ACTIVITY-BASED COST MODELING AND DYNAMIC SIMULATION STUDY OF AN INTERNATIONAL REUSABLE PACKAGING SYSTEMS

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ABSTRACT

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This study compares reusable to expendable packaging systems in a total cost analysis. It explores whether reusable packaging is an economically viable option to replace the expendable packaging in an international supply chain. It assesses the financial performance of reusable packaging, using a combination of Activity-Based Costing (ABC) with static and dynamic simulation.

Firstly, ABC method is used to visualize packaging activities and costs in an automotive part supply chain. Three packaging system costs (expendable, reusable, and rental packaging systems) are established, and for each the packaging activity drivers, activity costs and the total packaging costs were calculated.

Secondly, a static simulation was used to reveal interrelationships between the packaging and supply chain costs. Eleven scenarios were tested to learn if relative cost changes in one or more of the variables can influence the packaging decision. Overall, container cost ratio and cycle time were the most decisive factors in determining the packaging system cost. It was found that cycle time is a more important factor than shipping distance, meaning that time is more important than physical distance since it directly affects the number of required containers. Customs charges were also an important factor for implementing reusable plastic container system (RPCS) and rental plastic container system (RENS) internationally because this will reduce profitability of running reusable container system. Proper documentation for import tax exemption, free trade agreement and other contracts should be necessary.

Thirdly, a dynamic simulation method was used to compare and verify the company-provided data and ABC model. ARENA software was used to calculate the number of reusable plastics containers (totes) and costs for three international supply chain routes of a company. Seven scenarios were tested which evaluated system time and cost, resource utilization for the process and number of entities processed in the process. The greatest benefit of using the dynamic simulation was taking account of time during the logistical process such as identifying a bottleneck at ports due to loading and unloading process that is not revealed in the company-provided data or static simulation.

In summary, the cost ratio between expendable and reusable containers is the first thing to consider because of relatively longer cycle time and distance, a greater number of containers are required. However, shorter cycle time and efficient material handling can reduce costs by avoiding unnecessary logistical activities and lag time during trans-shipment and custom process. Standardized reusable containers, since they are interchangeable, reduce the number required for safety stock.

This study shows the amount of economic impact by adopting different packaging systems in the international supply chain, implying changing any elements of packaging process may change the cost driver for each activity, which eventually affects total logistics costs.

This research is limited because the simulation model is only for an automotive part supply chain from a single supplier to a single customer, and the analysis is limited to cost. The environmental performance such as packaging waste generated and greenhouse gas emissions, and long term performance of reusable container and operation systems are recommended for future research

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CHAPTER 1

INTRODUCTION

Packaging plays a critical role in the economics and sustainability of supply chains. Packaging not only protects the product from physical damage, but affects the cost of every logistical activity, such as transportation, freight handling, packing, warehousing, waste disposal, and information management.

Although the importance of packaging in supply chains has been widely addressed, the total cost and value of packaging has not been successfully estimated (Twede, 2009). Many companies often fail to include important logistical activity costs in their total packaging cost estimations (NEFAB USA, 2010). Most companies are not aware of the importance or nature of packaging-related costs. Limited resources and the lack of reliable packaging cost information make it difficult for them to make packaging management decisions (Dubiel, 1996). Beyond economics, an increasing emphasis on the environmental responsibility of packaging and logistics, combined with increasing complexity of supply chains, have forced packaging managers to find more sustainable and profitable strategies. However, without comprehensive financial analyses, business decision makers have difficulties identifying the opportunities for improvement throughout their entire logistics system (Holmes, 1999).

A choice between reusable and expendable shipping container systems is one such strategic opportunity. In the vehicle manufacturing business, where car manufacturers are always looking for a more cost effective and greener supply chain, reusable shipping containers have been a popular choice for leading companies such as GM, Toyota and Volkswagen (Nunes & Bennett, 2010). The global manufacturer John Deere & Co. reportedly invested an initial $20 million in containers to develop a reusable shipping container system (Kroon & Vrijens, 1995). Manufacturers have adopted these reusable systems because, by applying standard and ergonomic design principles, reusable shipping containers can reduce the cost of handling, materials and packaging waste (Modern Material Handling, 2006). However, there has been no published study documenting the total profitability, including logistics costs, of reusable shipping containers.

Previous studies of reusable packaging use cost inputs from the prospective users are limited to simplified logistical networks and are not an absolute indication of total costs and benefits for an end user. Mollenkopf *et al.* (2005) used a relative cost approach to compare reusable and expandable shipping containers in a case study using a static simulation methodology. The Reusable Packaging Association (2010) has developed a “Quick Economic Calculator” and “Environmental Calculator” to compare basic cost differences of one-way corrugated packaging verses reusable plastic packaging. Such methods can help guide packaging and supply chain decision-makers, but their static cost models do not reflect the dynamic nature of the supply chain and to systemically address economic trade-offs.

From an environmental performance perspective, WRAP (Waste & Resources Action Programme), a non-profit, government-funded company in the UK, tried to identify key factors that influence the environmental impact and performance of reusable packaging systems in a Life Cycle Analysis (LCA) literature review. This report found that although LCA studies can be useful for packaging decisions, LCA results cannot identify whether one packaging option is environmentally preferable to another because of various factors such as product and packaging type, supply chain management situations, etc. They find that some LCA studies have credibility issues because the results tend to favor sponsors (Wood & Sturges, 2010). Twede and Clarke (2004) argued that although LCA studies are popular and useful, a thorough financial analysis of shipping containers will likely come to the same decision since almost all of those costs are directly related to the company who paid, which internalizes most costs (like waste disposal and fuel) that would otherwise be considered “externalities.”

It should be noted that if a reusable packaging system does not perform properly, it can become a very expensive expendable packaging with more packaging waste. The system should be managed and monitored by a pool operator with authority and responsibility, especially during the collection process (Mckerrow, 1996). As the automotive industry has learned the value of packaging system management by trial-and-error, it has learned that reusable packaging systems have different financial and environmental effects depending on management of the system (Twede & Clake, 2004). Ownership, whether by the suppliers, customers or third-party logistics providers (3PLs), influence a range of factors including the respective bargaining power of the involved parties, compatibility with production systems, and the respective logistical capabilities of suppliers/receivers (Holmes, 1999).

The accounting method needs to be considered. Holmes (1999) found that it is not easy to estimate the total cost in traditional costing systems based on volume-based allocation of overhead (or indirect cost). Traditional accounting methods distort information, so that manager cannot identify cause and effect of logistical activities and supply chain processes. Traditional approaches to accounting based upon full-cost allocation can be misleading and dangerous – and are one reason why it is so difficult to calculate true packaging logistics costs.

Activity-Based Costing (ABC) methods have drawn interest because they can identify the cost associated with each level of various activities (e.g. cost per line item picked, cost per delivery, etc.) which enables to show a clearer picture of the true packaging and logistics costs. ABC traces the consumption of resources by identifying *activity cost drivers* which trace particular cost objects such as specific products and services (Brac, 2000).

Although it has not yet been applied to reusable packaging, ABC applied to packaging activity cost drivers should be able to yield better comparative measures of total packaging costs.

There has likewise been no research to compare returnable and expendable packaging with dynamic simulation methods. Simulation techniques are popular for supply chain studies because they provide answers to “what-if” questions, such as redesigning supply chains for an industry or a company (Chu, 2003). Hellstöm and Johansson (2007) introduced the methodological approach of combining case studies and simulation studies while introducing the concept of asset visibility for Returnable Transport Item (RTI). However, this study did not investigate transportation costs or effects of system management, like differences between various ownership options or logistical networks.

There has been some research focused on evaluating financial and environmental aspects between reusable and expendable packaging systems. However, no studies have developed integrated and theoretically comprehensive results that reflect the current trend of global supply chains and visualize the dynamics of packaging activity costs in the systems.

The key research objectives are to seek the best packaging management option for a global automotive company considering the financial performance.

Independent variables include packaging types (expendable and reusable shipping containers), ownership options (buying and rental), and other constraints (shipping distance , average daily volume, container weight, container quantity on a pallet, return rate, backhaul logistics volume factor, designed container life, buffers and safety stocks, cycle time, customs charges).

Two simulation methods are applied to compare costs of reusable packaging systems to single use expendable packaging systems for global supply chains. The first is a static, multivariate regression approach similar to Mollenkopf *et al.* (2005). The second is a dynamic, discrete-event simulation method which can better visualize constant changes of container flows.

This multi-disciplinary approach, combining packaging and supply chain management, is based on scientific, technical, economic and environmental aspects. The results reveal differences in total costs for packaging, supply chain operations, waste and externalities. The resulting dynamic simulation is intended to be scalable for use in other industries which consider implementing reusable packaging systems for their global supply chain.

CHAPTER 2

LITERATURE REVIEW

The literature review focuses on the purposed research objectives: comparing the financial and environmental performance between reusable and expendable shipping container systems for global supply chains. It is organized by four sections.

The first section is about the relationships between packaging functions and supply chain costs. It highlights importance of extended packaging functions such as sustainability and standardization, and shows how these functions affect packaging decisions.

The second section summarizes previous research on reusable versus expendable packaging shipping container systems. Findings regarding the advantages and disadvantages of these two systems are compared, and limitations of the research methods are discussed.

The third and fourth sections introduce theories and methodologies for activity-based costing and dynamic simulation. General concepts, approaches, limitations and rationales for the proposed study are explained based on the previous studies.

The results of literature review support the need for the proposed study and provide several pieces of information as a way to summarize the literature. In order to identify the true costs and benefits of a returnable packaging system in the global supply chain, relationships between packaging and supply chain should be viewed from holistic approach. Important criteria for the packaging decision making process such as initial costs, environmental effects, ownership and standardization are discussed, and these will be key variables for the study.

The literature review justifies the methodological framework to develop the proposed cost simulation model. Few researchers in the packaging field have used this combined approach, and so the literature review on these two parts is allocated to explain the concepts and general processes. Results of literature review leave important questions unanswered, which will be the objectives of this study. The limitation of the available literature proves the way for the creative work to be done for this research.

2.1. The relationships between packaging and supply chain

2.1.1. Function of packaging in supply chain

Packaging is the basic unit of logistical activities and its influence on supply chain efficiency is significant (Twede, 1992). Packaging plays major role in the operation of efficient and effective supply chains. As a key element of a supply chain, packaging not only protects the product from physical damage, but affects every logistical activity, such as transportation, freight handling, packing, warehousing, waste disposal and information management. Changing a packaging type, size, and operation methods can significantly affect overall supply chain efficiency in terms of economics and sustainability. Packaging managers and engineers need to make sure that a packaging system must meet required functions in the supply chain without sacrificing its primary goal, protecting a product.

The efficiency of material handling during supply chain processes is greatly influenced by package design, unitization and communication characteristics. The weight, volume, and fragility of industrial packaging determine transportation and material handling requirements and efficiency of overall logistical system performance (Bowersox, Closs, & Cooper, 2012).

Positive impact of proper packaging on supply chain can be found from numerous case studies. For example, a smart label that utilizes active radio frequency identification (RFID) technology can improve product traceability (McCartney, 2006). IKEA's "flat pack" furniture system significantly reduces transport cost and helps to take significant strategic advantage over other competitors (Rundh, 2009).

Kumar, DeGroot and Choe (2008) surveyed various US hospitals and concluded effective packaging design and packaging management significantly impact the supply chain cost for the health care industry. They emphasized that a more efficient and cost effective supply chain can be achieved with improved logistical packaging designs and collaboration with packaging suppliers, but there are no main drivers to the change. According to their estimation, improved packaging management can reduce the 1 million US dollars spent on waste disposal each year.

It is no wonder that some researchers insist that, for more effective packaging design for supply chains, packaging should be developed during the product development stage, so it does not restrain possible logistics improvements and cost saving opportunities (Klevas, 2005).

Packaging, as a function of supply chain, affects multiple supply chain metrics and is influenced by various supply chain activities such as freight handling, packing, warehousing and waste management. In order to explore the impact of packaging on a supply chain, the first step to understand interactions with a supply chain and identify the measurable performance metrics.

Hellstöm and Saghir (2006) focused on the interactions between the packaging and retail supply chain process and observed how each packaging function affects each logistics process. They found out that increasing standardization reduces handling costs, transport equipment costs and vehicle waiting time for loading and unloading, while increasing modal choices for shippers. They identified packaging activities in a retail supply chain and explained how retail supply chain processes are related to the each packaging activities, but they did not provide specific metrics for measurement.

Blanck (2008) discussed how the packaging dimension and weight ultimately affect distribution environmental impacts and energy use. For packaging optimization, he identified five key packaging performance drivers: packaging size, shipping weight, shipping densities, damage and reusable packaging.

Kye, Lee, & Lee (2013) discussed the perceived impact of packaging logistics on the efficiency of freight transportation (EOT) by developing a conceptual model with seven hypotheses based on previous literatures. For factors such as box modularity, palletization, returnable system, and information system were tested if these factors impact on EOT. This study only provide theoretical results and a statistical model based on a survey, therefore further development is necessary.

From the supply chain perspective, performance and optimization have been a long time issue and many measurable performance metrics and measuring tools have been introduced and applied in the logistics industry. A supply chain is a network of relationships among trading partners (Lockamy III & Smith, 2000) and consists of integrated activities between functions and companies (Hoek, 1998). A number of researchers have explored these interactions and performance measurements.

Andersson *et al.* (1989) reviewed previous research and proposed a model that separates the measures into internal and external logistics performance. Key elements for internal logistics performance measurement consist of logistical performance results compared to budget including inventory value, capital cost, turnover rates, productivity, internal lead times, etc. For external performance, they investigate the key performance indicators between units in the company, between the company and the customers, and between the company and the suppliers. As shown in Table 1, they suggested key elements of performance measurement that can be compared for the overall logistics performance versus the performance of the entire company.

Table 1: Key elements of performance measurement of logistics

Areas of Interest	Key Elements of Performance Measurement
Internal performance within the units	• Result vs. budget (logistics costs) - inventory value, capital cost - turnover rates - productivity - internal lead times
External performance between the different units in the company	• Availability (lead time and/or service level) • Reliability (quality and timing)
External performance for the entire company towards the customers	• Customer service elements (availability, reliability, lead times, etc.) • Turnover
Supplier performance towards the company:	• Quality • Reliability • Lead time • Price
The relation between the logistics performance and the performance of the entire company	• Result vs. budget - Return on assets - Total turnover rate - Total value in stock - Total capital cost

Ronen and Boaz (2005) introduced the six key global supply chain performance measurements defined in Table 2. These six are typical measurements for supply chain metrics, but definitions vary depending on the purpose of the study.

Each supply chain performance metric is an element for performance measurement and a packaging and packaging system can impact each element. In this research, key supply chain performance metrics affected by packaging will be identified and used for estimating overall efficiency and cost calculations.

Table 2: The six key global supply chain performance measurements

Performance measurements	Definitions
Throughput	The cash flow generated by actual sales (total sales minus refunds and cancelled transactions, etc.)
Operating Expenses	The total fixed expenses of the organization at the measured period. (Direct labor, indirect labor, rent, machine maintenance, etc.)
Inventory	Inventory costs of raw materials, work-in-process and finished goods (Note: The three inventory types are measured only by the costs of raw materials with no further allocation of costs.)
Lead Time	Response time from the customer's perspective
Quality	Each organization's own measurement of quality such as percentage of defects, percentage of products returned by customers, non-conformance quality costs etc.
Due-date performance	The organization's ability to adhere to its quoted delivery schedule.

2.1.2. Packaging cost in a supply chain

The goal of a business is to maximize profits, and profits are revenue after subtracting costs. In current competitive business logistics, reducing costs is often easier than increasing revenue to maximize profit. Without comprehensive financial analyses, business decision makers find it difficult to identify opportunities for improvement throughout an entire logistics system (Holmes, 1999). However, there has been little research to model and measure the performance and cost of packaging in a supply chain. Most studies have not successfully reflected the actual industry situation.

Twede (2009) argued that, although the importance of packaging in supply chains has been widely addressed and financial performance measurement of packaging have been discussed for decades, the total cost and value of packaging have not been successfully estimated. Most models and metrics (where there has been measurement) are focused on specific supply chains and a particular point of view.

The lack of the ability to quantify packaging value and measure its costs usually results in the total cost of packaging being neglected disappearing in the supply chain cost. Azzi *et al.* (2012) argued although its impact on supply chain costs and performances can be overwhelming, packaging activities are often perceived as a cost rather than a value added activities.

Most companies are not aware of the importance or nature of packaging-related costs, so they often fail to include important logistical activity costs in their total packaging cost estimations (Mollenkopf*, et al.* 2005). Limited resources and the lack of reliable packaging cost information make it difficult to make packaging management decisions (Dubiel, 1996). Dubiel (1996) concluded that many companies are not aware of the importance of packaging costs and do not attempt enough to discover potential cost saving options by separating packaging costs from prime cost activities such as logistical process. He pointed out that companies do not have enough knowledge of type of packaging cost, how to calculate the true packaging cost, and how to separate prime cost (such as manufacturing cost) from packaging cost.

The perception of total packaging cost in industry largely depends on a company's own self-interest. For example, Table 3 shows packaging cost criteria from several packaging suppliers' point of view: NEFAB USA (2010), John Henry Packaging Group (2010) and Security Packaging (2010)

Table 3: Examples of packaging cost criteria from packaging suppliers

Packaging cost criteria	Company
• Costs beyond materials and machinery are not aggregated or reported • Cost of filling and handling • Repacking through supply chains • Waste disposal/recycling costs • Externalities like pollution and resource depletion	NEFAB USA (2010)
• Product cost • Packaging Inventory • Obsolescence (e.g. packaging scrap) • Packaging distribution methods (e.g. shipping distance, delivery service, etc.) • Aesthetics (e.g. shelf appeal) • Quality • Service (e.g. meeting peak order cycle) • Purchasing	John Henry Packaging Group (2010)
• Cost of raw materials • Direct Labor • Indirect labor • Material movement • Warehousing • Waste management • Overtime • Quality control • Machinery operation	Security Packaging (2010)

Although these companies are all suppliers, NEFAB USA and Security Packaging tend to emphasize material costs and physical distribution costs while John Henry Packaging Group considers more about service and marketing costs. Many companies often fail to include some of important logistical activity costs in their total packaging cost estimations.

While calculating total packaging costs is generally subjective and some cost metrics are very difficult to quantify, identifying measureable packaging cost metrics and maintaining consistency are very important when it comes to comparing the impact of different packaging systems on a supply chain. Because of strong interactions of packaging and supply chain activities and functions, the impact of different packaging systems influence the performance metrics of the supply chain and vice versa. Not all performance metrics for supply chain are significantly influenced by packaging performance, but key evaluation factors will be identified for this study.

2.2. Reusable versus expendable packaging

This section of the literature review will focus on decision factors for choosing a reusable or expendable packaging system in a supply chain. Based on published studies, three factors including cost, ownership and standardization are examined and discussed.

2.2.1. Cost aspects

Aside from the environmental benefits, several companies have found that reusable packaging can be a profitable logistical solution. Reusable shipping containers can improve a company's supply chain management. Manufacturers have looking for more cost effective and geometric options such as collapsible or nestable features of containers. Potential advantages of reusable packaging operations include the following:

- *Reduces packaging waste, improve product protection and cut logistical operation costs by improving cubic efficiency for transportation and storage (Mollenkopf et al., 2005)*
- *Reduces packaging costs and environmental impacts (Silva et al., 2013)*

- *Reduces labor costs* (Holmes, 1999)
- *Reduces costs, shorter lead times, and better product quality with implementation of ISO 14000 standards* (Hanson, 2004)
- *Applies standard and ergonomic design of reusable containers that can reduce or eliminate multiple packing and repacking processes which create unnecessary complexity of distribution network, additional handling and material costs and increase lag time* (Modern Material Handling, 2006)

The vehicle assembly industry has been the leader in reusable packaging use during the past two decades. In 1995, John Deere & Co. invested $20 million in a reusable packaging system. Global automotive companies such as Ford, GM and Toyota have applied returnable container systems successfully (Kroon & Vrijens, 1995).

