have the low value of driver powers, i.e., the barriers that are located at the top of the digraph. Therefore, the company has to support the RL practice by providing adequate financial funding in its implementation; incorporate the RL into its company policy; and focus on developing strategies to raise awareness about the RL by conducting any socialization about the importance of the RL program as well as the benefits obtained by implementing the program. It is in accordance with the ISM since those barriers are located at the bottom of the digraph.

5. Conclusion and future research direction

The barriers of RL implementation in a car battery industry have been identified through literature review. They are eleven barriers which affect the implementation of RL practice, i.e., (1) lack of awareness about RL practice; (2) company policies; (3) lack of information systems and technology; (4) resistance to change to RL; (5) lack of appropriate performance metrics; (6) lack of training and education; (7) financial constraints; (8) lack of commitment by top management; (9) problems with product quality; (10) lack of strategic planning; and (11) reluctance of the support of dealers, distributors, and retailers. The barrier is assumed to be influenced by another barrier; thus, it is needed to understand the mutual relationship among the barriers in order to identify the root barrier which influences other barriers; and the barrier which is most influenced by others. A deep interview with five experts from academia and practitioners who have abundant experiences in the field of supply chain management are conducted to investigate the relationship among the barriers.

The root barrier and its relationship are depicted in digraph which is shown in Figure 2. The digraph shows that the root barrier in the implementation of RL in a car battery industry is the financial constraint. It means that the company has to provide a financial support in the RL implementation. Since financial constraint is considered as the root barrier, thus, eliminating this barrier is supposed to eliminate other barriers, i.e., the barriers that have positions above the root barrier.

MICMAC analysis by using MICMAC diagram is then employed to study the relationship between barriers' dependence and driver powers. There are four clusters in the MICMAC diagram which only cluster 1, 2, and 4 that are placed by the barriers. The first cluster namely autonomous cluster is placed by only one barrier, i.e., problems with product quality. The second cluster namely dependent cluster consists of five barriers, i.e., barrier 3, 4, 5, 6, and 11. The fourth cluster namely independent cluster also consists of five barriers, i.e., barrier 1, 2, 7, 8, and 10. It is suggested that the company has to eliminate the barriers that are located at the fourth cluster since they have strong driver powers that can influence other barriers.

One of the limitations of this research is when compiling the answers from the respondents (the total RM), it is only summed up to form the total RM. For the future research, the decision-making trial and evaluation laboratory (DEMATEL) could be used to compile the answers from the respondents to form the total RM. DEMATEL is widely used to confirm interdependence among variables and aid in the development of a directed graph to reflect the interrelationships between variables, see for example [29]–[31].

In this paper, it is used an arbitrary threshold, i.e., 3, to convert the total RM into the binary final RM. It means that every element in total RM below the threshold would be 0 in the final RM, and every element in total RM greater or equal 3 would be 1 in the final RM. For the future research, the cutting-edge method in multiple criteria decision-making: maximum mean de-entropy algorithm (MMDE) [32] could be used to set the threshold. The comparison between "above/below the arbitrary threshold" and the DEMATEL-MMDE methods will be an interesting area to be pursued.

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