Development of an Electronic Reverse Logistics Network Model: A Literature Review

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Abstract. The rapid development of technology and economy makes consumption of electronic products increased, so the potential for electronic waste will also increase. However, the high potential of this flow has not been matched by good waste management, especially in developing countries. One concept that can be applied to manage end-of-use products is reverse logistics (RL). Still, the RL concept, especially for electronic waste has not been practiced optimally. Therefore, it is necessary to have an RL management network on electronic waste to reduce the environmental impact and increase the economic value of waste. This study aims to explore the research progress of RL networks and recommended opportunity areas for further research using bibliometric analysis and systematic literature review (SLR). The output of bibliometric analysis is research trends on the topic of reverse logistics. The search process of bibliometric analysis is still limited to the keywords has not been done in-depth study of the contents of each article, so it needs to be continued with SLR. Articles obtained from bibliometric analysis are reviewed and analyzed using SLR so that the articles will be filtered and the numbers become smaller, so research opportunities in RL for electronics product can be identified.

1. Introduction

Emerging environmental issues such as global warming, water pollution, air pollution, land degradation, and others make people pay more attention to the environment [1]. The impact of industry on the state of the environment has been a concern for the past several decades. Many deterioration in environmental conditions can be seen from the presence of industrial activities that are spread globally [2]. Since 1990, the perspective of environmental management in companies has changed. Sustainable goals are now at the core of the company’s direction [3]. Company management began to pay special attention to initiating sustainable supply chain management (SSCM) practices [4] [5]. The international industrial climate also challenges organizations to focus on SSCM in achieving competitive advantage [6] by applying this concept to the entire product life cycle management including end-of-life [7]. This is because EOL is known to cause environmental pollution, potential additional costs, and is a waste of resources [7]. Some products still have poor EOL management, especially in Developing Countries. One of the products with EOL management that is still lacking in Developing Countries is electronic products.

The rapid development of technology and the economy in the last few decades has made choices of electronic products more diverse at more affordable prices [8]. This makes the population...
consumption of electronic products increases. When public consumption of electronic products increases, the potential for electronic waste will also rise. Electronic products will become electronic waste when the product is no longer able to provide benefits in accordance with the objectives of the owner. For example, the product is no longer functioning due to damage or because its technology and design are outdated [9]. The high potential of this flow has not been matched by good waste management [10]. Most developing countries do not yet have regulations on electronic waste collection and transportation systems until the final process. United Nations University even classifies waste management systems in some developing countries at the lowest level, because electronic waste management is still limited to informal initiatives. This management pattern is one of the differences between developing countries and developed countries [11].

Improper handling of waste can cause environmental pollution [12]. Environmental impacts caused by electronic waste are identified as ozone depleting substances [13]. So the need for extraction and proper treatment before the substance is disposed of in the open. Some electronic products also contain hazardous materials such as mercury, lead, cadmium etc. In addition to causing environmental impacts and containing hazardous materials, some electronic products also contain a variety of valuable materials such as ordinary metals, plastics, and precious metals [14]. Therefore there is a need for an electronic waste management plan. The design of electronic waste management, in addition to minimizing the impact on the environment will also increase the economic value of waste. The design of electronic waste management aims to utilize components or materials that can still be utilized, as well as to provide appropriate treatment of components containing hazardous materials or substances before being disposed of in the open. Electronic waste is waste that has high economic value compared to other wastes. If this waste is managed properly, besides providing benefits in terms of environmental preservation, it will also provide economic benefits.

Observing the adverse effects on humans and the environment arising from mishandling of electronic waste, there should be an appropriate electronic waste management procedure, one of which is to design Reverse Logistics (RL) in which the implementation is regulated and controlled by the government. RL is the concept of reusing used products to reduce waste and to improve industrial environmental performance [15]. RL is a process in an organization that includes a reverse distribution process from customers to producers, causing the flow of goods and information to flow in the opposite direction from forward logistics activities that support a product and return goods for recycling, remanufacturing, reuse and disposal [16]. In the concept of sustainability, RL can be defined as a business strategy that acts as a driving force in carrying out recovery activities effectively to improve sustainability. Recovery options in RL are remanufacturing, repairing, refurbishing, cannibalizing, and recycling [17]. Because RL is a series of processes that include product return, repair, dismantling, refurbishing, recycling, remanufacturing, and disposal of used or EOL products, RL network implementation is a strategic decision [18]. Decisions in RL can be taken for the long-term, such as decisions about the location of facilities, layout, capacity, and design; or the medium-term as related to integrating operations or deciding which information and communication technology systems support back handling or short-term decisions regarding inventory handling, vehicle routing, remanufacturing scheduling [19].