Besides the initial financial investment of purchasing reusable packages, operating a reusable packaging system increases transportation costs for returns, management costs for tracking, cleaning, sorting and storage space (NEFAB USA 201; Mollenkopf *et al.,* 2005; Twede 2004).

Although switching from expendables to reusable packaging containers has been a trend in some industries, there is no standard method of total cost estimation. Cost categories and the amount of details for packaging costs differ by researcher and the purpose of the study. Researchers exploring the supply chain effect of reusable packaging compared to expendable packaging have modeled different costs and activities although most cost research regarding reusable packaging management and cost evaluation is limited to material (packaging) and handling associated costs within simple logistical networks or domestic distribution. Since it is so difficult to estimate true packaging costs, and most companies do not have sufficient and reliable packaging cost information, it is difficult to make with decision whether they should switch from expendable packaging to reusable packaging.

Holmes (1999) summarized key criteria to consider reusable packaging operation for a company. Comprehensive financial analysis is the most important step to consider reusable packaging system. The decision makers need to identify opportunities for improvement throughout entire logistics system. The capital investment is significant, so this would not be possible without sound communication with key players in logistical chain including senior management staff and stakeholders.

Rosenau *et al.* (1996) outlined several cost factors that differentiate returnable packaging from expendable packaging. The Net present value (NPV) financial evaluation method is recommended because returnable packaging should improve logistics profitability comparing expendable packaging.

Mollenkopf *et al.* (2005) used relative cost approach to compare reusable and expandable packaging case study based on GM powertrain. Key metrics applied were container unit cost, cycle time, pack quantity, delivery distance, daily volume, average daily volume and peak volume. Although this research was limited to simple physical distribution of a set of automotive parts, it used a practical calculation method by simplifying cost factors of packaging and distribution activities (Mollenkopf *et al*., 2005). As shown in Table 4, they analyzed transportation, labor, recycling and disposal costs to compare packaging costs for automobile suppliers.

Honaker (2000) identified that the most important cost drivers to manage for reusable packaging system are cost per use, returnable packaging asset utilization, and average days in cycle. He considered “cost per use” to be the most important metric because this represents the total cost accumulated from the all activities associated with a supply chain. “Returnable packaging asset utilization” is related to the productivity of returnable packaging containers in the system and a measurement of utilization of containers. The “average days in cycle” relates to the total amount of time required for the complete rotation of the container.

Table 4: Comparison of reusable and expendable packaging costs

Reusable packaging costs	**Expendable packaging costs**
1. Transportation cost • Base transportation rate • Delivery distance • Frequency of supply • Average daily volume • Discount rate for return transportation (R) • Number of stops (R) • Stop-off rate (R) 2. Labor cost • Time to handle container • Labor rate • Pack quantity 3. Recycling revenue • Recycling rate per pound • Container weight • Pack quantity • Working days per year (R) • Cycle time (R) • Container life (R)	4. Transportation cost • Base transportation rate • Delivery distance • Frequency of supply • Average daily volume • Discount rate for return 5. Labor cost • Time to handle container • Labor rate • Pack quantity 6. Disposal cost • Disposal rate (E) • Container weight (E) • Pack quantity (E) 7. Recycling revenue • Recycling rate per pound • Container weight • Pack quantity

Note: R: Reusable container only, E: Expendable container only.

Some industrial calculation models have been developed to compare the basic cost differences of one-way corrugated packaging verses reusable plastic packaging. The “Quick Economic Calculator” is a cost comparison tool developed by the Reusable Packaging Association (RPA) (2010). The model uses basic assumptions and requires users to input various cost components into the model, such as purchase price, dwell time, annual number of packages shipped per year, returnable container cost per use, costs related to return containers, possible savings from packaging waste costs and labor costs. It is noticeable that this calculator does not include benefits of standardization by using returnable containers such as easier load, unload and better cube utilization. While the model uses factual inputs from prospective users, it is intended to be directional and not an absolute indication of exact cost benefits for an end-user.

Palsson *et al.* (2013) developed a theoretical evaluation model for the comparison of one-way and returnable packaging system used for the automotive part packaging and compared the environmental and economic impacts of two different packaging systems. They selected five environmental and six economic criteria and evaluated two packaging systems by calculating CO_2 emissions and costs. They provided very practical way to evaluate sustainability of a packaging system in a particular supply chain, but this paper was limited itself by taking only one case study and could not represent complexity of the international supply chain.

Dubiel (1996) insisted that the first step to compare the cost and performance comparison between reusable and one-way packaging systems is to separate the packaging process. He broke down packaging costs into ten categories as shown in Table 5. The primary categories are materials, machines, transport, storage, reusable systems, building, handling, resulting, waste disposal and other miscellanies, but the list and categories can be extended depending on organization's specific circumstances.

Dubiel (1996) compared cost types and structures of reusable, expendable packaging in cyclic system and one-way packaging. Expendable packaging in cyclic system includes costs of recycling, disposal, packaging management and redistribution, and one-way packaging is not.

Table 5: The breakdown of reusable packaging costs

Cost category	Detail costs	Cost category	Detail costs
Material cost	❑Cost for packaging material ❑Cost for packages ❑Cost for packaging accessories	Cost for buildings	❑Allocated write-offs for buildings ❑Allocated interest charges ❑Rent ❑Energy cost for light, heating and air conditioning ❑Cleaning cost
Cost for machines, appliances and tools (for manufacturing of packages and packing)	❑Allocated write-offs for machines ❑Allocated interest charges ❑Energy cost ❑Maintenance cost	Handling cost	❑Labor cost for manufacturing packages ❑Labor cost for packing
Transport cost (distinction between internal and external transports)	❑Allocated write-offs ❑Allocated interest charges ❑Labor cost ❑Energy cost ❑Freight	Resulting cost	❑Cost for redelivery , repair and delayed deliveries ❑Cost for settlement of damages ❑Cost for losses
Storage cost	❑Allocated write-offs for warehousing ❑Allocated interest for warehousing ❑Allocated interest for stored goods ❑Labor cost	Waste disposal cost	❑Collection cost ❑Sorting cost ❑Return cost ❑Recycling cost ❑Waste disposal cost (deposition, incineration) ❑Management cost
Cost (additional) for reusable systems	❑Allocated interest charges for circulating packages ❑Cleaning cost ❑Repair cost ❑Deposit fees	Other cost	❑Labor cost for controls ❑Cost for breakage and rejects ❑Insurance cost/premiums ❑Allocated risks

As shown in Table 6, reusable packaging requires additional costs for management such as capital lockup, repair, and cleaning compared to one-way and expendable packaging in cyclic system. However, allocation of costs and cost level for management varies depending on the particular system and management. For example, Dubiel did not include the cost for recycling and disposal for one-way packaging, but this cost cannot be ignored nowadays.

Table 6: Cost types and structure of reusable systems (modified from Dubiel 1996)

Types of costs	Reusable packaging	Expendable packaging (in cyclic system)	One-way packaging
Cost of capital lockup Cost of repair Cost of cleaning			
Cost of recycling/disposal Cost of administration (packaging management) Cost of redistribution			
Cost of carry (cost of damage, loss etc.) Cost of transportation and distribution Cost of handling Cost of Store for packaging material Cost of production (machines, facilities etc.) Purchase cost for packaging materials			

Note: The graphs in this table are only for representing type of costs and do not indicate amount of costs.

Kim, Glock and Kwon (2014) developed a stochastic returnable transport items (RTI) inventory model for a closed loop supply chain of a perishable product consisting of a single supplier and a single buyer. They examined three different cases depending on the stochastic lead time of RTIs: a) RTIs are returned early, b) RTIs are returned late, c) RTIs are returned late and shortages occur. They considered the following types of costs: inventory cost of keeping finished products and RTIs at the supplier and the buyer, cost of deterioration, shortage cost, and setup and ordering costs. The results of mathematical simulation showed that the longer lead time cause higher probability of large back orders by buyer and may lose competiveness of the supply chain.

Although outsourcing from overseas is now common practice in the manufacturing business, none of the cost models have been applied to international logistics operations. This is because reusable packaging containers are more likely to be used for domestic with well-organized distribution networks. However, international applications of reusable containers may be very effective depending on the managing system and container design.

With development of international pooling networks and product/package tracking technologies such as RFID, international reusable packaging operations may be viable option in an increasing number of cases. Maleki (2011) proved that implementing automatic identification technologies can improve the management of the returnable containers effectively.

Because of continuous increases in awareness of environmentally-friendly supply chain practices and improvement in the efficiency of global logistics systems, reusable shipping containers are increasingly being considered by original equipment manufacturers and their global third-party logistics providers (3PLs). A study on environmental sustainability performance of the major global 3PLs support the idea, as many 3PLs generated substantial cost savings from their sustainability initiatives. Global 3PLs are aggressively seeking growing opportunities with their sustainability initiatives as a “market differentiation factor” (Lieb & Lieb, 2010).

2.2.2. Impact of ownership

It should be noted if a reusable packaging system does not work properly; it can become a very expensive expendable packaging that increases packaging waste. As the automotive industry has realized the value of packaging system management with by trial-and-error from the past, reusable packaging systems have different financial and environmental effects, depending on the maturity of the program (Twede, 2004). The system should be managed and monitored by a pool operator with authority and responsibility especially during the collection process (McKerrow, 1996).

Designing an optimized return logistics system for returnable packaging containers starts with several important questions such as following (Kroon and Vrijens 1995, p. 63):

- *How and who should operate containers?*
- *How many containers should be needed in the system?*
- *How many and where the container depots should be?*
- *What are appropriate operation (service, distribution and collection) fees?*

Answers for these questions can vary depending on the ownership of the reusable containers.

Ownership options are an important factor to be considered because effectiveness of the reusable container application is largely dependent on efficiency of the managing system. Ownership (whether supplier, receiver (customer) or 3PL), influences a range of factors including the respective bargaining power of the parties involved, compatibility with production systems and the respective logistical capabilities of suppliers/receivers (Holmes, 1999).

McKerrow (1996) used the term "equipment pool" for any interchangeable and reusable packaging, and compared the five types of ownership: manufacturer, customer, joint, common and third party. Examples are shown in Table 7.

Table 7: Types of ownerships of reusable packaging

Types	Ownership	Examples
Manufacturer owned	A manufacturer	Tightly closed loop system such as between a glass manufacturer and a bottling plant
Customer owned	A receiver	Some automotive assemblers
Jointly owned	An industry association or independent body.	EURO pallet pool system
Commonly owned	A group of companies or cooperation	The Dutch Auction pool which is owned by co-ops of growers or fishermen
Third-party owned	An independent third party	CHEP pallet pool, IFCO fresh produce crate pool

Holmes (1999) examined three ownership arrangements (supplier, receiver and third-party) which are affected by various factors such as bargaining power of the parties involved. Although he identified some advantages and disadvantages for each of the three ownership options in Table 8, he explained that ownership decisions depend on negotiations and different circumstances.

Table 8: The advantages and disadvantages of the returnable container ownership options

Ownership types	Advantages	Disadvantages
Supplier-owned	- Reduced costs to supplier and customer - Supplier may enhance customer loyalty by reducing waste and management problems - Supplier can optimize logistics efficiency by own way	- Supplier bears Initial capital costs, tracking and maintaining costs
Receiver-owned	- Greatest potential to achieve financial benefits - Receiver can optimize logistics efficiency by own way	- Receiver bears initial capital costs, tracking and maintenance costs – higher risk
Third-party-owned	- No initial capital costs needed - Tracking and maintenance assured by contractor	- Reduced potential for savings

Dubiel (1996) viewed that finding a right decision is depending on technological suitability, meeting of ecological and legal requirements, and ultimately, the costs. He explained advantages and disadvantages for each of the three reusable systems: individual, bi/multilateral and pool as shown in Figure 1.

The individual system does not use standardized reusable containers and works only between senders and customers, while the bi/multilateral and pool system can exchange standard reusable containers more freely. For pool system, because an outsourced pooling company controls containers, forward and return logistics are simpler than other systems.

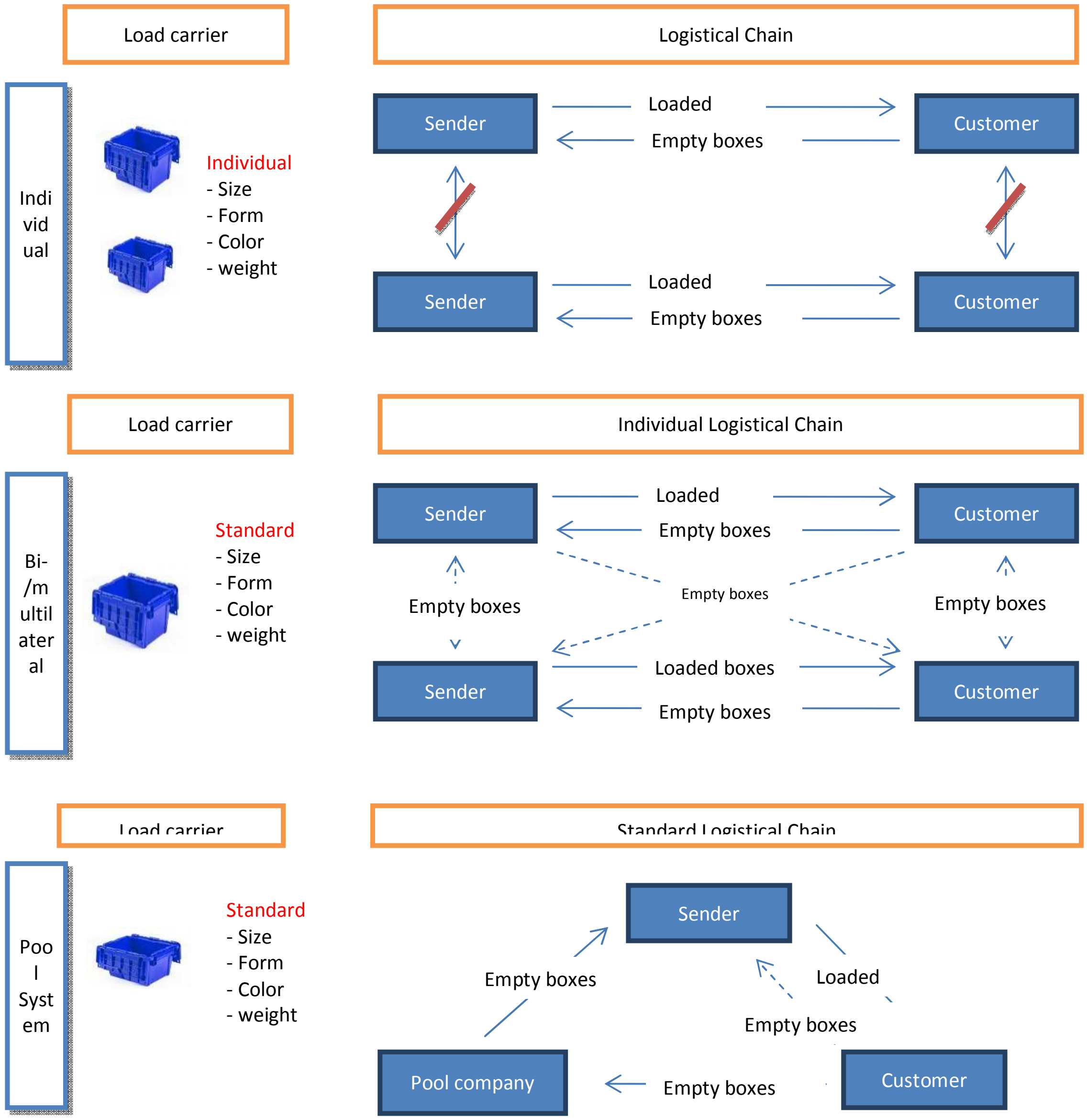

Figure 1: Organizational levels of reusable systems

Kroon and Vrijens (1995) summarized return logistics systems in the Netherlands into three types depending on responsibility of returnable container owner shown in Table 9. They find that most logistics operations including distribution, collection, cleaning and maintenance are handled by the 3PLs (Kroon and Vrijens 1995, p. 61).

Table 9: Return logistics systems in the Netherlands

System	Essence	Partners	Responsibility	Possibilities
Switch pool	Every partner has an allotment	Sender, recipient	Every partner is responsible for his own allotment	Direct switch
		Sender, carrier and recipient		Exchange-per-exchange switch
With return logistics	Return logistics by agency	Agency, sender Carrier, recipient	Agency	Transfer system Depot system with booking Depot system with deposit
Without return logistics	Rental of the containers	Agency, sender	Sender, also for the return logistics	Rental of the containers

From the perspective of 3PLs, Hofmann (2009) pointed out lack of studies in supply chain. The role of 3PL is particularly important in the international operation of returnable packaging systems, but this has not been considered because there have been lack of systems and participating partners. This has been a major disadvantage for reusable packaging systems in growing international trade.

In some cases, RPCs owned and controlled by 3PLs may lead to a significant reduction in international logistical activities such as extra handling, packaging waste and purchasing costs. For example, Eroski (Euro Pool System, 2010), a Spanish supermarket chain which has a partnership with Euro Pool System, reported the significant growth of the number of circulations of reusable crates for their fresh products from 250,000 to 55,000,000 per year between 1998 and 2009. However, it is still remained unknown how a 3PL-operated RPC system can contribute to a company in terms of profitability, sustainability and efficiency of international supply chain.

2.2.3. Impact of standardization

A primary requirement for the successful use of reusable containers is standardization of containers. Standardized packaging sizes, materials and weights enable supply chain integration. Standardized packages facilitate the automation of conveyor flow, increase efficiency of inventory control, and reduce purchase costs (Bowersox, Closs, & Cooper, 2012).

The success of Eroski Co. confirms that the standardization of the packaging ensures efficient order picking and low purchasing costs. Eroski Co. claimed that an established standardized and returnable packaging system can also contribute to their future supply chain plan, automatic pick system (Euro Pool System, 2010).

Standardization of packaging can significantly reduce supply chain management cost by establishing efficient unit load systems. Unit load system affects every distribution element such as transportation, storage, packaging, shipping and handling, and is a key cost driver of 12 to 15 percent of retail sales price (A.T. Kearney, 1999).

Standardization of pallet and packaging is the first step for efficient and seamless unit load systems, but no universally accepted pallet dimensions exist. Pallet dimensions vary depending on logistical environment and history of countries and industries, but a few different dimensions are widely used. Table 10 shows typical pallet dimensions and region most used in (Clarke, 2003).

