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**A Decision Making Framework for Reverse
Logistics Network Design**

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A Decision Making Framework for Reverse Logistics Network Design

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Abstract

The main objective of this research is to answer the following research question “How should a company design their reverse logistics network in a more efficient or responsive way?”

In this research, a conceptual framework has been developed based on several key factors for network design. Through the analysis of each key factor affecting network design decision, we have built a conceptual framework for reverse logistics network for companies to decide on whether to centralize versus decentralize their reverse logistics operations, and whether to outsource or insource some of their operations? Some existing studies are able to fit well in our proposed framework, giving us better insights to decision making in reverse logistics network design.

The proposed conceptual framework is helpful for the companies or organizations to make better decisions when designing their reverse logistics operations to achieve a lean or responsive network.

Keywords: Reverse Logistics, Network Design, Asia, Computer industry, Outsourcing

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1. INTRODUCTION

According to the Roger and Lemke (1998), Reverse Logistics is defined as “The process of planning, implementing, and controlling flows of raw materials, in-process inventory, and finished goods, from a manufacturing, distribution or use point to a point of recovery or point of proper disposal”. Recalls, commercial returns, wrong deliveries, warranties, repairs and refurbishment or end-of-life returns are some of the examples of reverse logistics that companies need to manage. It has historically been a neglected part of supply chain management, but is currently gaining much more attention due to its direct impact on profit margins, companies’ environmental image and corporate social responsibility. A typical reverse logistics chain process is shown in Figure 1 below:

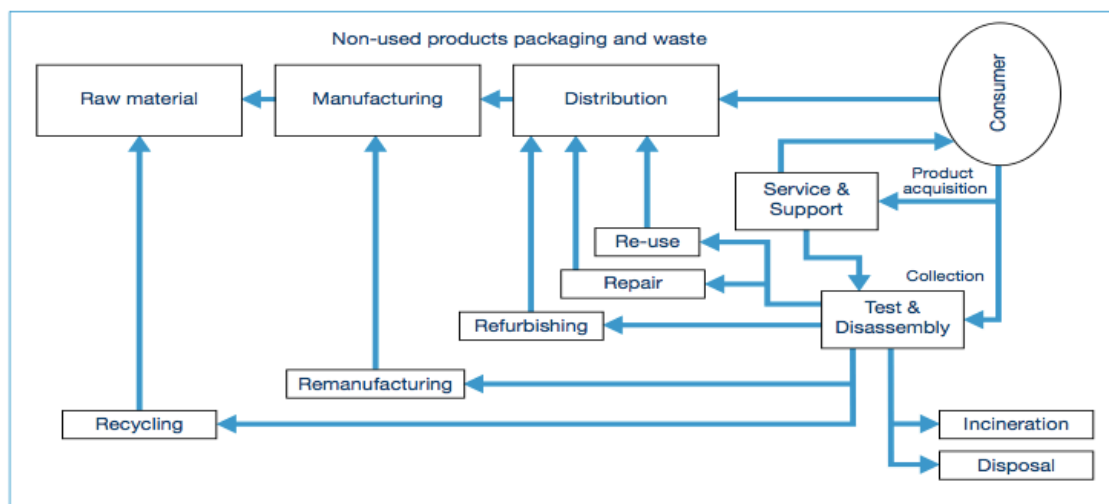


Figure 1 : An example of a reverse logistics chain

Much of the reverse logistics work has been focusing on product or industry such as electronics, transportation containers, auto parts, carpet recycling, papers and computer’s components. This is mainly due to the efficiency to be gained from product-specific knowledge in recycling or remanufacturing processes. While much research has focused on a particular product or industry, some research has been conducted to tackle the general case for reverse logistics across all products and industries. (Fleischmann, et al., 2000) identified characteristics of product recovery networks by dividing them into three types (bulk recycling, assembly product remanufacturing, and re-usable items) and then classifying the network characteristics within each group such as dedicated facilities, reuse in original market and mandatory recovery. Solutions have concentrated on mixed-integer linear

programming models for network design, largely deterministic facility location-allocation models. Recently, models have begun to incorporate stochastic programming and robust optimization approaches to address uncertainties in quality and quantity of return product. (Hsiao, L., & Chen 2012)

There are many trade-offs that must be considered for efficient reverse logistics networks. Among these trade-offs are centralized vs. decentralized sorting and testing, dedicated disassembly plants vs. in-plant remanufacturing, and company-specific versus industry-wide collection systems. Previously, researchers have used case studies to develop reverse production classifications, but have not addressed specific trade-offs that must be considered for network design. (Brito 2003)

Nowadays, under globalization's implications, designing or building operating networks is a must for the companies to span their business globally. These networks enable a company to sell its products to customers around the world while providing the firm access to worldwide resources. Thus, company needs to combine forward logistics and reverse logistics in network design to achieve better performance. Four critical areas – compatibility, configuration, coordination, and control should be evaluated to make sure that each network design decision yields a more competitive network.

In this research, we will address decisions in design of reverse logistics network and propose a framework for evaluating the necessary trade-offs in network design. It will also include factors which have impacts on network design decisions in reverse logistics.

1.1. Significance of the Research

This research is a compilation numerous of publications from top journals case studies and seminar reports in Reverse Logistics and Network Design. It gives us the opportunity to put together a list of key decision factors on Reverse Logistics Network Design so that we can propose a conceptual framework for reverse logistics network to help companies have proper decision for each business situation.

1.2. Research Questions and Objectives

The ultimate aim of the research project is to provide a framework to recommend to organizations or companies on how they could design an appropriate network for their reverse logistics to achieve their organizational objectives. In order

to make these recommendations, pros and cons of each network configuration will be evaluated to align with the business objective.