Waste management is an effort to SSCM. SSCM is a material, information and capital flow management which is a collaboration between companies along the supply chain by integrating objectives that cover the three dimensions of sustainable development namely economic, environmental and social [20]. Four key factors that play a role in waste collection are projected economic benefits that cover the costs of waste management systems, awareness of environmental issues, interest in promoting environmental issues, and social benefits such as job creation [21]. Collecting and utilizing waste can provide economic, social and environmental benefits. From an economic perspective, the collected waste is the potential to be a product with added value [22]. From an environmental perspective, recycling waste can minimize or eliminate waste that must be discharged into the environment [23]. From a social perspective, adding selling points from waste certainly requires business actors so that employment is created [24].
Based on this background, a good electronic waste management RL management network is needed so as to provide economic, environmental and social benefits. Hence, this study aim to provide an overview of research progress on RL networks and to recommend opportunity areas for further research. This paper is a literature review using bibliometric analysis and a systematic literature review of research developments relating to RL and sustainable networks.

2. Research Methods

This study combine bibliometric analysis and systematic literature review (SLR). The main reason for combining the two methods is SLR continues and completes bibliometric analysis. The output of bibliometric analysis is research trends on the topic of reverse logistics. The search process in the bibliometric analysis is still limited to the keywords of the title and the abstract of article has not been done in-depth study of the contents of each article, so it needs to be continued with SLR. Articles obtained from bibliometric analysis are reviewed and analyzed using SLR so that the articles will be filtered and the numbers become smaller. this step will then produce research opportunities in reverse logistics for electronics product.

Bibliometrics comes from the words biblio or bibliography and metrics. Biblio means book and metrics are measuring. Bibliometrics is defined as measuring or analyzing books / literatures using mathematical and statistical approaches [25]. Thus, bibliometrics is a systematic way used to analyze written and unwritten literature [26]. Bibliometric analysis is often referred to as scientometrics as part of the research evaluation methodology, and from a variety of literature that has been produced, allowing bibliometric analysis using a separate method [27]. Ref. [28] conducted a bibliometric analysis for literature review through five stages namely defining the appropriate search terms, initial search results, refinement of search results, initial data statistics and data analysis.

This study begins by searching for the right keywords. Scopus is used as a Web Database. In the Scopus database, the search process is performed on "article titles, abstracts, keywords" using the search keywords "reverse logistics", "network" and "sustainable". The search results from the Scopus database obtained 102 papers. The number of papers published is limited from 2013 to 2020. Search results are exported to csv format. Data analysis was performed with bibliometric analysis and network analysis. The search results from the bibliometric analysis included aspects: number of publications from 2013 to 2020, distribution of research by publications; distribution of research by country and distribution of research areas. Data analysis is presented in graphical form. From this stage we will find out research trends related to reverse logistics networks and measure whether the theme is still a prospect to be developed.

SLR is used to map and evaluate a literature to find out potential research gaps and to know the limits of knowledge, usually carried out through repeated cycles to determine the appropriate search words, search for literature, then complete the analysis [28]. SLR is the main method of synthesis and a rigorous review of the methodology of the research results. SLR can be done through 3 stages, namely planning, conducting and reporting [29]. The planning phase in this study is done by ascertaining what is needed in the literature study. The conducting stage is carried out by searching for sources of literature, which includes identifying research, selecting primary research, assessing the quality of literature, extracting data and continuing to monitor, and synthesizing data. SLR uses "searching" media from indexers such as Scopus, Science Direct, EBSCO, Emerald, SAGE, Springer Link and others). The reporting phase in this study produces systematic literature. A large number of articles are read and then analyzed so that they become much smaller. This analysis will produce future research opportunities in the study of reverse logistics networks. Figure 1 illustrates the flow of the current research literature phases.
3. Result and Discussion

3.1. Bibliometric Analysis

From the first collection of articles with the keywords, there are 102 articles found in the topic of reverse logistics, 72 from journals and 32 from conference papers. The number of papers published from 2013 until 2020 can be shown in Figure 2.

The distribution of the 102 selected publications form journals that explain network of reverse logistics based on publications is shown in Figure 3. It this Figure 3, that the most journal sources of the selected publications discussing the network of reverse logistics are from the Journal Cleaner Production (13 articles), followed by the International Journal of Production Economics (5 articles) and the International Journal of Production Research (3 articles)

Figure 1. The process of research literature

Figure 2. Number of RL Publications 2013-2020
The top ten research area are shown in Figure 4. Engineering is a research area that most often takes the topic of reverse logistics, which is 28%. Others research areas are business, management and accounting; decision sciences; environmental science, computer science, energy, social science, economic, econometric and finance, mathematics, and medicines.