Table 10: Typical pallet dimensions

Region most used in	Industry most used in	Dimensions	
		mm (W x L)	in (W x L)
North America (by typical industry)	Grocery, many others	1219 x 1016	48 x 40
	Telecommunications, paint	1067 x1067	42 x 42
	Drums	1219 x 1219	48 x 48
	Military, cement	1016 x 1219	40 x 48
	Chemical, beverage	1219 x 1067	48 x 42
	Dairy	1016 x 1016	40 x 40
	Automotive	1219 x 1143	48 x 45
	Drums, chemical	1118 x 1118	44 x 44
	Beverage	914 x 914	36 x 36
	Beverage, shingles, packaged paper	1219 x 914	48 x 36
	Military 1/2 ISO container, fits 36" standard doors	889 x 1156	35 x 45.5
	Retail	1219 x 508	48 x 20
Europe, Asia	Similar to 48x40", ISO2	1000 x 1200	39.37 x 47.24
Europe	Fits many doorways, ISO1	800 x 1200	31.50 x 47.24
	ISO0, half the size of EUR	800 x 600	31.50 x 23.62
	Quarter the size of EUR	600 x 400	23.62 x 15.75
	One-eighth the size of EUR	400 x 300	15.75 x 11.81
Asia	Japan, Korea	1100 x 1100	43.30 x 43.30
Australia	Fits for Australian Railway	1165 x 1165	45.87 x 45.87

Although several pallet standard dimensions are recommended and actively discussed in the International Standard Organization (ISO), packaging standards have not drawn much attention. The 600x400mm master module based on a 1200x1000mm pallet is the only dimension that the ISO has accepted (International Organization of Standardization, 2012)

Although this module is widely accepted by European and the US, some Asian countries have a different packaging module dimension as result of different national pallet standards, 1100x1100mm. For example, based on the fact that the area dimensions of standard pallets for the unit load system in Korea are 1100x1100mm and 1200x1000mm, the footprint size of 600x500mm has been advocated as the standard packaging module. This module is beneficial when several different sizes of packages need to be stacked together on a pallet as well as improving the exchange process of different sizes of pallets during the international shipping and handling. A new standard packaging module could improve dimensional integrity in the various international distribution environments (Kim, Lee, & Lee, 2009).

Pereira (2008) emphasized the important of packaging dimension standards. He studied the modular packaging system for fruit and vegetables and found out that two major factors, packaging standard sizes and the ability to interlock, were most important to improve stability and security of loads. He recommended a pallet standard size of 1,000mm x 1,200mm and divided it into modules 600mmx400mm, 400mm x 300mm and 300mm x 200mm (Pereira, 2008).

Peres (2008) recommended using two basic foot prints for packaging dimension standardization: 600mm x 400mm and 400mm x 300mm. He pointed out that the vital element of the total cost of the packaging is not simply the cost of the containers, but the cost involved in the supply chain systems. For example, in the US, a reduction of 14 percent in the cost of transporting grapes, and of 9 percent in the cost of oranges, is expected if distribution systems improve cube utilization throughout the supply chain.

Global automotive companies are considering standardization of pallet and packaging dimensions because this can eliminate unnecessary packing and repacking processes. Although U.S. automotive companies have well established returnable packaging systems, which use the basic footprint size of 48 x 45 inches, these have been a major obstacle for efficient global logistics. Due to different pallet and packaging footprints, many costly activities such as transferring from one pallet to another only increase overall logistics costs and decrease efficiency of logistics.

Recently, AIAG (American Automotive Action Group), a globally recognized and opinion leading organization of automotive OEMs and suppliers formed a working group to establish a global pallet footprint and recommended footprint of 1140 x 980mm pallet as the global standard pallet for automotive industry (Automotive Industry Action Group, 2010). The importance of packaging standardization in supply chain is currently regarded as one of the biggest issues in automotive logistics among industry experts (Automotive Logistics, 2010).

Furthermore, global standardization of pallets and packages can increase business opportunities for 3PLs like CHEP, Goodpack and iGPS. For example, CHEP, a multi-national pallet rental company, recently launched a global container and IBC pool business. Global pallet and packaging rental companies which already established their own pallet and packaging standards will need less investment while having more efficiency to run pool systems if packaging, pallets and other logistical means are globally standardized.

However, the trade-offs of standardization of packaging in logistics should not be ignored. Although standardized reusable packaging could fulfill logistical requirements and work well in marketing and environmental perspectives, replacing current transport packages requires major investments in packages and in the distribution network. For many cases, “all-embracing integration” concept can be a problematic and difficult to implement in real world. Adaptability and constraints of packaging standardization differ depending on companies and industries, for this reason, possible trade-offs of standardization must be carefully considered (Jahre & Hatteland, 2004).

Packaging standardization is a crucial element to improve efficiency of returnable packaging system in a supply chain and can help to integrate a supply chain. For international supply chains in the automotive industry, standardized reusable packaging can facilitate smooth and integrated packaging and logistics interfaces from suppliers to assembly plants. Hence, impact of packaging standardization on international automotive supply chains should be identified and financially studied.

2.3. Activity-Based Costing (ABC) in logistics

In order to determine packaging costs in a supply chain, it is important to understand that packaging not only consists of materials, but is also associated with many activities such as packing, unpacking, filling, palletizing, etc. Many activities are directly or indirectly mixed with supply chain activities and these are very hard to convert to financial terms, so Activity-Based Costing (ABC) concepts are used for this research.

Traditionally, supply chain management was viewed as a cost-generator rather than a possible source of competitive advantage. There were no distinctive concepts or discipline for supply chain management. In the 1980s, the discipline of supply chain management evolved and many researchers and companies started to find benefits in supply chain management. However, it is still very difficult to find the true cost of supply chain management because of different nature of the business compared to manufacturing. Logistics activities do not just generate cost, they also generate revenue through the provision of availability – thus it is important to understand the profit impact of logistics and supply chain decisions.

Especially in today's global logistics environment, it is difficult to make decisions based on using traditional cost accounting methods alone because it limits or distorts the true financial performance in an unstable and unpredictable market with a larger portion of indirect variable costs.

In modern logistics process, overhead and indirect costs are a larger component of the overall cost structure than direct costs due to an increased regulatory and environmental rule compliance; wider customer base and subsequent delivery channels; new and more complex technologies; and proliferation of product lines. (Kosior & Stron, 2006)

Traditional cost accounting systems such as a volume based cost system, overhead and indirect costs would be allocated to a job or function based on direct labor hours, machine hours, or direct labor costs, that leaves business decision make harder. Traditional approaches to accounting based upon full-cost allocation can be misleading and dangerous – and it would be impossible to calculate true packaging and logistics costs. It is no surprise that ABC methods have drawn interest from various industries because ABC aims to identify the cost attached to each level of activity (e.g. cost per line item picked, cost per delivery, etc.). ABC can present a clearer picture of the true packaging and logistics costs.

Lack of knowledge of logistics costs leads to businesses making uninformed decisions. From the logistics cost survey by Supply Chain Digest (2006), "40 percent of respondents said their primary measure of logistics costs is as a percent of sales. This compares with 25 percent who said the primary measure was in absolute cost, 16 percent who said it was cost by some unit of weight (hundred weight, kilograms, etc.), 11 percent who said it was cost per some unit measure (case, unit), and only 8 percent who said they used "activity-based costing" as the primary measure." Based on the report, logistics costs could be distorted depending on each reporting method, and there is no way to compare costs of logistics among companies directly.

Today's competitiveness of the global market increases the need for ABC costing systems. In the past, although traditional costing systems might generate incorrect costs and profit data, companies could make up or hide their mistakes because products or services with bigger margin of profits could compensate for the less competitive products or services. Now, in the world where margin of error is slimmer and the market is more competitive, knowledge of real costs of the products and services is becoming the key to company survival (Themidol *et al.,* 2000)

2.3.1. The general concept of ABC

Activity-based costing (ABC) has been introduced as more reasonable cost accounting method in order to find and measure more accurate and realistic cost allocations in a company. While traditional accounting methods allocate indirect costs to direct costs or direct labor costs, ABC attempts to turn overhead (indirect costs) into direct costs based on the number of activities related to the products (Varila *et al.,* 2007).

The American Institute of Management Accountants defined ABC as follows; "A methodology that measures the cost and performance of activities, resources and cost objects, assigns resources to activities and activities to cost objects based on their use, and recognizes the causal relationships of cost drivers to activities" (Themidol *et al.,* 2000, p1149). Themidol *et al*. (2000) summarized the terminology of ABC method as follows:

a. Activities: tasks or sets of tasks that require the consumption or utilization of resources and result in the completion of a specific service, or in the physical transformation of a product from one state to another;

b. Cost object: the final good or service created as a result of the performance of an activity or of a chain of activities *c.* *Resources: the ingredients required for the production of a good or of a service. They are referred to, in their most basic form, as labor, material, and capital*

d. *A cost driver: a variable that demonstrates a logical and quantifiable cause and effect relationship between the utilization of resources, the performance of activities, and the final cost object(s). ABC utilizes a multi- step cost assignment approach, in the first step; the resources consumed in the performance of activities are assigned to activities using "resource cost drivers." In the following steps, resource costs accumulated within the activity centers are assigned to the final cost object(s) using "activity cost drivers. "For simplicity, many use, instead of resource cost drivers and activity cost drivers, the terms resource driver and activity driver, respectively;*

e. *Operational cost drivers or cause of cost: those variables that determine the workload and hence explain why activities are performed. Inasmuch the cost object is considered the end of the trail, the operational cost driver can be viewed as the start of the trail*

f. *Cost object: the target of cost activity performance such as including products, service and customers.*

ABC can help a company to identifying resource allocations, labor-cost based costing and value added activities although it has some limitations. The advantages and disadvantages of ABC versus its traditional counterpart are summarized in Table 11

Table 11: Advantages and Disadvantages of Implementation of ABC

Advantages	Disadvantages
(1) ABC has helped firms across the world to become more efficient and more effective; (2) ABC provides a clear picture of where resources are being spent, customer value is being created, and money is being made or lost; (3) ABC offers a better alternative to labor-cost based product costing; (4) ABC identifies value-added activities; (5) ABC identifies many activity costs that are not related to production at all but are traditionally allocated to products as production cost. On the other hand, it identifies many marketing, selling and administrative costs that should be included to determine better product pricing estimates; (6) ABC indicates the areas where the change in firm operation to reduce costs will allow the firm to satisfy customer demands better; (7) ABC helps retailers with dual channel firms such as a combination of online and counter selling operation to identify how much they spend on marketing and other functions and where the costs should be allocated; (8) ABC eliminates or reduces non-value added activities; (9) ABC allows for the pursuit of competitive advantages to many firms through the identification of relevant cost drivers and activities.	(1) It is a resource-consuming activity. It is costly for the firm to adopt ABC because of the cumbersome accounting changes involved. (2) It is time-consuming due to the lengthy procedures it entails. It takes time for adjustment. (3) It is not appropriate for every firm; typically, firms with low overhead costs will not benefit from adopting this system. (4) It is a labor-intensive operation. (5) The benefits from the implementation of ABC are not always easy to define. (6) It may cause poor labor relations in the firm if people are not willing to buy into this concept or not willing to break from the status quo.

Although an ABC method appears to be very sound in theoretically, it has limitations to implementation in actual practice due to complexity of its operations and difficulty to maintain. Based on the survey conducted by Management accounting quarterly (Stratton & Lawson, 2009), the usage ranking of ABC as a management tool has been dropped from 11^{th} (in 1995) to 22^{nd} (in 2002). Esculier (1997) suggested that ABC should be only considered as “a complementary tool of direct costing management.”

However, Stratton and Lawson (2009) concluded that the ABC method is superior to other accounting methods for accurate overhead allocation, activity cost information, and cost- and profitability measurement. It can help managers to make more informed business decisions.

ABC cannot and does not replace traditional accounting systems and records, but it is useful tool for managers to make more informed business decision. Although ABC used majorly for manufacturing practices, there a number of studies can be found in cost modeling studies in supply chain management.

2.3.2. ABC applied to reusable packaging

Traditional approaches to accounting based upon full-cost allocation can be misleading and make it impossible to calculate true packaging and logistics costs. This is why an ABC accounting method should be considered.

Holmes (1999) found that comprehensive financial analyses are foremost important step to consider reusable packaging system, but it is not easy with traditional costing systems. Traditional costing systems based on volume-based allocation of overhead (or indirect cost) cannot give accurate and actual costing information to managers. This method could distort information, so managers cannot identify the cause and effect of logistical activities and supply chain processes.

Dubiel (1996) expressed that allocation of packaging costs within operational accounting is problematic or impossible. It is very difficult to achieve without structural changes in a company's accounting systems.

ABC methods have drawn interest in supply chain management because it can identify the cost attached to each level of activity (e.g. cost per line item picked, cost per delivery, etc.) by applying ABC to reusable packaging logistics, then a clearer picture of the true packaging and logistics costs will emerge. ABC traces the consumption of resources by identifying "activity cost drivers" which traces particular cost objects such as specific products and services (Brac, 2000). These activity cost drivers can be measured quantitatively and used to calculate total packaging costs.

Application of ABC to reusable packaging logistics could show the advantages of outsourcing activities to a 3PL. Stapleton *et al.* (2004) found that "ABC in a supply chain setting could identify opportunities for eliminating redundant activities existing within the supply chain, chain members with excessive resource consumption patterns, or analyzing alternative channel structures (p. 589)." They suggested that application of ABC in a supply chain might show that it would be more beneficial to outsource the logistics of a firm such as third party logistics providers.

The main elements of the ABC are *resources, activities*, and *cost objects* (Damme & Zon, 1999). ABC traces the consumption of *resources* by identifying *activity cost drivers* which traces particular *cost objects* such as specific products and services (Brac, 2000). These activity cost drivers can be measured quantitatively and used to calculate total product costs. General principles of an ABC model are shown in Figure 2.

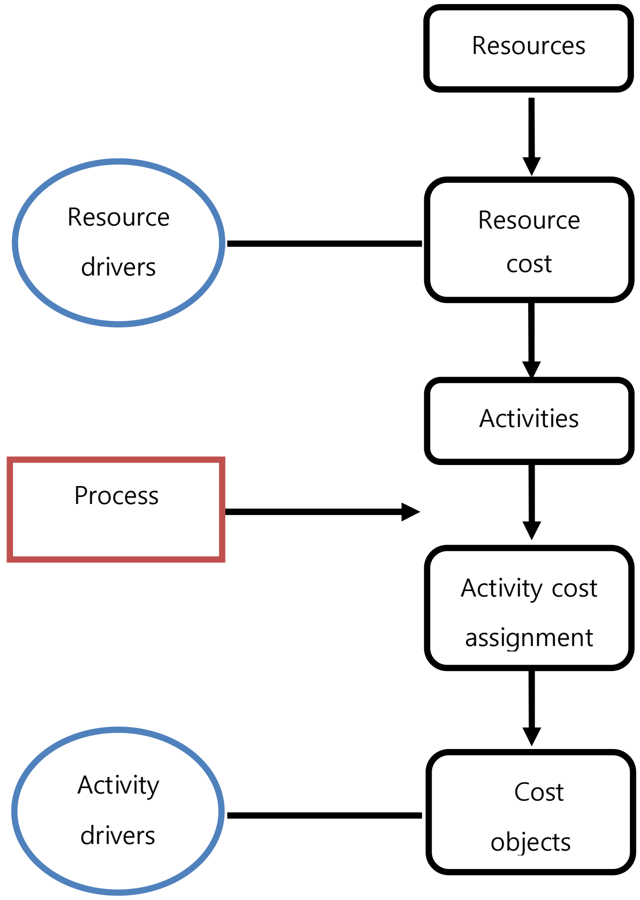

Figure 2: General principles of an ABC model

2.3.3. ABC process in supply chain management

Generally the ABC process for supply chains can be broken down into 7 steps as follows (Lin, Collins, & Su, 2001).

a. Analyzing supply chain functions

b. Breaking processes down into "activities"

c. Identifying the "resources" consumed for activities

d. Determining the cost for each activity

e. Determining "activity cost drivers"

f. Collecting activity data and

g. Calculating the final cost.

2.3.3.1. Analyzing supply chain functions

The first step is identifying and classifying the major processes in supply chain functions. Major processes include packaging, material handling, order processing, transportation, inventory, sorting, and return transportation management. Identified processes can be further analyzed and classified into activities.

2.3.3.2. Breaking processes down into *activities*

This step identifies the main activities that consume resources. Lin *et al.* (2001) suggested breaking down each logistics process into many possible activities for better cost analysis. For example, a warehousing processing in a logistical process may be broken down into the activities like Pick, packaging, labeling, weighing, sorting by region (Lin, Collins, & Su, 2001).

2.3.3.3. Identifying the *resources* consumed for activities

The amount of resource consumption depends on performance of the activities. Different types of activities can result in different amount or type of resource consumption. For example, if a company changes the Load activity by switching from manual labor to an automated forklift truck, labor resource should be changed to equipment resource. Most resources in a company can be categorized into six major categories: labor, materials, equipment, facilities, property, and capital (Damme and Zon 1999, p. 708). Table 12 is an example of activity and resource break downs for the delivery process.

Table 12: An example of breaking down of activity and resources: *Truck Drive*

Process	Activity	Resources
Delivery	Truck Drive	Labor (truck driver's salary)
		Equipment (truck)
		Capital (gas and oil)

2.3.3.4. Determining the cost for each activity

The cost of each activity can be determined by aggregating cost of the resources consumed for the activity, and resource consumption is measured by resource drivers. For example, a *truck Drive* consumes one man hour of work, then the resource is labor (truck driver's salary) and a resource driver is time. It is important to note that for some activities, particularly activities with indirect natures, use only a fraction of resources, extensive interviews and on-site observations are important processes to allocate more accurate resource consumption (Lin, Collins, & Su, 2001).

Every activity cost is influenced by the *activity driver*. An activity driver determines how much of an activity is used to produce a cost object. Examples of activity drivers are number of miles or number of packages. For example, an activity cost of *order Pick* is influenced by the activity driver such as *number of cases per order* since *number of cases per order* requires key resources such as *labor (time)* and *equipment* to perform the activity (Lin, Collins, & Su, 2001). Only the most relevant activity driver(s) should be identified and used for calculation to reduce confusion and distortion of costs.

Some examples of warehousing and transport activities and activity drivers are as shown in Table 13.

Table 13: Main warehouse and transport activities and activity drivers

	Activities	Activity drivers
Warehousing	Order receipt	Order volume and order source (electronic data interchange (EDI), fax, phone, or post)
	Unload incoming goods	Pallets or cartons
	Quantity and packaging	Pallets or cartons
	Palletize	Quantity of cartons
	Check incoming goods	Quantity and quality of supplier(including returns)
	Put away incoming goods	Quantity and number of returns
	Pick	Number of visits to pick location and percentage of back orders
	Packaging and labeling	Number of orders picked
	Replenishment	Quantity
	Load outgoing goods	Quantity
Transport	Delivery to consignee sites	Distance and square meters of pallets throughput
	Empty pallets and container returns	Space occupied and time required
	Unload in consignees' sites	Number of consignments and kind of consignee
	Collection at consignor locations	Distance and number of collections
	Sorting	Number of consignments and number of cartons per consignment
	Trucking	Distance and square meters of pallets throughput
	Booking in	Number of consignments to specific consignees
	Proof of delivery	Number of consignments
	Invoicing	Number of consignments

2.3.3.5. Tracing the costs to the cost objects

Activity drivers are usually expressed on a cost per unit basis such as a dollar amount per activity, derived by dividing the total cost of resources used on the activity. An example is the labor hours spent by the number of cases handled (Lin, Collins, & Su, 2001). This cost of each activity is for an individual cost object, which is the “object” of each activity such as products, customers and services. The cost object should be selected depending on the company’s decision making needs.

Table 14 shows some examples of logistics activities, resource (or cost) drivers, resources, activity drivers and cost objects (Stapleton, Pati, *et al.* 2004, p. 592).

Table 14: Examples of activities, resource (or cost) drivers, resources, activity drivers

Activities	Resource or cost drivers	Resources	Activity drivers	Cost objects
Order filling	Number, size or weight of units shipped	Sales liaisons employed, computer interface used	Sales liaison employed to expedite highly preferential customers	Product and/or service and/or customers
Warehousing	Number, size or weight of units shipped	Shelve space used, material handlers employed	Space needed to store type A products	Products and/or customers
Shipping	Number, size or weight of units shipped	Number of carriers used, trucks used	Freight $ used for transportation A products to B markets	Products and/or customers

2.3.3.6. Collecting activity cost data and calculating the final total cost.

In order to determine the total cost of an activity for an individual cost object, the usage amount of a cost driver in performing an activity is multiplied by the unit cost of the driver. If a cost driver of shipping cost is the number of units shipped, for example, the shipping cost can be calculated by multiplying with the unit cost of the driver, $/unit. The unit cost of the driver can be expressed differently depending on cost drivers as $/order, $/hour, etc.