The objectives of this research are to:

- Identify key factors related to Network Design Decision in Reverse Logistics
- Propose a framework to recommend a proper Network Design Decision in related industries and situations
- Apply the framework under different situations and industries.

In short, this research attempt to answer the following questions:

- What are the key factors to decide on Reverse Logistics networks?
- How many types of Reverse Logistics Network Design are there? What are advantages and disadvantages of each type?
- Which situations or industries will be suitable for each Reverse Logistics Network Design?

1.3. Research Methodology

The research methodology is to make use of secondary data to identify the factors for reverse logistics network design and then use some examples to test the capabilities of the conceptual framework in following manner:

- Identify the key activities or processes for Reverse Logistics operations such as collection, sorting and testing, processing of returns, storing of inventory
- Examine the pros and cons for each network configurations suitable for different scenarios
- Propose a conceptual framework for designing reverse logistics network
- Apply the proposed framework for different industries

2. LITERATURE REVIEW

2.1. Reverse Logistics

2.1.1. Definition of Reverse Logistics

(Dowlatshahi, 2000, p.143) defined reverse logistics as follows: “Reverse logistics is a process in which a manufacturer systematically accepts preciously shipped products or parts from the point for consumption for possible recycling, remanufacturing or disposal.” Another definition by (Hawks 2006) is that reverse logistics is “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.” She continues to explain that it as reverse logistics is the process of moving goods from their typical final estimation for the purpose of capturing value, or proper disposal. A more recent definition of reverse logistics by (Hsuan and Larsen et.al., 2015) is that reverse logistics encompasses a broad range of activities within, and outside of, logistics including: product returns, source reduction, recycling, material distribution, reuse of material, waste disposal and refurbishing, repair and remanufacturing.

Reverse Logistics (RL) is an issue that has received growing attention in the last decades, due to the occurrence and simultaneity of several situations. On one hand, there is a verifiable concern about environmental matters and sustainable development, as the many legal regulations that have been passed in a number of countries prove. On the other hand, economical reasons have also had their contribution in this increasing importance of RL issues. If operations are a major source of value-added (Quesada 2004) by means of the returned products, companies stand the possibility of recovering either constituent material which would no longer need to be purchased in the same quantities or added value. Whether the savings come only from materials, labour or/and overhead costs, some firms have already shown increasing interest in being efficiently involved as market competition shrinks the margin.

Perhaps due to its rapidly growing importance, the concept of RL evolves overtime. In fact, according to (Quesada 2004), there was not a largely accepted consensus about defining RL in practice. There were also other broad topics feasible

of being covered by it, such as activities, products, points in the supply chain, etc. Given that definitions sometimes overlapped in only certain aspects, some others could be judged as giving only a partial vision, whereas in other cases, they could become controversial due to different interpretations.

2.1.2. Importance of Reverse Logistics

According to the 24th Annual State of Logistics Report, during 2012, the cost of logistics activities accounted for approximately 8.5 percent of U.S. economy, which amounts to approximately \$1.3 trillion. Figure 2 shows logistics cost as a percentage of the Gross Domestic Product (GDP) for the U.S. over a 10-year span, and Figure 3 shows the logistics cost as a percent of GDP among different countries, in 2012 (Wilson 2013)

It is difficult to determine the percentage of logistics cost devoted to reverse logistics. In 1998, Rogers and Tibben-Lembke interviewed and surveyed several reverse logistics managers across the U.S. and estimated the reverse logistics costs to account for approximately four percent of total logistics costs. Due to increasing attention to reverse logistics over the past decade, this portion is expected to be much larger today (Rogers and Lembke 1998)