![Chart showing the number of publications by research area](chart.png)

**Figure 4.** Proportions of RL topic based on research area

Based on the search results, 102 papers were written by several authors with different nationalities. India is the country with the most authors from search results. Figure 5 shows the top ten countries with productive authors.
After analyzing the data, the next step is to do a network analysis using VOSviewer software. Network analysis is done by making a network visualization to find out the network that is among the articles from the metadata that has been downloaded, as many as 102 articles. The CSV format of the search results is opened using VOSviewer to determine what keywords often appear. The keywords frequency can be set, for example: 1, 2, 3, 5, 10, 20 etc.

Operation of VOSviewer software starts from creating data by selecting the data type. When we choose to make maps based on bibliographic data, we must determine the resource data file, the type of analysis, the unit of analysis, and the method of calculating the minimum occurrence of keywords. In this review, the response of the data file is the search results in CSV format, the analysis type is co-occurrence, the unit of analysis unit is the keyword, the method of calculation is the full calculation and the minimum number of events/occurrences is set to 10, then 17 keywords are fulfilled, as shown in Figure 6. A network of 17 keywords are shown in Figure 7. In this review, the data used are search results in CSV format with the type of analysis is co-occurrence, the unit of analysis is the keyword, the calculation method is the full calculation and the minimum number of events / occurrences is set to 10, then produces 17 keywords are fulfilled, as shown in Figure 6. The network formed from 17 selected keywords is shown in Figure 7.
Figure 6. Selected keywords based on bibliographic data of RL

Figure 7 shows a network consisting of nodes and edges. Nodes are represented by circles, each circle represents a keyword that often appears, taken from the title and abstract of the article. The size of the circle indicates the number of publications that have a relation with the term, both in the title and abstract of the article. The greater the size of the circle means the greater the number of articles that have relevance to these keywords. The biggest circle shows the keywords that appear most often, here logistics is the biggest circle, so logistics is the keyword that appears most often (see Figure 6). Whereas edge indicates the relationship between node pairs and the strength of the relationship represented by distance. The closer distance between one node to another node shows the high relationship between these nodes. Each keyword that is close together, shows that keywords that often appear tend to be in a position that is close to one another in visualization, for example the relation
between reverse logistics and supply chain in a red circle, is closer than the reverse logistics relation with the reverse logistics network.

Based on the proximity of the keywords, the cluster is built. Clustering here is used to get insight or a description of bibliometric grouping. Figure 7 shows that there are three groups/clusters identified. The first cluster is shown in red colour, consisting of 6 keywords, with the most common items being reverse logistics, supply chains, integer programming, reverse logistics networks, recycling, economic and social effects. The second cluster is shown in green colour, consisting of 6 keywords, namely sustainable development, logistics, transportation, environmental impact, supply chain management, optimization. The third cluster shown in blue colour consists of 5 keywords, namely stochastic systems, product design, network design, decision making and manufacture. Cluster shows keywords in one group. Connected to each other in one network, such as supply chain and reverse logistics in one cluster, the keywords are connected to each other. Keywords in keywords in one cluster have a closer relationship than keywords in other clusters. Cluster 1 is the most powerful cluster.

3.2. Systematic Literature Review

Reverse logistics (RL) is an efficient planning, implementation and control process, an effective flow of raw material costs, the process of inventory of finished goods and related information from the point of consumption to the point of origin for the purpose of regaining value or proper disposal [30]. RL also has the aim to reprocesses from an appropriate value or disposal based on information related from the consumer’s point of entry to the starting point of producer[31]. The increase in the value of RL in recent years is caused by the return volume of product returns increasing every day [32]. Therefore RL activities must be carried out efficiently and significantly [33]. According to [34] the product is returned or discarded because the product produced is not functioning properly or because the function of the item is no longer needed. There are several reasons for product returns that exist in the supply chain hierarchy, starting with manufacturing, then to distribution until the finished product reaches the end consumer. Therefore Dekker divides the reasons for product returns into three parts, namely manufacturing returns, distribution returns and customer returns. Manufacturing returns include all components or goods in the production phase which include surplus raw materials, quality control returns and production leftovers / by-products. Distribution returns are all returns in the distribution phase, which include product recalls, B2B (Business to Business) commercial returns, stock adjustments and functional returns (distribution items/carriers/packaging). Customer returns include B2C commercial returns (reimbursement guarantees), warranty returns, service returns (repairs, spare parts), end-of-use returns and end-of-life returns.