It is important to have a total cost approach in supply chain management because the goal of any organization should be reducing total costs rather than individual activity costs (Lin, Collins, & Su, 2001). Therefore, the manager should see every possible solution and consider trade-offs that might affect total costs of the supply chain.

2.4. Dynamic simulation studies

Managing efficient supply chain is a challenging task for any company considering current business trends of expanding supply chain network globally. Dynamic simulation can be one of the effective analysis techniques for establishing a company's supply chain strategy. In this section, complex nature of global supply chain, characteristics and applications of different simulation techniques and simulation studies in supply chain and packaging are introduced.

2.4.1. Complexity of Global Supply Chain

Extending supply chain globally is not a goal for a major company, but it is a result of a company's efforts to reduce production cost. Theoretically, the company should achieve its main goal: increasing profits by reducing manufacturing, inventory and material costs (Braithwaite, 1992). However, in reality, global sourcing causes complexity in a supply chain. Braithwaite (1992) identified major differences between global and local supply chains which increase the complexity are:

- Extended lead times of supply
- Unreliable lead times and transit times
- Multiple mode and consolidation options
- Intermediate local added value options
- Distrust between cultures.

Braithwaite (1992) pointed out that the most significant of these differences are extended and unreliable lead times of supply. He addressed the importance of the global logistics strategy, and identified packaging as one of the key componentsfor an efficient supply chain network along withmaterials management, facilities, source policy, local value added and transport.

For an automotive supply chain where Just-In-time (JIT) and Just-In-Sequence (JIS) are common practices and supplying automotive parts should be precise like a machine processing, speed and reliability are key indicators for delivery performance. Speed is related to supplier's responsiveness to perform the requested activity or fill an order, while reliability is related to capacity of suppliers to perform the promise (Milgate, 2001).

An extended global supply chain creates uncertainties in the form of demand variability, which can cause various supply chain problems such as planning, scheduling and control of delivery performance.

Complexity of supply chain is caused by great differences between countries in available information technology, logistical infrastructure, labor quality and supplier's performance standards.Among the three critical factors (uncertainty, technological intricacy and organizational systems) which cause complexity of global supply chain, he pointed out that the uncertainty causes most significant impact on delivery speed and reliability (Milgate, 2001).

Uncertainties in supply chain are usually due to demand, supply and technology variations. It is assumed that in a mature, established supply chain network, uncertainties are relatively low. However, if a supply chain network and process are in the early development stage and changing rapidly, high uncertainty in the supply chain occurs (Sun, Hsu, & Hwang, 2009).

Given the complex and dynamic nature of global supply chain, various changes such as new packaging types and new transportation routes could increase uncertainty of supply chain. Because successful implementation of a global reusable shipping container system largely depends on reliable and cost effective management of shipping containers, simulation techniques can be used to identify these uncertainties before the implementation of the system.

2.4.2. Computer simulation techniques

Computer simulation techniques can be a very useful tool in answering "what-if" questions such as redesigning supply chains for an industry or a company (Chu, 2003). Computer simulations have gained popularity because of their ability to solve complex questions by developing models to analyze interactions in the system by changing the input values and observing the output values.

Developments in computer hardware and advanced simulation software have enabled researchers to conduct more advanced and complex dynamic simulation studies. Advanced simulation software provides more flexibility and easy to use functions without the tedious and erratic programming procedures in the past (Kelton, 2010). In the manufacturing industry, dynamic simulation technology has been widely used to improve and optimize manufacturing systems (Tahar & Adham, 2010).

Although simulation is one of the most efficient tools in system analysis, there are some disadvantages of simulation studies which analysts should take account when they design and analyze simulation experiments. First of all, model building needs special training and time consuming efforts (Banks, Carson, Nelson, & Nicol, 2010). Even once it is created; analysts need to understand that the outputs would be randomly different depending on the time frame and probability distributions that the analysts chose. To reduce the unpredictable outcomes, analysts might be able to get rid of the uncertainty in the system, but they have to be careful that they should not over-simplify the system. It is safe to say that simulation study is for an approximate answer to the right problem rather than an exact answer to the wrong problem (Kelton, 2010).

A 12 step process of discrete event simulation is suggested by Banks *et al.* (2010).

a. *Problem formulation: a statement of the problem.*
b. *Setting of objectives and overall project plan*
c. *Model building. As much as possibly, create simple, but resemble real system.*

d. Data collection. Data collection is the most time consuming and labor intensive step of the simulation, so it usually starts with model building concurrently.

e. Coding or software modeling. There are number of options to convert the model into a computer program, but the most advanced tools are the visually animated simulation programs such as ARENA, Simul8 and ProModel.

f. Verify. Testing of modeling logic. In many cases, common sense is enough to complete this step without complicated mathematical verification process.

g. Validation by comparing the simulation output variables with actual data.

h. Experimental design. Design and evaluate alternatives with controlling of common parameters such as the initialization period, total simulation length, and number of replications.

i. Production runs and analysis. Run for analyzing the performance measures for the system such as efficiency, utilization and service rate for the model and alternatives.

j. Document program and report results.

k. Implementation of the simulation to the actual situation.

2.4.3. Simulation studies for supply chain

Kleijnen (2005) emphasized importance of simulation for supporting supply chain management decisions. He pointed out that the simulation may give researchers clear looks about the causes and effects of the supply chain performance by testing (or experimenting) inputs and model structures. The simulation model can explain great details of supply chain process such as order arrivals and machine breakdowns. He characterized a simulation model as follows.

- A simulation model is quantitative, mathematical and computer based.
- A simulation model is naturally dynamic because it has at least one variable and at least two different point of time.
- A simulation model is not solved by mathematical analysis, but time paths of the dependent variables are computed by given input values and initial model structures.

Kleijnen (2005) compared for different types of simulation used in SCM that can be useful for quantifying benefits and costs of decisions: spreadsheet simulation, system dynamics (SD), discrete-event dynamic systems (DEDS) simulation and business games. Typical usages and characteristics are compared in Table 15.

Table 15: Comparison of four simulation types for supply chain management

Simulation types	Typical usages	Characteristics
Spreadsheet simulation	Manufacturing resource planning (MRP), vendor managed inventory (VMI)	Often too simple and unrealistic
System dynamics (SD)	Supply chain, Bullwhip effects, feedbacks which compares target and real values	Views companies as systems with six types of flows: materials, goods, personnel, money, orders and information. Most SD model doesn't have randomness
Discrete-event dynamic systems (DEDS)	Most popular simulation method for SCM, use for Enterprise Resource Planning (ERP), alternative supply chain design	More detailed than spreadsheet and SD. It represents individual events and incorporates uncertainties (e.g. irregular consumer order)
Business games	Often used as a education and research tool for bullwhip effects, production scheduling, etc.	Easy to simulate technological and economic process, but difficult for human behavior modeling

There are a number of studies that have used computer simulation techniques to identify inefficiencies in supply chains and help mangers optimize supply chain costs. For example, bullwhip effect (BWE), a phenomenon that leads excessive safety stocks and inventory and inefficient production due to unstable and fluctuating demands by the customer, has been a frequent research theme because it can cause serious order fulfillment problems in global supply chain. Li and Duan (2009) designed and developed simulation software to simulate the impact of BWE and to compare between manufacturer and distributor. Centeno and Perez (2009) used ARENA simulation program to quantify BWE and evaluate management strategies.

2.4.4. Simulation studies in logistics packaging

Most dynamic simulations applied to reusable packaging are limited for certain part of supply chain process. Kroon and Vrijens (1995) sought a quantitative model that could be used in the planning of return logistics system for reusable containers. Key research questions were,

a. How many containers should be available in the system?
b. How many container depots should there be and where should they be located?
c. How should the distribution, collection, and relocation of the containers be organized?
d. What are appropriate service, distribution and collection fees?

They conducted a case study for a large logistics company in Netherlands, and carried out a simple simulation-optimization model which compared three return logistics systems such as a switch pool, a system with return logistics, and a system with return logistics. Because this study only provided a methodological framework without specific cost data, and was based on the strict environmental legislation such as Duales System Deutschland in Germany, a more sophisticated and refined study in different environment are needed (Kroon & Vrijens, 1995).

Castillo and Cochra (1996) presented a framework and a mathematical formulation for the optimal reusable bottle production and distribution system of a large soft drink manufacturer located in Mexico City, Mexico, and the results benefited the company improving product and container control and inventory behavior. Mathematical computations make it easy to compare packaging costs directly, but it cannot model the unpredictable and complex nature of global supply chain.

Gupta, Jarupan and Kamarthi (2003) used ARENA software to investigate the effect of vehicle management for a reusable packaging system in order to improve customer satisfaction, and concluded that different combination of dispatching and vehicle assignment schemes affect customer satisfaction differently.

Mollenkopf *et al.* (2005) used a combination of static simulation-regression analysis to compare the relative costs of reusable and expendable shipping containers, but it only focused on a single supply chain. They suggested using a dynamic simulation approach for a more realistic analysis of a complex packaging system.

Johansson and Hellstöm (2007) introduced the methodological approach of combining case study and simulation study while introducing the concept of asset visibility study for a returnable transport item. However, this study did not attempt to investigate transportation costs nor effects of managing a pool system.

Marchet, Melacini and Perotti (2011) developed a simulation model for evaluation of an order-Pick systems (OPSs) and used three design variables of duration, workload and number of daily Pick waves (customer orders). They found out the trade-off between the Pick efficiency and the sorting cost such as relationship of minimum number of daily packing orders versus pick costs.

From industry, simple cost equations or mathematical computation using computer software such as Excel have been used in industries for simple, direct comparisons (Walter, 1982; Reusable Packaging Association, 2010). Recently, Ijumba (2012) developed a simulation model to estimate and to optimize container fleet size using the stochastic model optimization method varying supply chain conditions of an OEM radiator closed loops.

Considering all simulation options and previous studies above, a discrete-event dynamic systems (DEDS) simulation technique is used for this study. The dynamic simulation technique enables researchers to model a sequence of events that occur over time, so it can be utilized for identifying and analyzing the dynamic behavior of reusable packaging systems caused by continuous demand and supply fluctuations. Key constraints that prohibit time- and cost-effective returnable shipping container flows are identified.

A DEDS can visualize constant changes of container flows and costs of reusable packaging systems, compared to single use expendable packaging systems, for global supply chains. A developed simulation model can help packaging and logistics managers identify where the possible constraints and bottlenecks are. Commercial simulation software, ARENA ®, is utilized to develop a model.

Statistical analysis is performed for validation and verification of the developed simulation model. The developed model is compared with actual data provided by a global logistics service provider and an automotive company. Based on the simulation outputs, recommendation for the optimum operation solution for packaging types (reusable or expendable), costs and benefits, structure of reusable shipping container management is provided.

CHAPTER 3

OBJECTIVES OF THE STUDY

This study is to answer the following questions: Can the reusable packaging be a financially viable option over the expendable packaging for a global supply chain? Can a combination of Activity-Based Costing (ABC) and simulation techniques be an effective way to measure the financial performance of the reusable packaging system? What are the key opportunities and constraints for implementing a successful reusable packaging system for the global supply chain?

To answer the questions, the following research objectives are determined.

a. To develop a framework for visualizing packaging costs in a supply chain using the ABC method.
b. To evaluate different types of reusable and expendable shipping containers in terms of relative costs, functionalities, structures, technologies and purposes.
c. To develop a dynamic simulation to reveal interrelationships between the packaging and supply chain. The developed simulation model can be used for evaluating relative influence of the various factors and performing comparative analysis on reusable and expendable packaging operation systems.
d. To identify and evaluate key trade-offs for implementing a reusable packaging system for the global supply chain.
e. To demonstrate the importance of using a more scientific approach in assessing the financial performance of reusable packaging, using a combination of case studies, ABC method, and dynamic simulation, so

the industry can significantly reduce its risk when making such packaging decisions.

CHAPTER 4

RESEARCH METHOD

Reusable packaging can be a sustainable and profitable investment -- or a costly and unsustainable mistake. This research explores impact of two different packaging options (reusables and expendables) on an international supply chain and use a new approach to find a practical solution.

In order to evaluate financial effectiveness of the perceived operating reusable, rental and expendable packaging systems in potential logistical routes for a global manufacturing company, three steps for an evaluation framework is derived from Zeng and Rossetti (2003) and Creazza, Dallari and Melacini (2010)

- **Step 1**: Identify packaging and logistics activities and develop the activity cost drivers (input parameters) associated with the total cost (See Table 16 for input and output variables)
- **Step 2**: Collect actual data and generalize for developing simulation models
- **Step 3:** Develop a static simulation model and perform a sensitivity analysis to assess the impact of key parameters
- **Step 4**: Develop a dynamic simulation model and simulate for a significant period of time (e.g. 5 years).
- **Step 5:** Validate and compare the simulation results with actual and ABC data derived from the sample company.

The proposed cost models compare the relative costs of each packaging system. By relative cost model approach, this research can generalized the results of the study while simplifying comparative analysis of three packaging options.

Although the analysis is performed based on actual situation and real data derived from leading global 3PLs, suppliers and automotive companies, their identity is not reported in this research for confidentiality reasons.

This study engaged partners with automobile companies, third party logistics providers (3PL) and packaging industries with particular emphasis on "transplant" manufacturers who have assembly operations overseas. Data were collected by Industry on-site interviews (in both suppliers and manufacturers), observations, and from company's database. Data acquired from the case study and activity based costing (ABC) analysis were utilized to develop the simulation model. The results are compared with actual data and ABC analysis.

A static simulation with comparative regression analysis based on ABC analysis is undertaken to test relative sensitivity of factors that affecting total packaging system cost for each system. Based on the sample data provided by "A" company, a triangular generating function from Excel was used to generate individual observations for each factors. Five hundred observations were generated and each observation represents a unique combination of independent variables. The simulation model developed is used for testing differing combinations of variables provided in Table 16.

A dynamic, discrete-event simulation (DEDS) method is applied to the study because it can visualize constant changes of container flows and costs of reusable packaging systems, compared to single use expendable packaging systems, for the global supply chain. The dynamic simulation technique enables researchers to model a sequence of events that occur over time, so it can be utilized for identifying and analyzing the dynamic behavior of reusable packaging systems caused by continuous demand and supply fluctuations. ARENA ® simulation software is used for the simulation model. The following sections describe details of the research model design.

4.1. Research model design

Figure 3 shows the conceptual research model for this study. As shown in the top portion of Figure 3**,** packaging types (reusable or expendable shipping containers) and associated costs, and supply chain routes and associated costs are featured for the strategic decisions of a global manufacturing company, while environmental uncertainties are classified as demand and supply variables. Uncertainties include supply and demand fluctuations, unexpected delays; oil price hikes, etc.

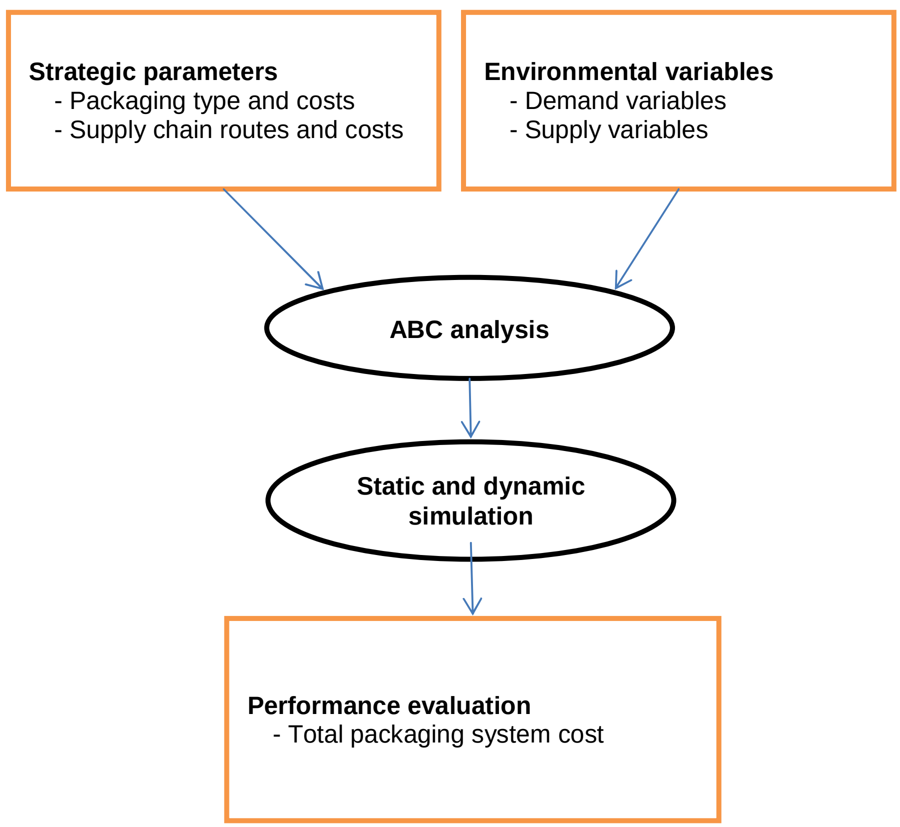

Figure 3: The conceptual research model

The packaging and supply chain cost model is developed utilizing ABC method based on the previous study (Lin, Collins, & Su, 2001). Packaging and supply chain performance will be determined in terms of total packaging cost, total supply chain cost. A concept model of packaging activity cost analysis is shown in Figure 4.

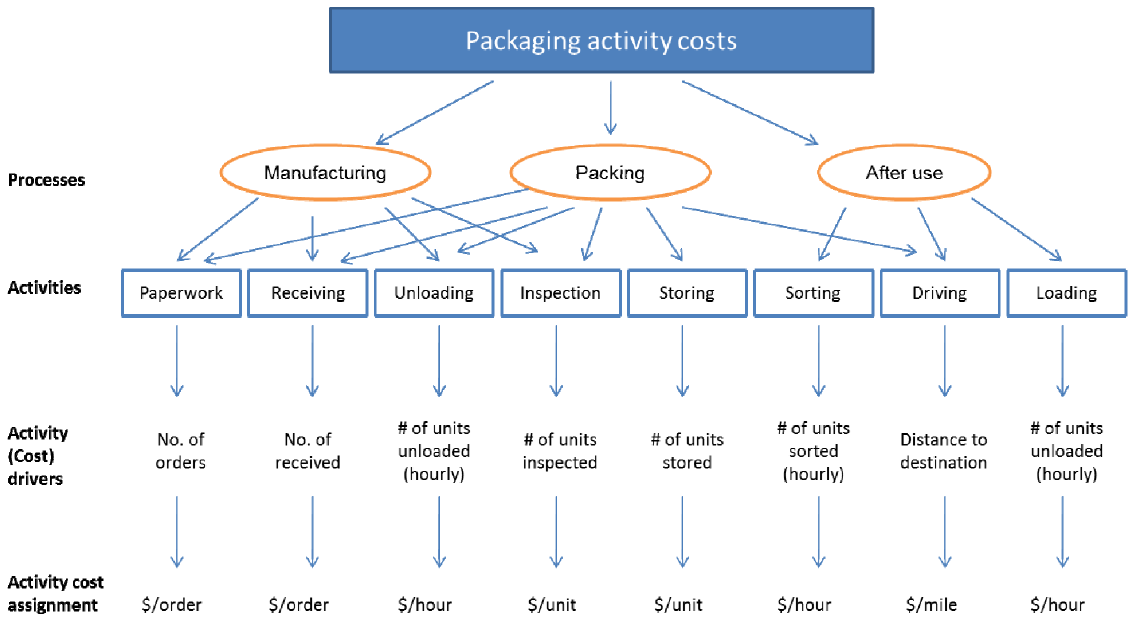

Figure 4: An example of the conceptual model for packaging activity cost analysis

Each activity is analyzed and calculated costs are used for input data for the simulation model. Figure 5 show the simulation process flow based on Banks *et al.* (2010) for this study.