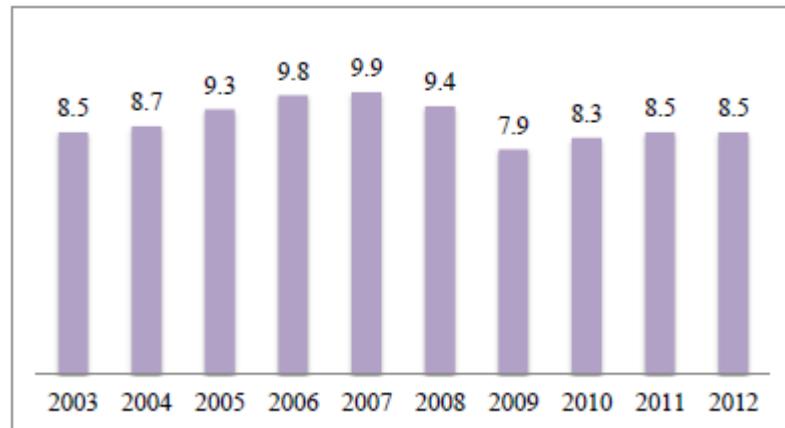


Figure 2. Logistics cost as a percent of GDP for US

Source: CSCMP's 24th Annual State of Logistics Report

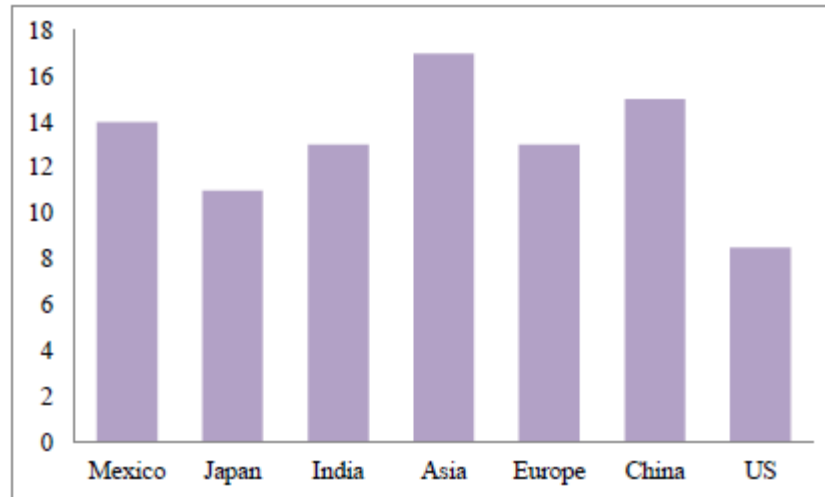


Figure 3. Logistics cost as a percent of GDP in 2012

Source: CSCMP's 24th Annual State of Logistics Report

More recently, economic motivations have also added to the driving force for developing reverse logistics networks. Recovery processes do not always denote the disposal of end-of-life products. In fact, some recovery processes, such as refurbishing and remanufacturing, are used to capture the incorporated value in old and used products. Several products and packaging material could be reused or sold to secondary markets after minor cleaning and repair.

Reverse logistics also playing an important part in the growth of an organisation; namely in financial, environmental and societal gains. It is therefore important not to overlook reverse logistics as organisations can markedly improve their customer service and response times along with environmental sustainability and company social responsibility (Güldem and Erdoğan 2011).

2.1.3. Key Processes of Reverse Logistics

Reverse logistics covers a broad range of items and activities which include:

- Movement of capital items and equipment to the next emergency response.
- Removal of containers and packaging from response area.
- Destruction of spoiled food commodities and out of date pharmaceuticals.
- Return of rejected goods to the suppliers.

- Movement of excess or over-supplied goods to other programs or organisations.

It is therefore important to consider the following questions, before designing any logistics network. They are:

- (1) What logistics activities and recovery processes are involved?
- (2) Which parties are in charge of performing the logistics activities?
- (3) Where should the logistics activities be performed?

Tan et al., (2003) studied of a US-based computer company's Asia-Pacific operations noted many inefficiencies and high costs in their RL programs. Consequently, (Tan and Kumar, 2006) developed a decision model to aid practitioners in controlling costs and maximizing profits in their potential RL activities. Some of the costs discussed by (Tan and Kumar, 2006) include transportation, customs duty, acquisition, handling, repair, reuse, scrap, storage, and freight costs.

Furthermore, Guide Jr and Pentico's (2003) framework addresses the expected costs of remanufacturing, logistics costs, and machine and labour costs. Some of these costs include remanufacturing costs, costs of acquiring returned products, value of time (e.g. opportunity costs), costs of lost sales, and inspection costs. These are just a few of the examples of key costs that are evaluated in determining which RL disposition to pursue. Indeed, a wide variety of costs associated with RL must be considered when deciding which RL disposition option to adopt. These costs associated with disposition may deter some firms from choosing certain disposition alternatives.

In reverse logistics, Barker (2010) mentioned that it has been established that there are four fundamental stages of flow: **(1) collection, (2) sort-test, (3) processing and (4) storage** (Flapper, 1996) ; (DeBrito et al., 2003) ; (Fleischmann et al., 2004).

Fleischmann et al. (2004) observes that some companies need to decide how to collect recoverable products from their former users, where to inspect collected products in order to separate recoverable resources from worthless scrap, where to process collected products to render them remarketable, and how to distribute recovered products to future customers.

Barker (2010) proposed a product recovery flow diagram showing the four

stages as shown in Figure 4. After the collection stage and the sorting or testing stage, the product is sent to processing, which may include finished product reuse, remanufacturing and spare parts recovery, reprocessed raw material and disposal of waste. The products are then stored centrally or return to the original source.

Stage 1	Stage 2	Stage 3	Stage 4
Collection	Sort and Test	Reuse, Repair, Remanufacturing, etc	Storage

Figure 4. Stages in Reverse Logistics Operations

Stage 1 (Collection)

Collection systems are either proprietary (company-specific), in which a company collects only its own products for recovery, or industry-wide, in which the same type of product from multiple producers is collected within the system. For proprietary collection systems, producers can use proprietary routing, in which the producer uses its own transportation system for collection, or they can outsource collection to a third-party logistics provider (Fleischmann et al. 1997)

A proprietary collection system is particularly beneficial when the company has a strong direct relationship with its customer, such as a lease-return relationship, or when there is high customer trade-in behaviour, such as there is in the business computer market (Fleischmann, 2000; Fleischmann et al., 2004). The proprietary collection system tends to strengthen those customer relationships, enhancing marketing and sales efforts. However, transportation costs may be higher than in an industry-wide collection system, because proprietary collection cannot take advantage of economies of scale available to higher volumes that an industry-wide system would handle.

Within a proprietary collection system, the company may either do its own collection using company trucks or freight providers, or it may outsource to a third party to pick up its products for processing. Collecting with company trucks or freight is an attractive choice when a company wishes to protect intellectual and proprietary information. It can be desirable for integrating forward and reverse flows,

such as for drop-off and pickup of reusable containers (Kroon and Vrijens, 1995). This system is also beneficial when there are relatively few customer sites. One drawback is potentially higher costs, as proprietary routing may be more expensive than outsourcing the collection system.

Outsourcing to a third-party for collection within a proprietary system may provide some economies of scale, as third-party logistics providers can pool shipping and facilities needs for multiple customers. This type of system may also be preferable for companies with large numbers of customer sites. Nevertheless, a third-party routing system has the drawback of reduced control by an individual company when it comes to intellectual and proprietary information.

Proprietary collection is a common choice for remanufacturing or remanufacturing systems. By contrast, industry-wide collection systems tend to be used for commodity-type products, such as paper recycling (Bloemhof-Ruwaard et al., 1996).