The 6R concept which includes Reduce, Reuse, Recycle, Recovery, Remanufacturing, and Redesign is closely related to supply chain activities, especially RL [35]. Reduce focus on the first stage of the product life cycle, with reference to resource reductions. Reuse refers to the reuse of functional components, can be used in the same new product or different product assemblies, after the components are disassembled from the previous product. Recycle, this activity involves the process of changing material that is considered as waste into a new material or new product. Recovery, includes the process of collecting post-use products, dismantling, sorting, and cleaning for reuse in the next life cycle. Remanufacturing is a process of restoration to the original specifications, which can be done, if the component does not have serious defects. Redesign, this process involves the act of redesigning the product in the next generation using components, materials, and resources obtained from the results of recovery in the previous life cycle, or products of the previous generation [36].

Reverse logistics has received a lot of attention from governments, companies and academics due to the increasing level of environmental stewardship, resource depletion and regulation. In Europe and other developed countries, RL has been enforced by regulations so that producers take greater responsibility for the end product of its useful life [37]. The product regulations include the Waste Electrical and Electronic Equipment (WEEE) Directive, Restriction of Hazardous Substances (RoHS) Directive, EU Directive on Energy-using-Products (EuP), EU Directive on Registration, Evaluation and Authorisation of Chemicals (REACH), E-waste regulations in Japan, China, India, Korea, United
States, Canada and other many nations Basel Convention/s, Basel Convention Partnership on the ESM of E-waste in the Asia-Pacific region Mobile Phone Partnership Initiative (MPPI), Partnership for Action on Computing Equipment (PACE), StEP Initiative and Regional 3R Forum in Asia [38]. The EU directive on Waste Electrical and Electronic Equipment (WEEE) is a regulation in the European Union on Waste Electrical and Electronic Equipment that imposes the obligation to collect most end-of-life products to electronic manufacturers [39]. Because there are regulations that regulate and supervise the handling of end-of-life or end-of-use products, the channel of handling post-use products in the European Union and developed countries, most of them already have formal channels. However, different conditions for RL practices may occur in developing countries, because not all developing countries have regulations for waste management. In developing countries, this situation is complicated because there are many objectives for end-of-life products in addition to the manufacturer's return system [37]. So there are still many RL practices with informal channels, waste management is still limited to informal initiatives.

Reverse logistics management of electronic products in formal channels by referring to existing regulations including those conducted by [40] in Canada, [41] in Taiwan, [39] in Europe, [42] in Canada, [43] in Turkey, and [44] in Denmark. Meanwhile, there are also formal channels but they are not regulated and monitored by the government because there is no regulation, namely in Vietnam [37]. Management of formal channels is an initiative of the company. Management through informal channels due to the absence of government regulations or initiatives from companies including those in India [45]. Ref. [46] uses formal and informal channels for electronic waste management in Indonesia, without supervision from the government due to the absence of regulations, so the implementation of formal channels is still limited to company initiatives. The management network between formal and informal channels has not been integrated [46].

The development of formal networks for non-electronic waste management was carried out by [47] for bicycle waste in Turkey, [18] for furniture products in Taiwan, [48] for tires in the city of Gran Santiago, Chile, [49] for household products and [50] for medical devices in Iran. The informal practice of managing non-electronic waste without regulatory rules was carried out by [51] for household appliance products in Mashhad Metropolitan, Iran and [52] for household appliances products also in the Gulf Cooperation Council (GCC) Area of the Cooperation Council For Arab countries in the Gulf which include Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates.

Waste management is an effort to create sustainable supply chain management (SSCM). SSCM is a material, information and capital flow management which is a collaboration between companies along the supply chain by integrating objectives that cover the three dimensions of sustainable development namely economic, environmental and social [20]. Four key factors that play a role in waste collection are projected economic benefits that cover the costs of waste management systems, awareness of environmental issues, interest in promoting environmental issues, and social benefits such as job creation [21]. Waste management when done well, will provide economic, social and environmental benefits. From an economic perspective, the collected waste is the potential to be a product with added value [22]. From an environmental perspective, recycling waste can minimize or eliminate waste that must be discharged into the environment [23]. From a social perspective, adding selling points from waste certainly requires business actors so that employment is created [24].

In developing the model, the sustainable aspects considered by researchers vary, which include economic aspects, environmental aspects, social aspects. There are those who only consider one aspect, there are two or three aspects of sustainability. Ref [51], [37], [47], [45], [18], [48], [44], [52] and [43] consider economic aspects in the built model. Ref [39] considers economic and environmental aspects in the management model developed. Meanwhile, ref [40], [41], [53], [50] develop management models by considering economic, environmental and social aspects. Ref [49] considers 3 aspects as well, but the third is not the social aspect but the engine efficiency. Ref [42] include aspects of timely delivery in addition to economic and environmental aspects. Ref [54] also
considers 3 aspects in the design of their models, which include economic, environmental and consumer satisfaction aspects.