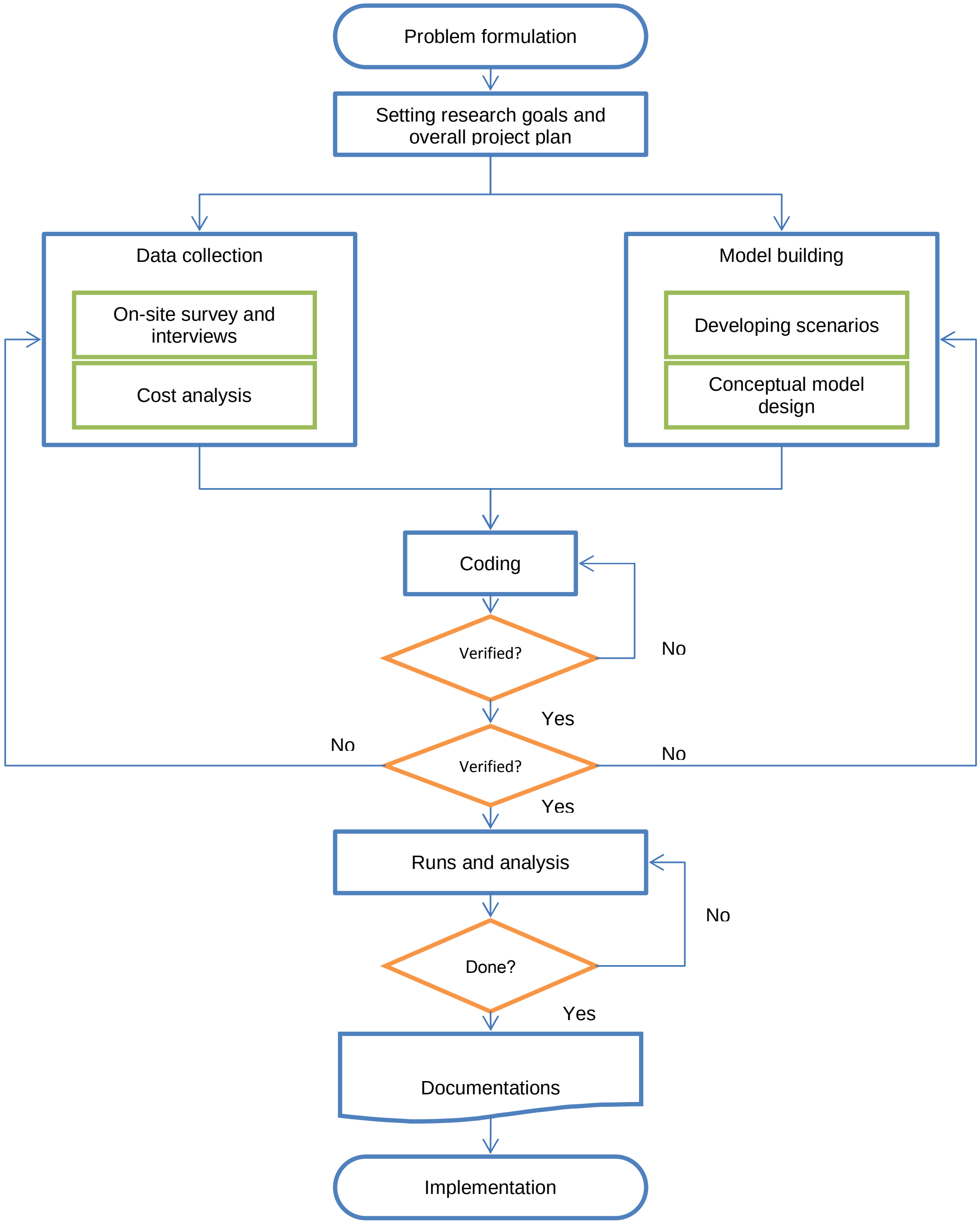

Figure 5: Simulation process flow

4.2. The international logistics routes investigated

After an in depth analysis of the literature and interviews with international freight forwarders and 3PLs, several international logistical routes are investigated for this study. The logistics process is performed by a 3PL from suppliers located in a specific geographic area (e.g. Far East), delivering goods to the manufacturing plants in a specific destination (e.g. Eastern Europe, USA and China). This study considers ocean container shipping with 40-feet containers as the primary international transportation mode considering its low freight rates despite long transit time.

For ocean container shipping, two types of shipment methods are considered, namely full container load (FCL) and less than container load (LCL). For LCL, shipments from several different suppliers are collected and consolidated at a cross-docking facility and they are shipped to the final destinations (Creazza, Dallari, & Melacini, 2010). Only FCL is considered for this study because costs of shipping methods are not directly related to the type of shipping containers.

After unloading and custom processes, all shipments are shipped by means of road transportation and unconsolidated at the 3PL's warehouses adjacent to the manufacturing plants. All goods packed with expendable shipping containers must be repacked in order to feed to assembly lines. Used reusable shipping containers are collected by manufacturers and stored temporarily before a 3PL consolidates containers for shipping back to suppliers.

4.3. Research variables

The ABC model and simulation needs a significant amount of data to fit the proposed variables. A portion of data is collected from industry on-site interviews and observations. Other data is based on historical data and a system database from the target company. Table 16 summarizes and explains the main research parameters and variables for the study.

Table 16: Research parameters and variables for the study

	Main parameters	**Influenced by**
Independent variables	Packaging parameters	Container part costs ($/container) Container weight (lbs/container) Product weight (lbs/part) Pack quantity (parts/container) Container return rate (percent/year, reusables only) Backhaul packaging volume factor (percent/container, reusables only) Designed container life (years, reusables only) Recycling / Waste disposal cost ($/container)
	Supply chain parameters	Delivery distance (miles) Buffers and safety stocks (percent of daily demand) Cycle time (days in shipping loop) Customs charges for customs clearance, brokerage, allocation fee ($/container) Inventory costs ($/container) Handling costs for terminal, material, disposal, cleaning, sorting, repairing, etc. ($/container) Facilities and equipment costs including labor, energy, etc ($/container) Risk costs for damage, loss, delay, insurance, etc. ($/year)
	Environmental variables	
	Demand	Average daily demand (containers/day) Changes in demand quantity (containers/day)
	Supply	Average daily supply (containers/day) Changes in supply quantity (containers/day)
Dependent variables	Total packaging system cost	Sum of total container costs incurred by packaging activities such as container purchasing costs, cost for transportation and inventory, and packing costs ($/container)

In order to reduce the complexity of input variables, the following assumptions have been made for this study.

- The types of packaging materials are not considered for this study. For example, if a shipping container is made of steel and designed for a single use, this container is regarded as an expendable packaging.

- The dimensions and packing quantity of containers are uniform across the expendable and reusable shipping containers. Hence, annual demand including buffers and safety stocks for containers will be same regardless of container types. Differences between expendable and reusable shipping containers in terms of packaging types are cost, weight and designed container life.
- Some supply chain costs including customs charges (e.g. customs clearance, brokerage, allocation fee), inventory costs, handling costs, facilities and equipment costs, risk costs (e.g. damage, loss, delay, insurance, etc.) are uniform across the two packaging alternatives, but rates are different depending on the location of the manufacturing plant.
- The reusable shipping container can have collapsible or nestable functions in order to reduce the total volume during backhaul logistics.
- Average production year for an automobile assembly plant covers 52 weeks, 5 days per week, for total of 260 days. This study will examine for at least 1 and up to 5 years of operation.
- Reusable shipping containers can be purchased or leased by a 3PL, and handled by the 3PL throughout the supply chain. All manufacturing plants are responsible to return all used containers to the 3PL and cannot share or use alternatively. Any loss or damage occurred at the plant should be responsible for the plant, and should be charged at full cost of the container.

For meaningful statistical analysis and simplifying to analyze the impacts and relationships among purposed variables (Mollenkopf, *et al*. 2005), ranges of each independent variable value are determined based on actual data obtained from the global 3PLs and automobile manufacturing companies. Table 17 shows the ranges (low, mode, and high) for the key independent variables.

Table 17: Independent variables and associated ranges

Independent variables	Ranges		
	Low	Medium	High
Expendables($/container)	0.5	1.5	3.0
Reusables Purchasing($/container)	2.0	5.0	10.0
Reusables Leasing($/container/day)	0.02	0.05	0.10
International shipping distance (miles)	500	5,000	10,000
In-land Drive distance (miles)	100	300	500
Average daily Volume (containers/day)	1,000	5,000	10,000
Container weight (lbs/container)	1	5	20
Container quantity on a pallet (containers/pallet)	15	60	120
Return rate (percent/year, reusables only)	80	90	95
Backhaul logistics volume factor(percent/container, reusables only)	0.5	0.7	1.0
Designed container life (year, reusables only)	2	3	10
Buffers and safety stocks (percent of daily demand)	2	5	10
Cycle time (days)	30	90	180
Customs charges ($/FCL 40ft)	500	800	1,500

4.4. Data collection

The research is based on an international supply chain case study. An extensive literature review and industry on-site interviews (in both suppliers and manufacturers) are performed to develop a conceptual simulation model. Data acquired from the case study and activity-based costing (ABC) analysis is utilized to develop the simulation variables.

The study engages partners with automobile companies, third party logistics providers (3PL) and packaging industries with particular emphasis on “transplant” manufacturers who have assembly operations overseas. Required data to fit the research variables are presented in Table 18.

Table 18: Required data for the study

Data Sources	Data
On-site interviews	• General description about the company, business and distribution networks • Description of the product, packaging and logistical activities • Packaging activities such as labor, time, cost associated with packing and repacking • Logistical activities such as labor, time, and cost associated with shipping, loading, storing, etc. • Logistical means such as pallets, trucks, ships, etc. • Packaging ownership (supplier owned, buyer owned, co-op owned, 3PL) • Location of supplier (domestic/international), physical distance • Average changes in daily demand and order quantity, order lead time
Observations	• Product types including materials, size, weight, etc. • Packaging types (expendables and reusables) including materials, size, weight, etc. • Packaging activities such as labor, time, delays, cost associated with packing and repacking • Logistical activities such as labor, time, delays, and cost associated with shipping, Load, Store, returning etc. • Logistical means such as pallets, trucks, ships, etc.
Historic Data / Company’s Database	• Description of the product, packaging and logistical activities • Product and packaging types (expendables and reusables) types including prices, materials, life, size, weight, etc. • Cost data of packaging related costs such as buying cost, labor costs, waste disposal costs, etc. • Cost data of logistical activity related costs such as buying cost, labor costs, vehicle payload, waste disposal costs, etc. • Average changes in daily demand and order quantity, order lead time • Logistical means such as pallets, trucks, ships, etc.

CHAPTER 5

PACKAGING COST ANALYSIS USING ABC METHOD

5.1. Process and activity descriptions

Based on the acquired data from observation, company information and industry on-site interviews (in both suppliers and manufacturers), packaging activities which affect packaging and supply chain costs were analyzed. Figure 6 shows an international packaging and automotive part supply chain network used for this study.

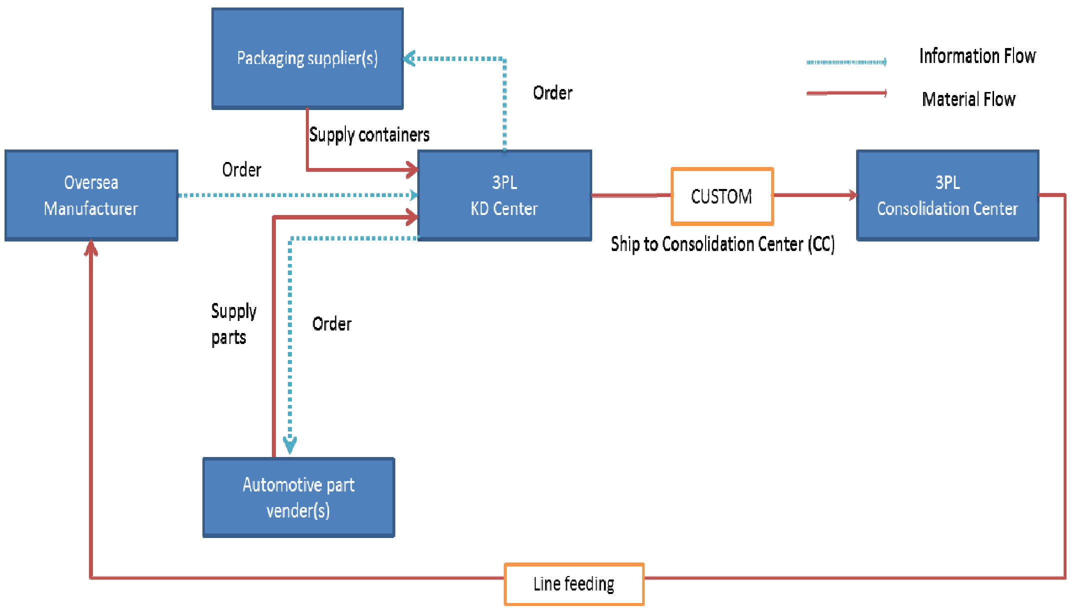

Figure 6: Proposed International packaging and automotive part supply chain flow for the study

The packaging cost models for each packaging type were developed utilizing ABC method based on a previous study (Lin, Collins, & Su, 2001). Packaging performance was determined in terms of total packaging system cost. The six processes and eighty activities for this study are shown in Table 19.

Table 19: Processes and activities for the typical packaging system for the international automotive part supply chain

Processes	Detail Processes	Activities
Purchasing (Inbound)	Receive from supplier(s)	1. Paperwork
		2. Receive
		3. Inspection
		4. Store (for inbound)
	Preparing shipments	5. Paperwork
		6. Pick
		7. In-house delivery
		8. Load the truck
	Drive to KD center	9. Drive
	Arrived at KD center	10. Unload
Packing	Packing at KD center or vender(s)	11. Paperwork
		12. In-house delivery
		13. Unpalletize empty boxes(or containers)
		14. Move empty boxes to packing area
		15. Pack (RPC)
		16. Pack (EXP)
		17. Move packaged products to shipping preparation area
	Preparing outbound shipments	18. Paperwork
		19. Pick
		20. Palletize product & packages
		21. Load
Outbound logistics (Shipping to plants)	Preparing shipments	22. Drive
		23. Unload of container from truck in CFS
		24. Wait for Customs
		25. Customs clearance departure (domestic port)
		26. Load of container to move container alongside ship
	Shipping from Busan, KR to port of Savannah, GA	27. Ship
	Arrived at port	28. Unload of container from ship
		29. Hold for Customs
		30. Customs clearance arrival (oversea port)
	Shipping to domestic Consolidation center (CC)	31. Paperwork
		32. Load of container to truck
		33. Drive
	Arrived at CC	34. Paperwork
		35. Unload
		36. Unpalletize product & packages

Table 19 (cont'd)

Processes	Detail Processes	Activities
Outbound logistics (Shipping to plants)	Transshipping (Expendables only)	37. Repacking(Expendables)
	Preparing line feeds	38. Move containers to feeding area
		39. Load
		40. Unload
	Line feeding	41. Line feeding
In-house return process	In house return (Expendables only)	42. Unload empty boxes from workstation
		43. Move containers to dunnage storage area
		44. Sort expendables
		45. Palletize empty boxes
		46. Load empty boxes to CC for recycling or disposal
	In house return (RPCs only)	47. Unload empty RPCs from workstation
		48. Move empty RPCs to dunnage sort area
		49. Sorting empty RPCs
		50. Store empty RPCs
		51. Palletize empty RPCs
		52. Load empty RPCs to CC for reuse
Backhaul logistics (RPCs only)	Preparing backhaul shipments	53. Paperwork
		54. Count and check containers
	Shipping from CC to reconditioning center	55. Drive
		56. Unload containers from truck in CFS
		57. Wait for Customs
		58. Customs clearance departure (oversea)
		59. Load of container to move container alongside ship
		60. Ship
		61. Unload from ship
		62. Hold for Customs
		63. Customs clearance arrival (domestic)
		64. Load of containers
		65. Drive (send to reconditioning center)
	Arrived at reconditioning center	66. Paperwork
After use process	Reconditioning process (RPCs)	67. Unload
		68. Unpalletize empty RPCs
		69. Inspection
		70. Recondition (cleaning, repairing, etc)
		71. Palletize empty RPCs
		72. Sort
		73. Store empty containers
		74. Paperwork
	After use Process at CC (Expendables)	75. Pick
		76. Sort
		77. Load
	Disposal/recycle	78. Drive
		79. Disposal
		80. Recycle

Resource drivers, activity cost drivers and cost units of the drivers are identified for each activity as shown in Table 20.