These systems are also beginning to be prevalent for computers and electronic products, due to government mandates for industry wide e-waste collection systems. One benefit for this type of system is economies of scale due to higher volumes. It also does not complicate a company's forward supply chain, as an industry wide system is typically a completely separate product return stream, collected by a third-party entity, as it is for e-waste. However, an individual company has limited control over this type of collection system, and that includes costs and routing. Also, higher start-up costs may be incurred for an industry-wide collection system, because of the much larger scale and scope of the system.

Stage 2 (Sort and Test)

Good gatekeeping consisting for sorting and testing is the first critical factor in making the entire reverse flow manageable and profitable. Often in companies where the return policies are lenient consumers tend to abuse their privileges. Also customers sometimes do not read the instructions of the return policies correctly, which leads unnecessary trouble for the retailers and in turn the manufacturer. A good gatekeeping process can help the manufacturer in keeping this to as low as possible.

Sorting and testing can be performed either at a centralized site, or at

distributed locations. A centralized site is common for a commodity-type product, such as construction sand recycling (Barros et al., 1998) or carpet recycling (Louwers et al., 1999; Realff et al., 2000), owing to efficiencies from higher volumes. But a centralized site is also desirable for high cost testing procedures, because it minimizes costs of testing equipment and specialized labour. One drawback to centralized sorting and testing is the risk of higher transportation costs for shipping scrap to the testing facility first, rather than directly to waste disposal.

Distributed sort-test sites are often used if low-cost testing procedures are available, such as for paper recycling (Bloemhof-Ruwaard et al., 1996; Kleineidam et al., 2000), machine refurbishing (Thierry et al., 1995; Krikke et al., 1999), or reusable containers and equipment (Kroon and Vrijens, 1995; Rudi et al., 2000). Scrap can be identified early and shipped for disposal, reducing transportation costs. However, testing procedures must be consistent and reliable, and the network may be more complicated because scrap and usable return product are shipped in separate streams.

Stage 3 (Processing)

Once the type of recovery process is determined (recycling, reprocessing raw material, remanufacturing and spare parts recovery, or reuse), the key decision is whether to reprocess at the original facility, which is the method use for copiers industry (Krikke et al., 1999a), or at a secondary facility, which is the method use for carpet industry (Realff et al., 2000).

(Thierry, et al. 1995) defined five categories of remanufacture and refurbishment. These five categories are **repair, refurbishing, remanufacturing, cannibalization, and recycling**. The first three categories: repair, refurbishing, and remanufacturing, involve product recondition and upgrade. Cannibalization is simply the recovery of a restricted set of reusable parts from used products. Recycling is the reuse of materials that were part of another product or subassembly.

Processing at the original facility provides increased efficiency from use of original facility equipment and processes, and it is often used for machine remanufacturing or spare parts recovery processing. However, there may be a need for increased processing capacity, which would be a drawback.

In zero return programs, the manufacturer or distributor does not permit

products to come back through the return channel. Instead, they give the retailer or other downstream entity a return allowance, and develop rules and guidelines for acceptable disposition of the product. The zero return policy often tends to have a negative effect in customer satisfaction and affect its brand.

The benefits of processing at a secondary facility or outsource to a third party include economies of scale if done across the entire industry rather than for a single manufacturer, which makes this a good choice for a bulk commodity-type product such as construction sand. The drawbacks include the need to establish new, separate facilities with a possible loss of processing efficiency.

Stage 4 (Storage)

Once the products have been processed, they are sent for storage either centrally or back to the source of returns. Some products that are slow moving are stored centrally as there is no market demand while those products in high demands are distributed to the locations nearer to the customers.

In summary, Figure 5 describes the flow activities in Reverse Logistics (Barker and Zabinsky 2008)

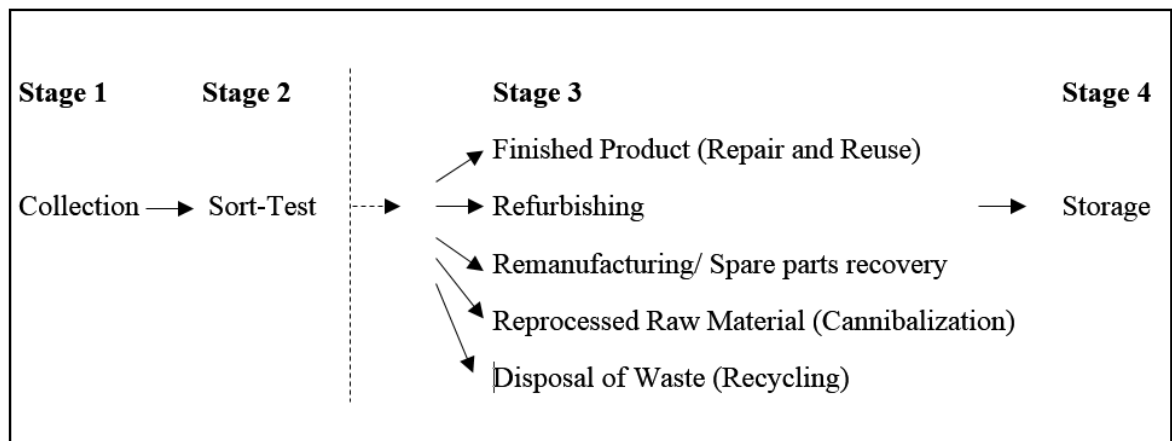


Figure 5. Stages in Reverse Logistics Processes

2.1.4. Key factors to consider in Reverse Logistics Network Design –

A. Centralised versus decentralised processing

Centralised processing has existed for many years, but only recently the full use of centralized return centers has been achieved by manufacturing companies. In a centralized system, all products for the reverse logistics pipeline are brought to a

central facility, where they are sorted, processes, and then shipped to their next destinations. This system has the benefit of the reverse logistics flow customers, which often leads to higher revenues for the returned items. Also this process can help in determining the right reverse channel for the returned items.