The solution method used to solve the reverse logistic network problem is mostly using the exact method, only a few researchers use the metaheuristic approach including [18], [50] and [52]. Research opportunities for RL network area based on channels and sustainable aspects can be seen in Table 1.

Table 1. Research based on channels and Sustainable Aspects

| Reference | Channels | Regulation | Aspects |
|-----------|----------|------------|---------|
|           | Formal   | Informal   | Economic | Environment | Social |
| [51]      | √        |            | √        |            | √      |
| [40]      | √        | √          | √        | √          | √      |
| [37]      | √        |            |          |            | √      |
| [41]      | √        | √          | √        | √          | √      |
| [49]      | √        | √          | √        | √          | √      |
| [39]      | √        | √          | √        | √          | √      |
| [47]      | √        |            | √        | √          | √      |
| [45]      | √        | √          |          |            | √      |
| [18]      | √        |            | √        |            | √      |
| [48]      | √        | √          | √        | √          | √      |
| [42]      | √        |            | √        | √          | √      |
| [53]      | √        |            | √        | √          | √      |
| [54]      | √        | √          | √        | √          | √      |
| [44]      | √        |            | √        | √          | √      |
| [52]      | √        |            |          |            | √      |
| [50]      | √        | √          | √        | √          | √      |
| [46]      | √        |            | √        | √          | √      |
| [43]      | √        |            | √        | √          | √      |
| Research opportunities | √ | √ | √ | √ | √ |

3.3. Research Opportunities

Based on bibliometric analysis and systematic literature review (SLR), the research opportunities that might be done are:

a. The results of network analysis show keywords such as remanufacturing, product return forecasting, reprocessing product pricing, product quality reprocessing do not appear, even when the keyword frequency value is reduced until number of co-occurrence 1. This becomes an opportunity to be developed.

b. From network analysis, between network design and reverse logistic network the relationship is low, which is shown from a long distance, so the two keywords are different clusters. Merging these two keywords into a reverse logistic network design can be done for future research.

c. Analysis based on country, research in the reverse logistics area is dominated by developed countries, so research in this area for developing countries is still a potential to be studied.

d. It is necessary to study differences in waste management in developed and developing countries, especially with regard to regulations so that the appropriate management channels for developing countries can be determined.

e. Most problems are solved using the exact method, for more complex cases, it can be developed and resolved with a metaheuristic or hybrid metaheuristic approach.

f. For multi-objective problems that consider more than one sustainable aspect. Each aspect may have different weights, so weighting is needed for each aspect. Weighting for each purpose can be done using decision making such as Analytical Hierarchy Process (AHP), Analytic Network Process (ANP), Fuzzy AHP, fuzzy ANP etc. Mixed methods research provides an opportunity to be developed in the case of reverse logistics networks.
4. Conclusion
The search results published in the last 8 years between 2013 until 2020, there were 102 articles on reverse logistic network and sustainable. The output of bibliometric analysis is research trends on the topic of reverse logistics. The search process of bibliometric analysis is still limited to the keywords has not been done in-depth study of the contents of each article, so it needs to be continued with SLR. Articles obtained from bibliometric analysis are reviewed and analyzed using SLR so that the articles will be filtered and the numbers become smaller, so research opportunities in RL for electronics product can be identified. The results of bibliometric analysis show that RL research is still a trend and has the potential to be developed, this is confirmed by the many publications on RL topics in reputable journals in the last 8 years. RL research is mostly carried out by developed countries, and the area of engineering research takes up the largest portion of RL topics. Network analysis results show remanufacturing, product return forecasting, reprocessing product pricing, product quality reprocessing, a reverse logistic network design can be done for future research. Analysis based on country, research in the reverse logistics area is dominated by developed countries, so research in this area for developing countries is still a potential to be studied.

It is necessary to study differences in waste management in developed and developing countries, especially with regard to regulations so that the appropriate management paths for developing countries can be determined. Most problems are solved using the exact method, for more complex cases, it can be developed and resolved with a metaheuristic or hybrid metaheuristic approach. For multi-objective problems that consider more than one sustainable aspect. Each aspect may have different weights, so weighting is needed for each aspect. Weighting for each purpose can be done using decision making, for example AHP, ANP, fuzzy AHP, fuzzy ANP etc. Mixed methods research provides an opportunity to be developed in the case of reverse logistics networks.

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