Table 20: Proposed activities and activity cost drivers considered for calculation

Processes	Detail Processes	Activities	Resource drivers	Activity cost drivers	cost unit of the driver
Purchasing (Inbound)	Receive from supplier(s)	Receive (paper work)	Administrators employed	Total time worked	$/hour
		Unload	Material handlers employed & equipment used	Time required to check a container	$/hour
		Inspection	Inspectors employed	Time required for inspection per container	$/hour
		Store (for inbound)	Space used	Space occupied and time required	$/sq. ft/day
	Preparing shipments	Paperwork	Administrators employed	Total time worked	$/hour
		Pick	Material handlers employed & equipment used	Time required to pick a container	$/hour
		In-house delivery	Material handlers employed & equipment used	Time required to pick a container	$/mile
		Load (Load the truck; and dispatch the truck)	Material handlers employed & equipment used	Time required to load a container	$/hour
	Drive to KD center	Drive	Drivers employed	Distance and square meters of pallets throughput	$/mile
	Arrived at KD center	Unload	Material handlers employed & equipment used	Time required to Unload a container	$/hour

Table 20 (cont'd)

Processes	Detail Processes	Activities	Resource drivers	Activity cost drivers	cost unit of the driver
Packing	Packing at KD center or vender(s)	Paperwork	Administrators employed	Total time worked	$/hour
		In-house delivery	Material handlers employed & equipment used	Time required to pick a container	$/mile
		Unpalletize empty boxes(or containers)	Material handlers employed & equipment used	Time required to pick a container	$/hour
		Move empty boxes to packing area	Material handlers employed & equipment used	Time required to move a container	$/mile
		Pack	Material handlers employed & equipment used	Time required to pack a container	$/hour
		Move empty boxes to packing area	Material handlers employed & equipment used	Time required to move a container	$/mile
	Preparing outbound shipments	Paperwork	Administrators employed	Total time worked	$/hour
		Pick	Material handlers employed & equipment used	Time required to pick a container	$/hour
		Palletize product &pkgs	Material handlers employed & equipment used	Time required to pick a container	$/hour
		Load	Material handlers employed & equipment used	Time required to load a container	$/hour

Table 20 (cont'd)

Processes	Detail Processes	Activities	Resource drivers	Activity cost drivers	cost unit of the driver
Outbound logistics (Shipping to plants)	Preparing shipments	Drive	Drivers employed	Distance and square meters of pallets throughput	$/mile
		Unload containers from truck in CFS	Material handlers employed & equipment used	Time required to Unload a container	$/hour
		Wait for Customs	Space used	Space occupied and time required	$/sq. ft/day
		Customs clearance departure (domestic port)	Administrators employed	Total time worked	$/hour
		Load containers to move container alongside ship	Material handlers employed & equipment used	Time required to load a container	$/hour
	Shipping from export port to import port (Expendables & RPCs)	Shipping	Material handlers employed	Distance and square meters of pallets throughput	$/mile
	Arrived at port	Unload containers from ship	Material handlers employed & equipment used	Time required to Unload a container	$/hour
		hold for Customs	Space used	Space occupied and time required	$/sq. ft/day
		Customs clearance arrival (oversea port)	Administrators employed	Customs clearance cost per container	$/cont ainer
	Shipping to domestic Consolidation center (CC)	Paperwork	Administrators employed	Total time worked	$/hour
		Load containers to truck	Material handlers employed & equipment used	Time required to load a container	$/hour
		Drive (dispatch the truck)	Driver employed	Number of orders picked	$/mile

Table 20 (cont'd)

Processes	**Detail Processes**	**Activities**	**Resource drivers**	**Activity cost drivers**	**cost unit of the driver**
Outbound logistics (Shipping to plants)	Arrived at CC	Paperwork	Administrators employed	Total time worked	$/hour
		Unload	Material handlers employed & equipment used	Time required to Unload a container	$/hour
		Unpalletize product & pkgs	Material handlers employed & equipment used	Time required to pick a container	$/hour
	Transshipping (Expendables only)	Repack(Expendables)	Material handlers employed & equipment used	Time required to pack a container	$/hour
	Preparing line feeds	Move containers to feeding area	Material handlers employed & equipment used	Time required to move a container	$/mile
		Load	Material handlers employed	Time required to load a container	$/hour
		Unload	Material handlers employed & equipment used	Time required to Unload a container	$/hour
	Line feeding	Line feeding	Material handlers employed & equipment used	Time required to move a container	$/mile
In-house return process	In house return (Expendables)	Unload empty boxes from workstation	Material handlers employed & equipment used	Time required to Unload a container	$/hour
		Move containers to dunnage storage area	Material handlers employed & equipment used	Time required to move a container	$/mile
		Sorting expendables	Material handlers employed	Time required to sort a container	$/hour
		Palletize empty boxes	Material handlers employed & equipment used	Time required to pick a container	$/hour

Table 20 (cont'd)

Processes	Detail Processes	Activities	Resource drivers	Activity cost drivers	cost unit of the driver
In-house return process		Load empty boxes to CC for recycling or disposal	Material handlers employed & equipment used	Time required to load a container	$/hour
	In house return (RPCs)	Unload empty RPCs from workstation	Material handlers employed	Time required to Unload a container	$/hour
		Move empty RPCs to dunnage sort area	Material handlers employed & equipment used	Time required to move a container	$/mile
		Sort empty RPCs	Material handlers employed	Time required to sort a container	$/hour
		Store empty RPCs	Space used	Space occupied and time required	$/sq. ft/day
		Palletize empty RPCs	Material handlers employed & equipment used	Time required to pick a container	$/hour
		Load empty RPCs to CC for reuse	Material handlers employed & equipment used	Time required to Unload a container	$/hour
Backhaul logistics (RPCs only)	Preparing backhaul shipments for RPCs	Paperwork	Administrators employed	Total time worked	$/hour
		Count and check containers	Material handlers employed	Time required to check a container	$/hour
	Shipping from CC to reconditioning center (RPCs)	Drive	Drivers employed	Distance and square meters of pallets throughput	$/mile
		Unload containers from truck in CFS	Material handlers employed & equipment used	Time required to Unload a container	$/hour
		Waiting for Customs	Space used	Space occupied and time required	$/sq. ft/day
		Customs clearance departure (oversea)	Administrators employed	Number of orders picked	$/hour

Table 20 (cont'd)

Processes	Detail Processes	Activities	Resource drivers	Activity cost drivers	cost unit of the driver
Backhaul logistics (RPCs only)	Shipping from CC to reconditioning center (RPCs)	Load containers to move container alongside ship	Material handlers employed & equipment used	Time required to load a container	$/hour
		ship	Material handlers employed	Distance and square meters of pallets throughput	$/mile
		Unload from ship	Material handlers employed & equipment used	Time required to Unload a container	$/hour
		hold for Customs	Space used	Space occupied and time required	$/sq. ft/day
		Customs clearance arrival (domestic)	Administrators employed	Customs clearance cost per container	$/container
		Load containers	Material handlers employed & equipment used	Time required to Unload a container	$/hour
		Drive (send to reconditioning center)	Drivers employed	Distance and square meters of pallets throughput	$/mile
	Arrived at reconditioning center	Paperwork	Administrators employed	Total time worked	$/hour
After use process	Reconditioning process (RPCs)	Unload	Material handlers employed & equipment used	Time required to Unload a container	$/hour
		Unpalletize empty RPCs	Material handlers employed & equipment used	Time required to pick a container	$/hour
		Inspection	Inspectors employed	Time required for inspection per container	$/hour
		Reconditioning (cleaning, repairing, etc.)	Quantity of containers	quantity of containers to be cleaned	$/container

Table 20 (cont'd)

Processes	Detail Processes	Activities	Resource drivers	Activity cost drivers	cost unit of the driver
After use process	Reconditioning process (RPCs)	Palletize empty RPCs	Material handlers employed & equipment used	Time required to pick a container	$/hour
		Sort	Material handlers employed	Time required to sort a container	$/hour
		Store empty containers	Space used	Space occupied and time required	$/sq. ft/day
		Paperwork	Administrators employed	Total time worked	$/hour
	After use Process at CC (Expendables)	Pick	Material handlers employed & equipment used	Time required to pick a container	$/hour
		Sort	Material handlers employed	Time required to sort a container	$/hour
		Load	Material handlers employed & equipment used	Time required to load a container	$/hour
	Disposal/ recycle	Drive	Drivers employed	Distance and square meters of pallets throughput	$/mile
		Dispose	Weight of material	Weight of containers disposed	$*lb/containers
		Recycle	Weight of recyclable material	Weight of containers recycled	$*lb/containers
		Paperwork	Administrators employed	Total time worked	$/hour

The following main activities, typical for third party logistics operators, were identified and classified as shown in Table 21: purchasing, logistics administration, transportation (outbound and backhaul), warehousing operations, and after-use activity. The following sections (5.1.1 to 5.1.5) describe each activity and cost driver.

Table 21: ABC cost analysis for five logistical activity areas

Cost Types	Details
Logistics administration cost(AC) ($/container)	Sum of costs incurred by administration activities including customer service, order processing, production planning, procurement, purchasing, planning, scheduling and dispatch, custom charges, inventory control, general administration and management costs
transportation(outbound) cost(TCF) ($/container)	Sum of costs incurred by outbound transportation activities including Load, Unload, Drive, equipment and energy uses
transportation(backhaul) cost(TCB) ($/container)	Sum of costs incurred by backhaul transportation activities including Load, Unload, Drive, equipment and energy uses
Warehousing cost(WC) ($/container)	Sum of costs incurred by warehousing activities including Receive, in-house handling (Pick, repacking, consolidation, put-away, etc.), equipment, storage and energy uses
After use cost/revenue	
After-use cost(AC) ($/container)	Sum of costs incurred by cleaning, reconditioning, repairing, disposal activities
Recycling revenue(RE)	Sum of revenue incurred by recycling activities

5.1.1. Packaging purchasing activities

All (either expendable or reusable) packaging containers and automotive parts are either purchased or produced by oversea suppliers. Packaging purchasing costs include the annual purchasing costs for expendable and reusable, and annual rental cost for the reusable containers. The numbers of containers required and material costs were calculated for each packaging system.

Although purchasing activity is a part of the activity-based cost equation for expendable and reusable containers, the rental system does not require any purchasing activity in this case because the rental company provides the containers directly to KD center. Each purchasing activity is assigned into the logistics administration and warehousing categories.

5.1.2. Logistics administration activities and cost drivers

Logistics administration activities includes paper work for customer service, order processing, production planning, procurement, purchasing, forecasting, planning, custom charges, scheduling and dispatch, and inventory control, general administration and management. Table 22 shows the logistics administration activities and activity cost drivers considered in this research.

Table 22: Logistics administration activities and activity cost drivers considered for calculation

Processes	Detail Processes	Activities	Activity cost drivers	cost unit of the driver
Purchasing (Reusables & Expendable)	Purchase and Receive from supplier(s)	Receive paper work	Quantity of order	Total time worked ($/hour)
	Prepare shipments	Paperwork	Quantity of order	Total time worked ($/hour)
Packing (for all three systems)	Pack at KD center or vender(s)	Paperwork	Quantity of order	Total time worked ($/hour)
	Prepare outbound shipments	Paperwork	Quantity of order	Total time worked ($/hour)
		Customs related paperwork	Quantity of order	Total time worked ($/hour)
	Dispatch to Consolidation center (CC)	Paperwork	Quantity of order	Total time worked ($/hour)
	Arrive at CC	Paperwork	Quantity of order	Total time worked ($/hour)
Backhaul logistics (Reusables& rentals only)	Prepare backhaul shipments for reusables	Paperwork	Quantity of order	Total time worked ($/hour)
		Customs related paperwork	Quantity of order	Total time worked ($/hour)
	Arrive at reconditioning center	Paperwork	Quantity of order	Total time worked ($/hour)
After use Process (Reusables & Expendable)	Recycle or disposal	Paperwork	Quantity of order	Total time worked ($/hour)

Most logistics administration activities are clerical activities related to paperwork and data entry that requires labor cost and time. The main activity cost driver for administration has been the quantity of orders because it was manual data entry activity, but quantity is not an important cost driver nowadays since most orders and paper works are linked with EDI or other management software (Griful-Miquela, 2001). In this case, quantity is not a cost driver anymore, but the frequency of incoming and outgoing goods still consumes resources of time and labor.

5.1.3. Warehousing activities and cost drivers

Two warehousing/distribution center processes are assumed in this study: KD (knock down) center and consolidation center.

The KD center, as shown in Figure 7, products (automotive parts) and containers are received separately from respective suppliers and assembled into packaged goods. In KD center, the automotive part is arriving as a knock down kit consisting of the smaller parts needed to assemble a product to export.

In this process, the associated cost and time are not significantly different between expendable and reusable containers assuming packing activity for both containers requires same amount of labor and time.

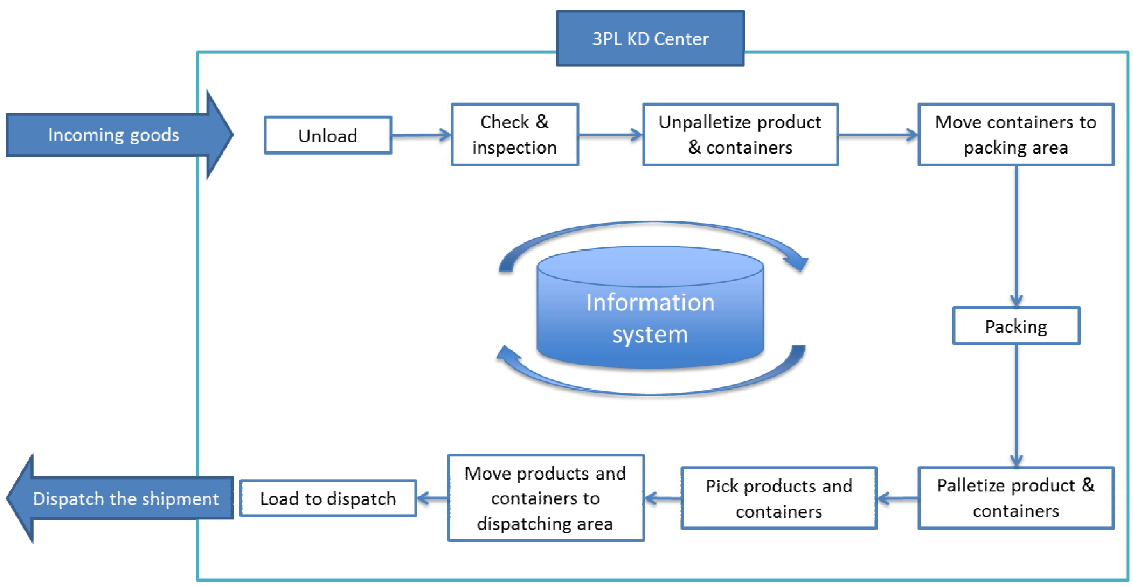

Figure 7: Warehouse (KD Center) activities

Figure 8 shows typical activities observed in the consolidation center near the car manufacturer. The main purpose of the consolidation center is to help the efficient supply flow of automotive parts from oversea and local supply chains to the actual car manufacturing plants.

The consolidation center is differ from warehouse since the center does not store goods for long time, but distributes just-in-time to meet the daily needs of plants. Only expendable packaging requires a repacking activity in order to meet the feeding system of the manufacturer. The repacking activity, in addition to the labor and time, requires repacking materials. Repacking material costs are included in material purchasing cost. There are certain types of expendable packages that do not need repacking, but most expendable packages need to be repacked since those are not designed for direct feeding and containers are partly damaged during international shipping process.

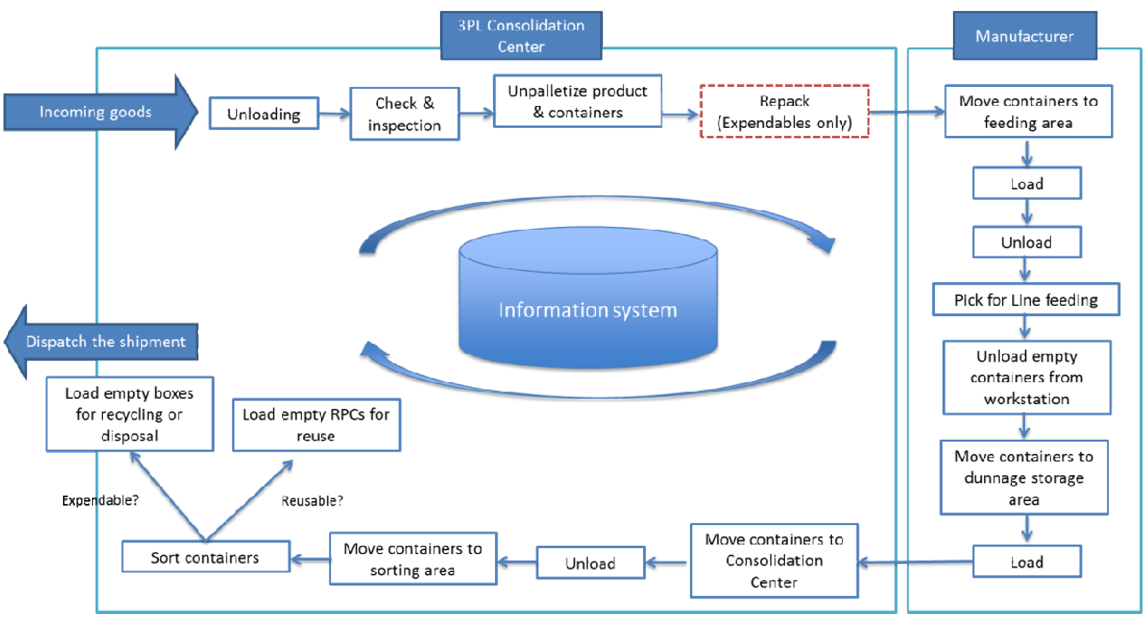

Figure 8: 3PL Consolidation Center activities

In this research, warehouse ownership is not considered because the cost (whether it is rented or owned) is not directly related to each activity and most packaging related activity is related to the quantity of product. However, it may need to allocate them to consignors in a different way if additional warehousing facility is necessary to perform activities.

It should be noted that this activity cost calculation for warehousing does not take into account unused space or capacity in the warehouse, so empty space or unused warehousing resources are excluded. In this way, it is possible to show clearly only packaging and logistics activity costs.

The following is a brief explanation of these typical activities:

a. **Inspection/Checking** incoming or returning containers involves inspecting/checking if the actual product received is the same as the figure on the invoice. The main cost driver is **the quantity of product (or container) received**, and the cost can be calculated with the time required to sort a certain quantity of containers multiplied by labor costs.

b. **Storing** involves storing the pallets at the storage location. The main cost driver is **the quantity to be stored**, which determines the time spent in this activity. The number of containers on a pallet is important because it affects unit cost of Store per container in the warehouse. The cost can be calculated with the time to store a certain quantity of containers multiplying by space usage rate.

c. **Picking** takes a place when an order is made; main cost driver should be the number of items picked during warehousing process. The picking cost should be calculated by the number of picked multiplied by amount of time and associated labor to pick a pallet load of products from a storage location.

d. **Moving** involves moving the products in the warehouse such as moving products from arriving dock to the storage location. The main cost driver is **the quantity to be moved**, which determines the time, labor and equipment spent in this activity.

e. **Unloading** is carried out when the goods from the packager or manufacturing plant arrive at the logistics company's warehouse. A very common practice is unloading pallet loads of products with forklift, so main cost driver is quantity of products unloaded. By observation and interviewing, the time spent for unloading a pallet should be calculated. The unloading cost should be calculated by observed time to unload a pallet multiplied by relevant labor and equipment to perform this activity. **Loading** is the opposite of unloading and the main cost driver is also **quantity.**

f. **Packing (including labeling and repacking)** involves packaging/repackaging each order and putting on the label with the information about consignee, delivery route, and so on. The main cost driver is the number of containers. Packing costs involved are the time of the workers responsible for packaging and the material used in this activity. In this case, only labor cost is considered since material cost is already taken into account separately.

g. **Palletizing** involves loading shipping containers to the pallet and securing the load with stretch wrapping, banding, or any other methods. Supposing the entire product loaded is palletized, the main cost driver of palletizing activity is quantity. Palletizing cost should be calculated with the time required to palletize a certain quantity of shipping containers multiplied by labor and equipment costs. **Unpalletizing** is the opposite of palletizing, dismantling incoming loads from a pallet. The main cost driver is also **quantity.**

h. **Sorting** includes arranging and organizing used containers by their specifications in order to reuse, recycle or dispose. The main cost driver is **quantity**, and cost should be calculated the time required to sort a certain quantity of containers multiplied by labor costs**.**

Table 23 shows warehousing activities and activity cost drivers considered in this research.

Table 23: Warehouse activities and activity cost drivers

Processes	Detail Processes	Activities	Activity cost drivers
Receiving	Receive from supplier	Inspecting incoming containers	Quantity of containers received
		Storing (for outbound)	Space occupied and time required
	Prepare shipments	Picking	Number of visits to pick location
		In-house delivery	Distance and square meters of pallets throughput
		Loading (Loading the truck; and dispatching the truck)	Quantity of containers received
	Arrive at KD center or vender(s)	Unloading	Number of orders picked
Packing	Pack at KD center or vender(s)	In-house delivery	Distance and square meters of pallets throughput
		Packing	Number of orders picked
	Prepare outbound shipments	Picking	quantity of containers
		Loading	quantity of containers

Table 23 (cont'd)

Processes	Detail Processes	Activities	Activity cost drivers
Outbound (Ship to the assembly plant)	Ship to domestic Consolidation center (CC)	Loading	Quantity of containers loaded
	Arrive at CC	Unloading	Quantity of containers Unloaded
	Prepare line feeds	Moving containers to feeding area	Quantity of containers loaded
		Loading	Quantity of containers loaded
	Line-feed	Line feeding	Quantity of containers loaded
	In house return (RPCs)	Unloading empty RPCs from workstation	Quantity of containers Unloaded
		Moving empty RPCs to dunnage sort area	quantity of containers
		Storing empty RPCs	Space occupied and time required
Backhaul logistics (RPCs only)	Prepare backhaul shipments for RPCs	Counting and checking the order, etc)	Quantity of containers
	Ship from CC to reconditioning center (RPCs)	Unloading	Quantity of containers Unloaded
After use Process	Arrive at reconditioning center Reconditioning process (RPCs)	Unloading	Quantity of containers Unloaded
		Inspection	Quantity of containers inspected
		Reconditioning (cleaning, repairing	Quantity of containers cleaned
		Storing empty containers	Space occupied and time required

5.1.4. Transportation activities and cost drivers

As shown in Table 24, transportation activities include driving, shipping, custom related fees, equipment and energy uses. Expendable container system is only considering forward transportation and after-use driving activities, but reusable and rental systems include backhaul (reverse) transportation and custom related fees during returning process.