On the other hands, decentralized system is suitable if products or items are returned from consumers to retailers. Then the particular sales outlets serve the function of a “gate-keeper”. (Hsuan and Larsen et.al., 2015)

The network model in Reverse Logistics that a manufacturer chooses will depend on industry and geographic considerations. The first decision is between a centralized and a decentralized approach (see Figure 6). Factors to consider here include: Product lifecycle, Product value and cost, return volume and geographic distribution of returns.

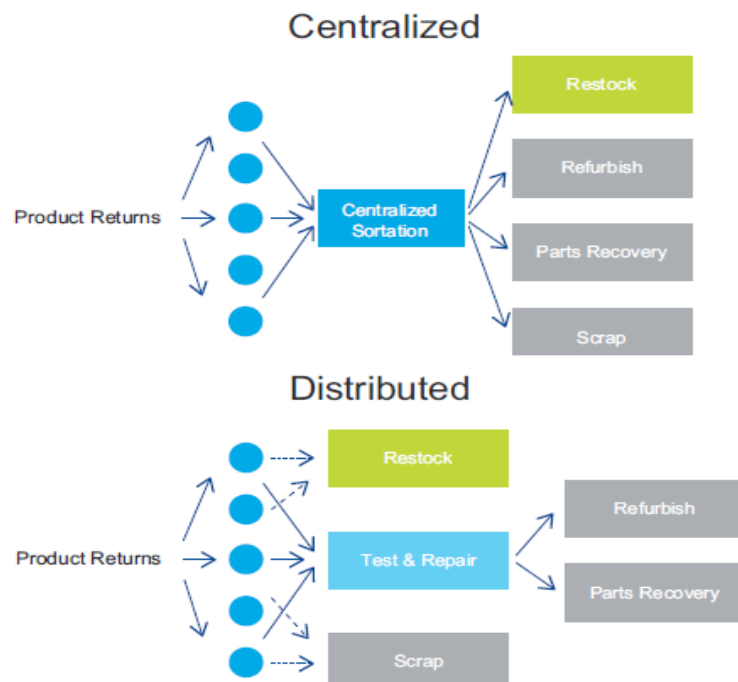


Figure 6. Centralized and Distributed Reverse Logistics Network

B. In-house vs. third party logistics providers (3PL)

The second network decision is to choose between insourcing or outsourcing of reverse logistics operations. For insourcing, the company is responsible for the entire reverse logistics process, including reuse of the recovered material. In the case of

outsourcing, the third party provider is partly or totally in charge of the reverse logistics process.

Companies prefer to outsource their reverse logistics processes if they do not have enough resources or it is not part of their core competencies. Depending on existing personnel skills, the maturity of the reverse logistics process, and cost, organizations may choose to outsource to third-party logistics (3PL) providers – either the complete process or selected segments (for example, transportation or sorting). Examples of successful 3PL's performing reverse logistics include FedEx, Genco and ASTAR (Mazahir, et al., 2011). In fact, outsourcing can be in different forms. In some instances, it may only involve outsourcing transportation and/or warehousing activities, whereas in other instances it may refer to outsourcing the entire logistics process (Marasco 2007). The extent to which logistics activities could be outsourced also depends on the type of product and industry. Certain activities, such as remanufacturing, require more specialized levels of knowledge and technology and are often carried out in house, whereas less specialized activities, such as recycling, may be outsourced to third parties (Fleischmann et al. 1997).

An outsourced model would require careful selection of the 3PL partner based on capabilities, proven track record, and alignment of services with the outsourcing company's objectives and strategies (Ene and Öztürk 2014); (Fleischmann 2001). The challenge for 3PL providers is designing a logistics network that adapts to all requirements and demands of their several clients. However, an efficient network will enable 3PLs to consolidate volumes and shipments and benefit from economies of scale and scope (Fong 2005).

C. Open Loop versus Close Loop Supply Chain Network

Open loop Supply Chain: Traditional or open loop supply chain is a "system whose constituent parts include material suppliers, production facilities, distribution services and customers linked together by the feed forward flow of materials and feedback flow of information" (Stevens 1989). It is characterised by a supply chain in which there is no flow back from the customer is referred to as an 'open loop supply chain' (Debo 2002).

Close loop Supply Chain : Closed-loop supply chains (CLSC) are supply chain networks that "include the returns processes and the manufacturer has the intent of

capturing additional value and further integrating all supply chain activities" (Wassenhove 2009).

The main difference between open loop and closed loop in reverse logistics is in deciding the final storage for the recovered products. In a closed loop reverse supply chain, recovered products are generally returned to original source or producer. But in an open loop reverse supply chain, recovered products are not returned to original source but stored in a different location (Ene and Öztürk 2014).

2.1.5. Summary of literature review

Most of the literature reviewed agrees that companies should consider the following factors at each stage of the reverse logistics operations: to centralized vs. decentralized reverse logistics processing, to outsource or insource its operations and to consolidate their shipments or ship direct between stages of their reverse logistics operations. This will affect its costs, service level, shelf life and residual value of the returns. Furthermore, the reverse logistics network design should be consistent with the business strategy (Barker and Zabinsky 2008).

3. RESEARCH METHOD AND DESIGN

3.1. Research Method

The aim of the research project is to provide a framework to recommend to organizations or companies about how they could design an appropriate network for their reverse logistics to achieve their organizational objectives. In order to make these recommendations, key factors related to network design decision are identified and their impacts are evaluated.