Table 24: Transportation activities and activity cost drivers considered for calculation

Processes	Detail Processes	Activities	Activity cost drivers
Outbound Transportation (Ship to plants)	Drive to KD center or vender(s)	Drive (dispatch the truck)	Distance and volume efficiency of truck (quantity of cartons per truck)
	Drive to port	Drive (dispatch the truck)	Distance and volume efficiency
	Ship from export port to import port	Ship	Distance and volume efficiency of sea container (quantity of cartons per pallet & sea container)
	Drive from port to consolidation center (CC)	Drive (dispatch the truck)	Distance and volume efficiency
Backhaul Transportation (reusables only)	Drive to port	Drive (dispatch the truck)	Distance and container quantity
	Ship from CC to reconditioning center	Ship	Distance and container quantity (quantity of cartons per pallet & sea container)
	Customs clearance at arrival port	Customs clearance and brokerage	Customs clearance cost per container
	Drive to reconditioning center	Drive (send to reconditioning center)	Distance and container quantity
After use	Drive to Disposal/recycling	Drive (dispatch the truck)	Distance

5.1.5. After-use activities and cost drivers

As shown in Table 25, after use activities include all the processes related to the disposal and recycling. The main cost drivers are weight of containers disposed or recycled and will consume labor and equipment for the process. Rental systems do include this activity because all costs associated with after-use activity are included in the purchase cost.

Table 25: After-use activities and activity cost drivers considered for calculation

Processes	Activities	Resource drivers	Activity cost drivers
After use	Disposal	Weight of material	Weight of containers disposed
	Recycling	Weight of recyclable material	Weight of containers recycled

5.2. Packaging system cost calculations

Total packaging system costs for three systems were calculated based on identified activity cost drivers and resources consumed. The activity cost calculation models for three systems (expendable, reusable and rental packaging system) are explained. To clarify the acronyms used for the calculation, Table 26 provides the definitions of acronyms.

Table 26: Definitions of acronyms used in calculations

- CC: Container cost ($/container): purchasing cost of an expendable container (ECC) or a reusable container (RCC)
- DRC: Daily rental cost ($/container/day)
- DD: Delivery distance (mile)
- CR = Constant rate per mile, $/mile
- FS = frequency of supply, days
- ADV: Average daily volume (containers/day)
- CW: Container weight (lbs/container): weight of container
- PW: Product weight (lbs/part): weight of product
- PQ: Pack quantity (parts/container): quantity of products in a container
- CRR: Container return rate (percent/year, reusables only): return rate of reusables per year
- BCV: Backhaul container volume factor (percent/container, reusables only): percent volume of reusable nesting or collapsible containers during backhauling process
- DCL: Designed container life (years, reusables only): container life
- PVF: Peak volume factor due to Buffers and safety stocks (percent of daily demand)
- CT: Container cycle time (days)
- CCF: Custom Charges ($/FCL 40ft)
- CCC: Custom Charges ($/container)
- RC: Reconditioning cost ($/container)
- WDC: Waste disposal cost ($/container)
- CDQ: Changes in demand quantity (containers/day)

5.2.1. Expendable packaging system cost (EPSC)

Expendable packaging system cost is sum of five types of cost: container cost, logistics administration, transportation, warehousing, and after-use cost and minus recycling revenue for expendable packaging materials. All cost unit is $/container.

$$EPSC = ECC + EAC + ETC + EWC + EAC - ERE$$

Where

EPSC = expendable packaging system cost, \$/container

ECC= expendable container cost, \$/container

EAC = logistics administration cost, \$/container

ETCF= outbound transportation cost for expendable container system, \$/container

EWC= warehousing cost for expendable container system, \$/container

EAC = after-use cost (disposal) for expendable container system, \$/container

ERE = recycling revenue for expendable container system, \$/container

5.2.1.1. ECC= expendable container unit cost

Expendable container costs include container cost, repacking material cost (80 percent of original container cost), and reusable container costs (for feeding the parts at the assembly plant). For example, container cost (CC) is \$3.7 if a container unit cost is \$2.0, a container cost for repacking is \$1.6, and a reusable container cost is \$0.1 (\$10/100 times). Later, procurement costs (e.g. 5 percent of CC or \$0.155) will be added to logistics administration cost (EAC) as purchasing activity related costs such as planning, supplier management, ordering, etc.

$$ECC(\$/container) = CC + CC_r + CC_m$$

Where

ECC= expendable container cost, \$/container

CC = container cost, \$/container

CC_r= repacking material cost, \$/container

CC_m= reusable container costs, \$/container

5.2.1.2. EAC = logistics administration cost for expendable packaging system

Logistics administration cost is related to the time spend for paperwork (or data input) and labor is the key resource to consume. Note that labor rates vary depending on the location. Table 27 shows standard administration time and cost for each container type.

Table 27: Standard administration time and cost for each container

Container types	Observed total time per container (hours)	Cost ($/container)	Activities involved
EXPs	0.75	$ 0.17	Purchasing (Order requests from customer, scheduling, etc.), counting, checking, and shipping paperwork (numbers, destinations, truck scheduling, bill of freight preparation, etc.)
RPCs	1.05	$ 0.28	Purchasing (Order requests from customer, scheduling, etc.), counting, checking, and (forward and backhaul) shipping paperwork (numbers, destinations, truck scheduling, bill of freight preparation, etc.)
RENs	0.88	$ 0.25	Purchasing (Order requests from customer, scheduling, etc.), counting, checking, and (forward and backhaul) shipping paperwork (numbers, destinations, truck scheduling, bill of freight preparation, etc.)

For example, if labor rate in Korea is $100 per day, the hourly rate should be $100/day / 8 hours = $12.5/hour. Labor rate in the US is applied much higher which is $200 /8 hours = $25/hour. The cost of EAC per container is suggested as:

$$EAC(\$/container) = \frac{(TC_o \times LR_o) + (TC_l \times LR_l)}{AVC} = \frac{\frac{hour}{cycle} \times \frac{\$}{hour}}{\frac{containers}{cycle}}$$

Where

EAC = logistics administration cost, $/container

TC_o = sum of time required for logistics administration activity at overseas, hours/cycle

TC_l = sum of time required for logistics administration activity at local, hours/cycle

LR_o = labor rate for administration per hour at overseas, \$/hour

LR_l = labor rate for administration per hour at local, \$/hour

AVC = average container volume during 1 cycle (containers/cycle)

5.2.1.3. ETC= outbound transportation cost for expendable container system, $/container

Transportation cost is sum of total costs incurred by forward transportation activities including drive, shipping and custom related fees ($/container). Mileage rates for truck Drive also vary depending on the location. For example, mileage rate in Korea is $3.00 per mile, but it is $1.5 per mile in the US due to gas price difference.

$$ETC\ (\$/container) = \frac{(M_{L1} \times DD_{L1}) + (M_S \times DD_S) + (M_{L2} \times DD_{L2})}{FS \times ADV} = \frac{\$/mile \times mile}{days\ x\,(\frac{containers}{day})}$$

Where,

ETC= outbound transportation cost for expendable container system, $/container

M_x = constant rate per mile, \$/mile (M_{Lx}: constant rate per mile for in-land Drive, M_S: constant rate per mile for ocean shipping)

DD_x: delivery distance, mile (DD_{Lx}: in-land delivery distance, mile, DD_s : ocean delivery distance, mile)

FS = frequency of supply, days

ADV: average daily volume of containers, containers/day

Load efficiency of containers on the pallet, pallets on a truck, and pallets on a sea container are both important factors to calculate total transportation costs. All containers are shipped using the standard pallet (1140x980mm) and 5 ton truck which can load up to 10 pallets. Sea container holds 48 pallets at a time. See Table 28.

Table 28: Loaded containers per 5 ton truck and container

Container Type	Containers / pallet	pallets / 5 ton truck	Containers /5 ton truck	Containers/ 5 ton truck if average load efficiency is 80 percent	Pallets per container (W x D x L)	Containers / sea container
A	120	10	1,200	960	2 x 2 x 12	5,760
B	60	10	600	480	2 x 2 x 12	2,880
C	39	10	390	312	2 x 2 x 12	1,872
D	30	10	300	240	2 x 2 x 12	1,440
E	24	10	240	192	2 x 2 x 12	1,152
F	15	10	150	120	2 x 2 x 12	720

Figure 9 shows how to load containers in a sea container. Load efficiency is 89.2 percent for this illustration.

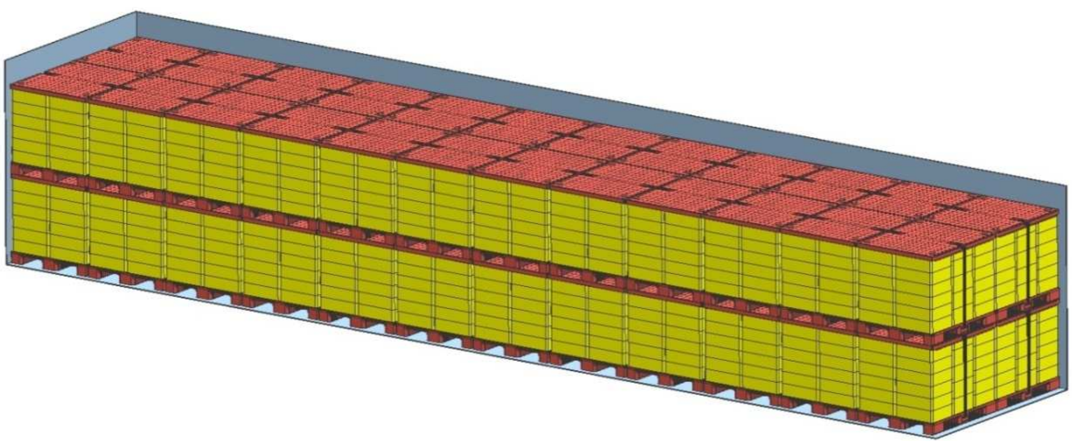

Figure 9: An example of loaded containers in a 40 feet sea container

5.2.1.4. EWC= warehousing cost for expendable container system, \$/container

Warehousing cost is the sum of total costs incurred by warehousing activities including Receive, in-house handling (picking, loading, unloading, packing, repacking, dispatching, moving, storing, consolidation, putting-away, etc.), equipment, storage and energy uses (\$/container)

Calculating warehousing costs is the most complicate due to various activities and cost drivers. It should be noted that most warehousing activities during the international shipping requires a pallet load as the basic unit of activity.

$$EWC(\$/container) = \sum WC_i$$

Where,

EWC = warehousing cost for expendable container system, \$/container

WC_i = cost required for each warehousing activity, \$/container

And WC_i can be described as follows.

$$WC_i = WC_{pi} + WC_{pi} + WC_m + WC_l + WC_{pl} + WC_{pa} + WC_{so} + WC_{st}$$

Table 29 describes the common activities (WC_i) and activity cost drivers carried out for warehousing in a 3 PL logistics company.

Note that only resources consumed for containers and packaged products are considered in this equation because of this research purpose to calculate only activity costs related to container movement, labor and machine costs differ depending on the location of activity performed. Table 30 is warehousing activity cost calculation formulae.

Where,

T_x: Time required to complete X activity for a container, hour

L_x: Labor costto complete X activity for a container, \$/hour

E_x: Equipment costto complete X activity for a container, \$/hour

R_{st}: Store rate per hour, \$/hour-ft^2

$A_{container}$: Area of a container, ft^2/container

Table 29: Main warehousing activities and activity cost drivers

Activities	Resources	Activity cost drivers
WC_{ic} (Inspection/checking)	Time & labor required for inspection/checking a container	Quantity of containers
WC_{st} (Storing)	Space occupied and time required	
WC_{pi} (Picking)	Time, labor and equipment required to pick a container	
WC_{mo} (Moving)	Time, labor and equipment required to move a container	
WC_{lo} (Loading/ Unloading)	Time, labor and equipment required to load/unload a container	
WC_{pk} (Packing, repacking & labeling)	Time and labor required to pack/unpack a container	
WC_{pl} (Palletizing / Unpalletizing)	Time, labor and equipment required to palletize/unpalletize a container	
WC_{so} (Sorting)	Time and labor required to sort a container	

Table 30: Warehousing activity cost calculation formulae

Activities	formulae
WC_{ic} (Inspection/checking)	$WC_{ic}(\$/container) = T_{ic} \times L_{ic}$
WC_{lo} (Loading/ Unloading)	$WC_{lo}(\$/container) = T_{lo} \times (L_{lo} + E_{lo})$
WC_{st} (Storing)	$WC_{st}(\$/\text{hour}) = R_{st} \times A_{container} \times T_{st}$
WC_{pi} (Picking)	$WC_{pi}(\$/container) = T_{pi} \times (L_{pi} + E_{pi})$
WC_{so} (Sorting)	$WC_{so}(\$/container) = T_{so} \times L_{so}$
WC_{mo} (Moving)	$WC_{mo}(\$/container) = T_{mo} \times (L_{mo} + E_{mo})$
WC_{pk} (Packing, repacking & labeling)	$WC_{pk}(\$/container) = T_{pk} \times (L_{pk})$
WC_{pl} (Palletizing / Unpalletizing)	$WC_{pl}(\$/container) = T_{pl} \times (L_{pl} + E_{pl})$

Note that storing cost (WC_{st} (storing)) is depending on the warehouse rental (or owning) cost per area and day. For example, if rental cost per m^2 is \$4.9/day, pallet area is 1.12 m^2, number of containers on a pallet are 120, and stacking number is 2, the daily rate for the a container will be \$4.9/day x 1.12 m^2 / (120 x 2) = \$0.023/day. Table 31 is actual data used for the calculation.

Table 31: Warehousing cost calculation

	Unit cost ($/hour)				Observed average activity time per pallet (sec)	No of activities					
	Korea		US			Korea			US		
	Labor	Machine	Labor	Machine		EXP	RPC	REN	EXP	RPC	REN
WC_{ic} (Inspection/checking)	11.4		22.7		110	1	2	1	0	1	1
WC_{pi} (Picking)	11.4	28.4	22.7	34.1	125	2	2	1	1	0	0
WC_{mo}(Moving)	11.4	28.4	22.7	34.1	150	4	4	3	3	3	3
WC_{lo} (Load/ Unload)	11.4	28.4	22.7	34.1	90	6	9	6	8	9	9
WC_{pk}(Packing, repacking & labeling)	11.4	28.4	22.7	34.1	1300	1	1	1	1	0	0
WC_{pl} (Palletizing / Unpalletize)	11.4	28.4	22.7	34.1	540	2	4	4	2	3	3
WC_{so} (Sorting)	11.4	28.4	22.7	34.1	180	0	1	1	2	1	1
WC_{cl}(Cleaning) (fixed)	$3.6 per pallet load				5.0~6.5/con-tainer	0	1	0	1	1	0

For this calculation, all pallets for storage were stacked up to 4. See Table 32 for the calculations.

Table 32: Example of storing cost calculation

Container type	Rental rate (KO, m^2, day)	Rental rate(US, m^2, day)	Cont-ainers /Pallet	Stack-ing layer	Cont-ainers	Day	Unit hourly Storing cost per container (KR, $)	Unit hourly storing cost per container (US, $)
A	4.9	2.7	120	4	480	1	0.0004	0.0002
B	4.9	2.7	60	4	240	1	0.0009	0.0005
C	4.9	2.7	39	4	156	1	0.0013	0.0007
D	4.9	2.7	30	4	120	1	0.0017	0.0010
E	4.9	2.7	15	4	60	1	0.0034	0.0019

5.2.1.5. EAU= after use activity cost and revenue for expendable container system, $/container

After use activity cost and revenue for expendable container system (EAU) is related to amount of materials disposed or recycled. EAU can be calculated as below.

$$EAU = EAC - ERE$$

- **EAC: after use cost, \$/container:** Sum of total costs incurred by disposal activities, \$/container

$$EAC(\$/container) = DR \times CW$$

Where,

EAC = after use activity cost for expendable container system, \$/container

DR = disposal rate per pound, \$/lb

CW = container weight, lbs/container

- **ERE: recycling revenue, \$/container:** Sum of total revenue incurred by recycling activities, \$/container

$$ERE\ (\$/container) = RR \times CW$$

Where,

ERE = recycling revenue for expendable container system, \$/container

RR = recycling rate per pound, \$/lb

CW = container weight, lbs/container

Table 33 is summary of the after-use activity cost calculation that includes disposal cost and recycling revenue.

Table 33: After-use activities and cost drivers for expendable container system

Processes	Activities	Resource drivers	Activity cost drivers	Cost unit
After-use	Disposal	Weight of material	Weight of containers disposed	$\frac{\$ \times \text{lb}}{\text{containers}}$
	Recycling	Weight of recyclable material	Weight of containers recycled	$\frac{\$ \times \text{lb}}{\text{containers}}$

5.2.2. Reusable packaging system cost (RPSC)

Similar to expendable packaging system cost, reusable packaging system cost (RPSC) is sum of five types of cost: container cost, logistics administration, transportation, warehousing, after-use cost and minus recycling revenue for reusable packaging materials, but RPSC includes backhaul transportation cost for returning used containers. All cost unit is $/container.

$$RPSC = RCC + RAC + RTCF + RTCB + RWC + RAC - RRE$$

Where,

RPSC = reusable packaging system cost, $/container

RCC= reusable container cost, $/container

RAC = logistics administration cost, $/container

RTCF= outbound transportation cost for reusable container system, $/container

RTCB= backhaul transportation cost for reusable container system, $/container

RWC= warehousing cost for reusable container system, $/container

RAC = after-use cost for reusable container system, $/container

RRE = recycling revenue for reusable container system, $/container

5.2.2.1. Reusable container cost

In order to calculate reusable container cost, first of all, the number of containers to run the system must be calculated (Mollenkopf, *et al.* 2005).

$$N = CT \times ADV \times CRR \times PVF$$

Where,

N = number of containers required

CT = container cycle time, days

ADV = average daily volume, containers/day

CRR = reusable container return rate per year, percent/year

PVF = peak volume factor due to Buffers and safety stocks, peak daily volume/average daily volume

CT is total time that reusable containers require to complete one full rotation from the point of distribution center. CRR is replenishing rate, as a percent of N, because we cannot expect to bring every reusable container back due to various reasons such as damage, stolen, etc., a certain percent of containers should be refilled. PVF is a buffer factor to prepare uncertain needs and volume changes in daily basis.

Based on the number of containers required, reusable container cost (RCC) can be calculated as below.

$$RCC\ (\$/container) = \frac{CUC\ x N}{AV\ x DCL}$$

Where,

RCC= reusable container cost, $/container

CUC = container unit cost, $/container

N = number of containers required

AV = annual volume, containers/year

DCL = designed reusable container life, years

5.2.2.2. Logistics administration cost for reusable packaging system

Like expendable packaging system, the logistics administration activity cost (RAC) is sum of total costs incurred by administration activities for returnable packaging system including paper works for customer service, order processing, production planning, procurement, purchasing, forecasting, planning, custom charges, scheduling and dispatch, and inventory control, general administration and management costs ($/container)

Similar to EAC equation, most logistics administration activities are clerical activities related to labor cost and time.

$$RAC(\$/container) = \frac{(TC_o \times LR_o) + (TC_l \times LR_l)}{AVC} = \frac{\frac{hour}{cycle} \times \frac{\$}{hour}}{\frac{containers}{cycle}}$$

Where,

RAC = logistics administration cost, \$/container

TC_o = Sum of time required for logistics administration activity at overseas, hours/cycle

TC_l = Sum of time required for logistics administration activity at local, hours/cycle

LR_o = labor rate for administration per hour at overseas, \$/hour

LR_l = labor rate for administration per hour at local, \$/hour

AVC = average volume during 1 cycle (containers/cycle)

5.2.2.3. Transportation cost for reusable container system

Transportation cost for reusable container system is sum of total costs incurred by outbound and backhaul transportation activities including driving, shipping, custom related fees, equipment and energy uses (\$/container). Unlikely expendable container system that is only considering forward transportation, reusable container system needs not only to include backhaul transportation, but also to add customs clearance and brokerage fees, if it is an international trade.