The key research activities are to:

- Identify key factors related to Network Design Decision in Reverse Logistics
- Propose a framework to recommend a proper Network Design Decision in related industries and situations
- Apply the framework in different situations and industries.

3.2. Research Design

Our research objective is to highlight the importance of reverse logistics and develop a conceptual framework for reverse logistics network design. To achieve this, we test on the proposed framework on different industries.

The reason we choose case study as our research design is because it brings us to understand the complex issues in more depth. Case studies have been widely used to examine contemporary real-life situations and provide the basis for the application of ideas and extension of method. (Yin, 1984, p.23) defined the case study research method is an empirical inquiry that the researchers must conduct to investigate a phenomenon within its real life context when the boundaries between phenomenon and context are not clearly evident or in which multiple sources of evidence are used.

A focused literature review is conducted as a necessary step in structuring a research field. We focus mainly on reverse logistics, network design and the interface between them. We identify a few key factors that influence decision in network design. From there, we propose a conceptual framework and applying it to different industries to determine if it is suitable and beneficial to the companies or organizations.

4. RESEARCH FINDINGS

In this section, we propose a conceptual framework for designing reverse logistics network. The framework is shown in Table 1 and it is developed based on the literature review and secondary data from company websites. The framework involves 4 stages in selecting their mode of reverse logistics operations: (1) Collection, (2) Sorting and testing, (3) Processing and (4) Storing.

	1. Collection		2. Sorting & Testing		3. Processing		4. Storage
	Internal Operation	Outsource	Internal Operation	Outsource	Internal Operation	Outsource	Centralised or Decentralised
Centralised							
Decentralised							

Table 1. Conceptual Framework for Designing Reverse Logistics Network

There are two dimensions to consider at each stage in designing the network, namely: Internal processing versus outsourcing, and centralizing versus decentralizing of operations.

Our proposed framework can be used in the following manner in order for companies to design their reverse logistics network:

1. Collection

At stage one involving collection of product returns, company can decide if they want to centralise or decentralise their operations. It is important to decide whether reverse logistics should be centralised or decentralised. Centralised reverse logistics is a system, where one organisation is responsible for collection, sorting and redistribution of returned items, and in the case of a decentralised system, multiple organisations are involved (Halldorsson & Skjott-Larsen 2007). It will also need to decide on operating their collection themselves or outsourcing to third party providers as shown in Table 2.

	Centralised	Decentralised
In-house	For company that need to have better control of their operations and customers are willing to send their products to the centralise collection center. Example of such configuration is the collection of computer or commodity that customers will send back to a centralised collection center.	For company that need to involve many collection centers to cover large geographical locations. Example of such configuration is the collection of electronic appliances where customer will send back to a nearby collection center or retailer.
Outsourcing	For company that do not have resources for collection and the volume of returns fluctuate widely. Third party collection can pool their collection services with other companies' returns to achieve economies of scale. Example of such configuration is the	For company that do not own any stores or outlets such as e-commerce companies and need to access third party channel to collect the products on their behalf. Example of such configuration is the collection of mobile phones with their resellers

	collection of printer that customers will send back to a centralised outsource collection center.	or via post offices.
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Table 2. Collection Options for Reverse Logistics Network

2. Sorting and Testing

At stage two involving sorting and testing of product returns, gate keeping is performed here. Again, company can decide to centralise or decentralise their operations. In the case of a centralised system, gatekeeping activities are performed by one organisation, and all returned goods (usually returned to retailer) are delivered to a certain facility for the inspection and sorting, from where they are transported for further reuse or reprocessing. Whereas in a decentralised system, often retailers perform gatekeeping activities and then goods are sent to different (depending on results of inspection) facilities for reuse/resale, for value recovery (thereto different organisations can handle different types of recovery), for recycling or for disposal. This requires the presence of specific and formal guidelines for the identification of the product condition, local skills to perform the initial inspection, and a logistics infrastructure to process the items further (Halldorsson & Skjott-Larsen 2007:16). The decentralised system usually is more beneficial for time-based strategies (Blackburn et al. 2004), as the individual item can be delivered faster and in more direct way. However, a centralised system offers economy of scale in logistics, and lower costs of managing reverse flows and of developing and maintaining the necessary amount of resources and competencies.

It will also need to decide on performing the sorting and testing in-house or outsource to third party providers as shown in Table 3.

	Centralised	Decentralised
In-house	Suitable if the testing equipment is expensive, it makes more economical sense to centralise the testing and if special skills are needed to operate on these equipment, it is best to	Suitable if the testing equipment is inexpensive and the equipment can be operate easily by any operator. Example of such configuration is the electronic appliance

	perform them in-house to protect its knowledge or its intellectual properties. Example of such configuration is the computer industry where the testing equipment used are expensive and they need special skills to operate.	products where simple testing can be conducted to determine its workability.
Outsourcing	Suitable for large volume return where the scale of operations is large and labor intensive. Example of such configuration is the commodity industry where large volume of products are return for sorting before they can be processed.	Suitable for very high volume of returns to cover large geographical locations. Example of such configuration is the mobile phone industry where the return volume is high and sorting can be performed by the retailers or other third parties.

Table 3. Sorting and Testing Options for Reverse Logistics Network

3. Processing

Stage three involves processing of the product returns in which the operations are either outsourced if the return volume is high and unpredictable or perform internally if the operations require special skills to protect its intellectual property as shown in Table 4.

	Centralised	Decentralised
In-house	Suitable if the process is proprietary, it makes more economical sense to centralise the processing to protect its knowledge. Example of such configuration is the computer industry where the repair or remanufacturing processes require special skills.	Suitable if the process is proprietary and customer expect shorter turn around time. Example of such configuration is the electronic appliance products where repair can be carried out by their own outlets.
Outsourcing	Suitable for large volume return where the scale of operations is large and labour intensive. Example of such configuration is the commodity industry where large volume of products is	Suitable for very high volume of returns to cover large geographical locations. Example of such configuration is the mobile phone industry where the return volume is high and

	return for recycling.	some simple repair can be performed by the retailers or other third party providers.
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Table 4. Processing Options for Reverse Logistics Network

4. Storage

At the final stage of storing the product returns, the products are either sent back to the original source or store centrally as shown in Table 5.

Centralised	Decentralised
This is suitable for products that are slow moving and are either bulky or expensive. It makes more economical sense to store them centrally after processing to reduce transportation and warehousing costs. Example of such configuration is the paper recycling, waste recycling, and engine overhaul.	This is suitable for products that are in high demand and they are sent back to the original source to meet the demand or for stock rotation. Example of such configuration is the mobile phone industry where phones are repaired and sent back to its original location.

Table 5. Processing Options for Reverse Logistics Network

Table 6 shows some of the previous research works on reverse logistics with different network design from stage 1 to stage 4.

Case Study	Stage 1: Collection	Stage 2: Sort/Test	Stage 3: Processing	Stage 4: Storage
Bloemhof- Ruwaard, et al. 1996	Waste disposal stream for paper with huge number of collection sites	Sorting at collection site, paper compacted into bundles	Recycled paper production, final product recycled paper	Centralised storage due to its weight and volume.
Barros, et al. 1998	Waste removal from relatively few construction sites	Sorted at central sorting facility into clean, half-clean, and polluted sand	Polluted sand cleaned at central facility, final products are clean and half-clean sand	Centralised storage due to its bulkiness

Krikke, et al. 1999	Collection through installers using proprietary route	Decentralized sorting, low-cost testing at collection site	At original plant, final products are refurbished machines and spare parts	Decentralised storage spare parts due to high demand from different sites.
Realff, et al. 2000	Collected from customer sites	Decentralized testing, either at collection sites or centralized processing site	Depolymerizing (high- cost) at central facility final products are nylon raw material	Centralised storage due to its weight.
Fleischmann, et al. 2004	Collection from business customers on expiration of lease contracts	Sorting and testing at central disassembly centre	Repair at disassembly centre, final products are refurbished machines and spare parts	Centralised storage of spare parts to reduce inventory costs.
Hong, et al. 2006	Collection at municipal and non-profit sites from residential customers	Sorting at distributed collection sites, sorted e-	Commercial processing sites process for recycling. Scrap sent to commercial processing sites	Centralised storage due to its bulkiness

Table 6. Summary of case studies on reverse logistics processes

5. APPLY THE FRAMEWORK TO DIFFERENT INDUSTRIES

It is important to determine some of the characteristics of the product returns before deciding on the right option for each stage of the reverse logistics network.

The key characteristics that help company to apply the framework are:

- a. Weight and volume of returns
- b. Residual value of the returns
- c. Product life cycle of the returns.

To illustrate the application of the framework, let's use the computer and industry as shown in Table 7.

	Weight of returns	Volume of returns	Residual value of returns	Product life cycle of returns
Computer	Light	High	High	Short

Table 7. Characteristics of computer and scrap metal industries

5.1 Computer Industry

Computer includes PCs, mini-computers, printers and computer accessories. As a first step, companies must decide whether to support all the products they sell or only some. For instance, Kodak supports its digital cameras but not its disposables. Many PC manufacturers, such as Dell and Hewlett-Packard (Tan, et al, 2013), support all the products they currently make but discontinue support for products they have stopped manufacturing. Some businesses choose to service complementary products as well as their own. Others may support competing products in addition to their own to generate economies of scale from the service technologies they've developed. ABB, for instance, supports all the process control equipment in factories that have installed its automation systems, thereby providing a one-stop service solution to customers.

To do that, they need to analyze the parameters that govern after-sales support from the customer's viewpoint as well as from their own. On the one hand, customers measure a service provider's performance by the amount of time it takes to restore a failed product. They have to weigh the levels of response they need against the prices they are willing to pay. On the other hand, to respond quickly to breakdowns, manufacturers have to locate spare parts close to customers and invest in larger stockpiles (Tan, et al, 2013).

The faster the response to customer, the greater their costs will be. Thus, instead of segmenting customers by sales volumes, geography, or technological capabilities, companies must create a variety of service products that meet customers' needs and willingness to pay. Companies can sort products into end products, modules, sub modules, and piece parts, all of which they can use interchangeably to deliver after-sales services. However, each bears a different cost and entails its own response time. Replacing a failed product with a standby end product is faster but more expensive than replacing a module. Replacing a module is faster and more expensive than replacing a sub module. Companies should keep this product hierarchy in mind when deciding what spares to stock.

The decision at each stage of reverse logistics can be illustrated in Table 8:

COMPUTER INDUSTRY	1. Collections		2. Sorting & Testing		3. Processing		4. Storage
	Internal Operation	Outsource	Internal Operation	Outsource	Internal Operation	Outsource	Centralised or Decentralised
Centralize						✓	✓
Decentralize	✓		✓				✓

Table 8. Proposed configuration for the computer industry

Stage 1 (Collection)

The computer company should decentralize the collection all the defective parts in their own service center. This will give them more control on their return policy and ensure the returns are managed within the warranty period.

Dell has organized special recovery teams through the Dell Asset Recovery Service program for collection. A Dell team comes to the work site of the client and hauls away the computers as part of the contract that Dell has with that client. Dell also overwrites the hard drives to ensure confidentiality of its client’s information. In order to provide a higher level of security to the customer, the data wipe process can be performed on site by Dell’s team.

Dell collaboration with charity organization also increases the amount of collection points for the used equipment both for individual customers and small businesses. Dell clients can in fact drop off their used computers, peripherals and other business technologies at any Charity location, or schedule a pickup. In return, Dell offers a 10 percent discount on the following online software or accessories purchase (Dell Inc., 2012). This way, Dell outsources the collection process to a charity organization which results both in a costs’ reduction for the collection and in an improvement of Dell’s corporate image.

Stage 2 (Sort and test)

Sorting and Testing are decentralized to ensure good parts are rejected from the process immediately. Some customers are not familiar of operating the computers and mistakenly thought it is faulty. The equipment used in testing the computer is not complicated and can be operated without much training. Parts that cannot be service will be scrapped immediately instead of sending them to the processing center. This will save some transportation and administration costs.

All the equipment collected by Dell is returned to a regional Dell facility. Here the equipment received by business and individual customers is examined to determine its condition and if there is any economic value to extract. At the Dell's equipment processing site, a test is performed to check and test the degree of functionality, RAM and hard drive sizes, processor speed, display, monitor and printer performance, etc. Based on this functional test, a quality grade is awarded to the equipment which determines its future use.

In order to reduce the unwanted returns to the regional Dell facility, a pre-screening strategy is adopted by Dell (Guide, Souza, Van Wassenhove, & Blackburn, 2006). This strategy consists of screening the computers at the time when the mail back service is required. Computers from Dell cannot be returned directly unless a phone call has been placed to a technical customer service representative. The customer service representative often tries to understand the customer problems and help them to solve the problems instead of returning the machines. This strategy allows Dell to decrease its reverse logistics costs while improving the customer service level.

From this point a computer can have four possible routes (Kumar & Craig, 2007).

- It can be donated to charity, when requested by the customer,
- It is moved to a logistics hub for sales.
- If refurbishment is not possible, component reuse is the next option: the usable components and materials are retrieved and are moved into the logistics hub. This spare parts inventory is utilized in case of service calls, where they can be used for replacement of components of computers acquired for resale.
- Any component that Dell cannot use is sent for proper disposal or for further breakdown into basic materials.

On the other hand, HP has completely outsourced the recovery of used products to external partners. HP does not screen the returned product, it is done by the customers themselves. This means that customers take the responsibility of deciding whether to recycle the equipment or to trade-in their product. However, since the clients do not have the proper tools to assess the condition of the equipment, it might send the return products to the wrong recovery method.

HP also has trade-in option for professional clients when changing their old

equipment with HP brand new products. The used equipment can be assessed by an external partner for refurbishment or reuse and if there are some residual values from the old equipment, this can be refunded to customers. However, the majority of clients is not keen of this option and prefers to recycle the used equipment. This is due to the fact that professional clients are highly sensitive to private data recorded in their computers.

Stage 3 (Processing)

Some companies have outsourced the repair services to third-party providers. If a company's objective is to turn service into a core competence, it should process in-house. Otherwise, they can outsource processing to achieve economies of scale.

Dell has implemented the Asset Recovery Services program which is currently running in 38 countries to manage their product returns. This program provides the logistics and disposal of owned and/or leased equipment in an environmental friendly way (Dell Inc., 2012). If some residual value can be extracted from the used equipment, business customers can decide, once products have been refurbished, whether to resell it through the Dell Outlet, or to donate it to the charity foundation. In case products cannot be refurbished, components are then evaluated for recycling or reuse.

In the case of HP, majority of end of life products collected at the client's site is sent for recycling. For this purpose, HP has partnered with an authorized 3PL company who will collect these products at the client's site and transports it directly to a treatment facility for recycling the material. The entire process is strictly controlled by HP to ensure that the equipment is properly recycled.

Stage 4 (Storage)

Some computer companies have setup warehouses to store the remanufacture red parts and supply them to the channel partners. These warehouses would be located closer to customers, and manufacturers could also stock parts right on customers' premises in the case of banking system. The central stocking pool will response to demand slower but their costs will be lower. The slow moving parts are sent to the central stocking pool for reuse to minimize transportation and storage costs. HP and Dell have centralized their storage in their regional DC to take advantage of lower storage costs and inventory pooling

Other fast moving parts are decentralized to facilitate stock rotation. This will replace or parts from outdated model each warehouse with newer parts so that they can support new computer models. Since these parts have shorter life cycle with high margin, it makes sense to decentralize their stocking locations to respond faster to customer demands. Most mobile phone companies tend to decentralize their storage of parts to support stock rotation and to shorten response time.

6. CONCLUSION

In this research, we evaluate each key factor related to reverse logistics network design and propose a conceptual framework to help companies to decide whether they should centralize or decentralize, outsource or insource, use open or close loop supply chain for their reverse network.

The conceptual framework involves 4 stages in reverse logistics operations namely: (1) Collection, (2) Sorting and testing, (3) Processing and (4) Storing. There are a few inputs to consider when making a network design decision on reverse logistics: weight of returns, residual value of the returns, and product life cycle of the returns. Based on these inputs, there are two dimensions in our framework to consider at each stage for the companies to design reverse logistics network: internal processing versus outsourcing, centralizing versus decentralizing of operations. Additional input is to consider need to consolidate shipments between stages.

We have illustrated how the conceptual framework can be used in scrap metal, rubber or computer industries and how it could help companies to align their supply chain strategy, whether they would to design a responsive or efficient reverse logistics network. This will in term lead to making decision on centralizing or decentralizing the network, outsource or in-house any of the four stages of reverse logistics process (collection, sorting and testing, processing and storing), and finally to consolidate shipments between stages.

Future research

Our current research only makes use of a few industries to study its fitness. Thus, the framework has not been tested widely or become generalized. Future research could study more industries to verify and further improve on the framework.

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