RTCF (outbound transportation cost for reusable container system) is exactly same as expendable container system.

- **RTCF= outbound transportation cost for reusable container system, \$/container**

$$RTCF\ (\$/container) = \frac{(M_{L1} \times DD_{L1}) + (M_S \times DD_S) + (M_{L2} \times DD_{L2})}{FS \times ADV}$$

Where,

RTCF= outbound transportation cost for reusable container system, \$/container

ETC= outbound transportation cost for expendable container system, \$/container

M_x = constant rate per mile, \$/mile (M_{Lx}: constant rate per mile for in-land Drive, M_S: constant rate per mile for ocean shipping)

DD_x: delivery distance, mile (DD_{Lx}: in-land delivery distance, mile, DD_s : ocean delivery distance, mile)

FS = frequency of supply, days

ADV: average daily volume of containers, containers/day

- **RTCB= backhaul transportation cost for reusable container system, \$/container**

Backhaul transportation cost for reusable container system (BTCB) calculation requires several factors affecting total cost. d is a discount rate for the backhaul transportation applies at the flat rate of 70 percent of the forward transportation cost. BVF (Backhaul container volume factor) is a volume factor for the reusable container which has a function to reduce its volume by nesting or collapsing during backhauling process. Container return rate per cycle (CRR) is a percent of containers returned to the departed point (in this case, 3PL's distribution center). The RTCB is calculated as follows:

$$RTCB\ (\$/container)$$

$$= \frac{(M_{L1} \times DD_{L1}) + (M_S \times DD_S) + (M_{L2} \times DD_{L2})}{FS \times \square DV}\ x\, d\ x BVF\ x CRR + CCC$$

$$= \frac{\$/mile \times mile}{days\ x\, (\frac{containers}{day})} + \frac{(\$/FCL40ft)}{containers/FCL40ft}$$

Where,

RTCB= outbound transportation cost for reusable container system, \$/container

M_x = constant rate per mile, \$/mile (M_{Lx}: constant rate per mile for in-land Drive, M_s: constant rate per mile for ocean shipping)

DD_x: delivery distance, mile (DD_{Lx}: in-land delivery distance, mile, DD_s: ocean delivery distance, mile)

FS = frequency of supply, days

ADV = Average daily volume, containers/day

d = discount rate for reusable, percent

BVF = Backhaul container volume factor

CRR = Container return rate per cycle, percent/cycle

CCC: Custom clearance charge, \$/container

Custom clearance charge (CCC) is considered only for backhaul logistics (e.g. reusable container). This includes customs clearance fee which is imposed by local customs to clear goods, brokerage fee which is charged by a specialized freight broker agent, and other custom related direct costs. For example, if average custom charges for reusable containers in 40ft sea container is \$909.1 for shipping 1200 reusable containers, it will be \$0.76 per container (\$909.1/1200ea = \$0.76/container).

5.2.2.4. RWC= warehousing cost for reusable container system, \$/container

The cost calculation formula for warehousing cost of reusable container system (RWC) is almost same as expendable container system, but it requires different activities as shown in Table 23 which describes the common activities carried out for warehousing in the logistics company and its activity cost drivers. RWC can be calculated as follows:

$$RWC(\$/container) = \sum WC_i$$

Where,

RWC = warehousing cost for reusable container system, $/container

WC_i = cost required for each warehousing activity, $/container

5.2.2.5. RAU= after use activity cost and revenue of reusable container system, $/container

The cost calculation formula for after use activity cost for reusable container system (RAU) is sum of total costs incurred by reconditioning(cleaning), repairing and disposal activities as shown in formula. Recycling revenue is sum of total revenue incurred by recycling activities same as expendable container system.

$$RAU(\$/container) = RAC - RRE$$

- **RAC: after-use activity cost, $/container**

After-use activity cost for reusable container system (RAC) includes reconditioning cost such as cleaning and repairing costs. Cleaning cost is depending on many factors such as locations, cleaning technology, equipment, time, shape of containers, etc. In this study, researcher uses a fixed observed cost which is $3.6 per full pallet load based on the company data. For example, the cleaning cost for a pallet load of containers containing 60 containers will be $3.6/60 = $0.06 per container.

$$RAC(\$/container) = DR \times CW + (R_{recon} \times T_{recon})$$

Where

RAC = after-use activity cost for reusable container system, $/container

DR = disposal rate per pound, $/lb.

CW = container weight, lbs./container

R_{recon}: Basic reconditioning (cleaning and repairing) rate per container, \$/container

T_{recon}: Time required to complete X activity for a container, hour

- **RRE: recycling revenue, \$/container**

Only small amount of recycling revenue (RRE) is expected compared to expendable container system if reusable container system works properly. The mathematical formula for RRE is same as expendable container system as follows:

$$RRE\left(\frac{\$}{container}\right) = \frac{RR \times CW}{\frac{WD}{CT} \times CL \times CRR}$$

Where

RRE = recycling revenue for reusable container system, \$/container

RR = recycling rate per pound, \$/lb.

CW = container weight, lbs./container

WD = Working days, 260 days/year

CT = Cycle time, day

CL = Expected container life, year

CRR = Container return rate per cycle (reusables only, return rate of reusables per year)

5.2.3. Reusable Container Rental System Cost (CRSC)

Notable difference between owned reusable and rental container system is calculation of basic container costs, warehousing costs and after-use costs.

$$CRSC = CRC + CAC + CTCF + CTCB + CWC + \mathrm{CAC}$$

Where

CRSC = container rental system cost, \$/container/cycle

CRC= container rental cost, \$/container/cycle

CAC = logistics administration cost, \$/container/cycle

CTCF= outbound transportation cost for reusable container rental system, \$/container/cycle

CTCB= backhaul transportation cost for reusable container rental system, \$/container/cycle

CWC= warehousing cost for reusable container rental system, \$/container/cycle

CAU= after use activity cost for reusable container rental system, \$/container

5.2.3.1. Container rental cost

Reusable container rental cost (CRC) can be calculated as below.

$$CRC\ (\$/container/cycle) = CUR\ x CT\ x (1 + (1 - CRR))\ x PVF$$

Where

CRC= container rental cost per cycle, \$/container-cycle

CUR = container unit rental rate, \$/container-day

CT = container cycle time, days/cycle

CRR = reusable container return rate

PVF = peak volume factor due to buffers and safety stocks, peak daily volume/average daily volume

CUR contains basic purchasing cost, depreciation, financial costs and profit for a rental company. For example, the basic purchasing cost for a reusable container is \$2/container, depreciation period is 3 years, interest rate is 7.5 percent and profit margin is 5 percent, daily rental cost will be (\$2/365 X 0.075) + (\$2/365/3)) + ((\$2/365 X 0.075) + (\$2/365/3)) X 0.1 = \$0.0025/container/day.

$$CUR\ (\$/container/day) = \frac{RCC\ x IR}{365} + \left(\frac{RCC}{365/dp}\right) + \left(\frac{RCC\ x IR}{365} + \frac{RCC}{365/dp}\right) x pm$$

Where,

CUR = container unit rental rate, $/container/day

IR = interest rate

dp = depreciation period

pm = profit margin

N = number of containers required per day

5.2.3.2. Other costs

Logistics administration cost (CAC) and warehousing cost (CWC) activities are very similar, but slightly different depending on involved activities. This is because many rental companies do some administration and warehousing activities for their customers, so these activity costs are already included in their daily rental cost (See Table 34). The outbound transportation (CTCF), backhaul transportation (CTCB) and the after use activity cost and revenue (CAU) are identical with reusable packaging system. The formulae for rental packaging system are summarized in Table 34.

Table 34: Summary of the reusable container rental cost calculation

Cost, $/container	Formulae
CAC (logistics administration cost)	$= \frac{(TC_o \times LR_o) + (TC_l \times LR_l)}{AVC}$
CTCF (outbound transportation cost)	$\frac{(M_{L1} \times DD_{L1}) + (M_S \times DD_S) + (M_{L2} \times DD_{L2})}{FS \times ADV} + CCE$
CTCB (backhaul transportation cost)	$\frac{(M_{L1} \times DD_{L1}) + (M_S \times DD_S) + (M_{L2} \times DD_{L2})}{FS \times ADV} \times d \times BVF \times CRR + CCE$
CWC (warehousing cost)	$(WC_{pi} + WC_{pi} + WC_m + WC_l + WC_{pl} + WC_{pa} + WC_{so} + WC_{st}) + \frac{FC}{AVC}$
CAU (after use activity cost and revenue)	Reconditioning cost: $DR \times CW + (R_{recon} \times T_{recon})$ Recycling revenue: $RR \times N \times CW x (1 - CRR)$

5.2.4. Summary

Table 35 compared different elements of activities of each packaging system. Generally speaking, reusable and rental packaging system tend to require more complex and many activities compared to expendable packaging system. All cost formulae are summarized in Table 36.

Table 35: Comparison of different cost elements of three packaging systems

Area of activity costs	Packaging systems		
	Expendable packaging system (EXPS)	Reusable packaging system (RPCS)	Rental packaging system (RENS)
Container purchasing	Depends on no. of containers needs	Depends on no. of containers needs	Depends on basic rental cost and no. of containers needs
Administration	Administration related costs including purchasing, receiving and sending	Need additional administration activity for replenishment process	Need additional activity for replenishment process, but need less activity for purchasing
Transportation	Forward transportation cost only	Forward and backhaul transportation cost	Forward and backhaul transportation cost
Warehousing	Only need forward logistics process	Need additional activity for backhaul logistics	Need additional activity for backhaul logistics
After use	Disposal and recycling process	Affect less than expendable system. Replenishment process including Reconditioning is required	Affect less than expendable system. Replenishment process including Reconditioning is required, but parts of the process is included in rental cost

Table 36: Summary of packaging system activity cost formulae

Area of activity	**Formulae** Expendable packaging system (EXPS)	Reusable packaging system (RPCS)	Rental packaging system (RENS)
Container purchasing	$ECC = CC + CC_r + CC_m$	$RCC = \frac{CUCN}{AVDCL}$	$CRC = CURCTCRRPVF$
Administration	$EAC = \frac{(TC_o \times LR_o) + (TC_l \times LR_l)}{AVC}$	$RAC = \frac{(TC_o \times LR_o) + (TC_l \times LR_l)}{AVC}$	$CAC = \frac{(TC_o \times LR_o) + (TC_l \times LR_l)}{AVC}$
Trans-portation	$ETC = \frac{(M_{L1} \times DD_{L1}) + (M_S \times DD_S) + (M_{L2} \times DD_{L2})}{FS \times ADV} + CCE$	$RTCF = \frac{(M_{L1} \times DD_{L1}) + (M_S \times DD_S) + (M_{L2} \times DD_{L2})}{FS \times ADV} + CCE$ $RTCB = \frac{(M_{L1} \times DD_{L1}) + (M_S \times DD_S) + (M_{L2} \times DD_{L2})}{FS \times ADV} dBVFCRR + CCE$	$CTCF = \frac{(M_{L1} \times DD_{L1}) + (M_S \times DD_S) + (M_{L2} \times DD_{L2})}{FS \times ADV} + CCE$ $CTCB = \frac{(M_{L1} \times DD_{L1}) + (M_S \times DD_S) + (M_{L2} \times DD_{L2})}{FS \times ADV} dB + CCE$
Ware-housing	$EWC == \sum WC_i$	$RWC = \sum WC_i$	$CWC = \sum WC_i$
After use	$EAC = DR \times CW$ $ERE = RR \times CW$	$RAC = DRCW$ $RRE = RR \times NCW(1 - CRR)$	$CAC = DR \times CW$ $CRE = RRN \times CW(1 - CRR)$

CHAPTER 6

COMPARATIVE REGRESSION ANALYSIS USING THE ABC MODEL

For the purpose of this study, regression analysis is used to identify and quantify the impact factors that determine packaging system costs in an international supply chain. ABC costs for five logistical activity areas are calculated based on the formulae explained throughout 5.2. Sixteen independent variables are identified and tested.

The purpose of the regression analysis is to seek the relative differences among different packaging systems rather than absolute differences. It imploys a static simulation approach used by Mollenkopf*, et al.* (2005) and is a regression analysis to compare realtive differences between systems as the independent variables in the model change. Dependent variables are the cost differences among reusable (RPCS), expendable (EXPS) and rental systems (RENS)[1]. The cost differences is subtracting the system cost from one to the other (e.g. reusable system cost – expendable system cost), thus the results of regression equations mean the amount of the difference among the systems. Three systems are compared one by one.

Given the elements of costs in Table 35 and equations in Table 36, the independent variable of time, labor and cost of logistical activities are different among the expendable, reusable and rental container systems. Multiple "what if" analyses can be performed to determine the sensitivity of each system to changes in any of the model variables or parameters.

In order to understand the relative influence of the various factors cooperated in the model, a combination simulation-regression analysis was undertaken. A static

[1] RPCS: Reusable packaging system using reusable container: EXPS: Expendable packaging system using one-way container: RENS: Rental packaging system using reusable container.

simulation approach was employed to create multiple independent observations, based on the sample data provided by “A” company, as shown in Table 17.

Since the factor values ranged from low to medium to high, a triangular generating function from Excel was used to generate individual observations for five factors. The unit cost was basically calculated based on the size of containers.

Five hundred observations were generated and each observation represents a unique combination of the eleven factors with factors independently following a triangular distribution. Each of the variables is explained below.

The *container unit cost* range is based on three package sizes. The low cost settings represent a small 380mm x 240mm x 105mm (outside dimension) totes that is made from either single-wall corrugated fiberboard or injection molded plastic. The mode settings are based on 480mm x 380mm x 200mm single wall corrugated fiberboard containers with customized inserts or customized vacuum-formed plastic containers. The high cost settings are based on a large 960mm x 380mm x 200mm double wall corrugated fiberboard box with wood supports or a reusable steel rack. The high cost packages hold the biggest and heaviest parts.

For purposes of the regression analysis, the container cost factor is combined into a single variable representing the ratio of the container costs (reusable unit cost divided by expendable unit cost).

As shown in Table 17, the low cost (small) container ratio is 2/.5 = 4; the medium cost container ratio is 5.0/1.5=3.3; and the high cost (large) container ratio is 10/3 = 3.3. For rental system, reusable container is used at the daily rate of reusable container divided by 100. The cost ratio approach enhances the generalizability of the research by making the relative cost differential the important variable.

Shipping distance was varied from 500 miles (low) to 5,000 miles (mode) to 10,000 miles (high). The high distance, 10,000 miles, was chosen considering the approximate distance between the U.S. West coasts and Korea East coasts.

In-land delivery distance was varied from 100 miles (low) to 300 miles (mode) to 500 miles (high) considering the distance from the port to the consolidation center. The high distance, 500 miles, was chosen considering the approximate distance between the U.S. South coasts and consolidation centers of clients in the middle of the US.

The range used for *container quantity on a pallet* varied from 15 parts per container (low) to 60 (mode) and 120 (high) based on actual data.

Cycle time ranged from 30 days (low), 90 days (mode), and 180 days (high). Note that cycle time includes transit time in both directions as well as dwell and queuing time at both the supplier and customer sites. While many automobile manufacturers aim for a short cycle, poorly managed systems require more time.

Average daily volume ranged from 1,000 (low), 5,000 (mode), and 10,000 (high) parts per day, while *buffers and safety stocks* was estimated as a percentage of average daily volume, ranging from 2 percent (low) to 5 percent (mode) to 10 percent (high).

For both reusable and rental system, three variables are added to determine the impact of return rate, backhaul volume factor and designed container life.

Return rate ranged from 80 (low), 90 (mode), and 95 (high) container per cycle. *Backhaul volume factor* was used for foldable and/or nesting type of containers. The factor was estimated as a percentage of decreased volume, ranging from 0.5 (low) to 0.7 (mode) to 1.0 (high). *Designed container life is one of the most important cost factors for reusable containers.* This ranged from 2 (low), 3 (mode), and 10 (high) years.

6.1. Fixed and assumed data

Cost and other operating assumptions were also necessary to complete the analysis. The cost model is based on the assumption that transportation occurs once every day for reusable, rental and expendable systems. Fixed and assumed data used of the ABC modeling are provided by the company "A" and "B," and shown in Table 37.

Table 37: Fixed and assumed data used for the cost modeling

Standard labor rate		**Foreign country, $/hour**	**11.4**
		US, $/hour	22.7
Standard equipment rate		Foreign country, $/hour	28.4
		US, $/hour	34.1
Storing rate		Foreign country, $/m^2-day	4.9
		US, $/m^2-day	2.7
Transportation cost	mileage rate (truck)	53`, Local (US)	5.0
		5 ton, oversea (KO)	3.0
	Shipping mileage rate ($/mile)		0.3
	Discount mileage rate for returns, percent		30
	Reusable volume factor, percent		10
After-use costs	Expendable container	disposal rate, $/lb	0.010
		recycling rate, $/lb	0.015
	Reusable container	disposal rate, $/lb	0.015
		recycling rate, $/lb.	0.020
Frequency of supply		number per day	1
Basic cleaning rate		$/pallet load	3.6
Working days, year		Days	260

Labor cost is related to the difference in time required to handle packages in each system. The handling time is calculated for the ABC calculation (see section 5.1 for a review of the different processes and activities). The difference in operations and the time estimates are based on observations and measurements from company "A" and company “B,” in 2010, described in section 5.1. Standard labor rate in a foreign country (Korea) is assumed to be $11.4 /hour, but the US is 22.7 $/hour. Equipment rate, storing rate and transport rate are all different depending on where the container is handled. See Table 37 for details.

The shipping mileage rate is assumed to be 0.3 $/mile and 30 percent of discount transport rate is applied for a return trip. Ten percent of volume factor is added for the reusable container since most reusable containers require thicker wall and rib structure, which take up extra space.

For the reusable option, empty containers are cleaned before sending them back to warehouse, so 3.6 $/pallet load of basic cleaning rate is applied. Regardless of system types, frequency of supply is 1 per day and working days are 260 days per year.

Due to loss and damage, the return rate varies from 80 percent to 95 percent. It is also assumed that the weight characteristics are the same for the packaging systems.

For simplification, the initial analyses assume a 2-year project life for the reusable container system, due to the fact that some firms use a 2-year payback period justification basis and others (especially in the automotive industry) base packaging decisions on a product life of two model years. This is a bias in favor of expendable packages since most reusable shipping containers can last much longer.

6.2. Base regression analysis results

Tables 38 through 40 compare the cost of RPCS (reusable packaging system), EXPS (expendable packaging system) and RENS (rental packaging system). They compare the different variables which impact on the cost differentials of three different packaging systems.

When the RPCS and EXPS are compared in Table 38, cost ratio between reusable and expendable containers, designed container life, cycle time, custom charges, shipping distance, container weight, average daily volume, and back haul volume factor are variables that have significant impact on the packaging system cost.

Table 38: Base regression analysis results comparing between reusable packaging system and expendable packaging system costs

RPCS – EXPS	Variables	Standardized coefficients (Beta)	t	Sig.
R: .878 R Square: .772 Adjusted R Square: .763	(Constant)		-2.908	0.004
	RPC / EXP	**0.656**	**22.872**	**0.000**
	Designed container life (year, RPC)	**-0.321**	**-11.269**	**0.000**
	Cycle time (days)	**0.231**	**8.136**	**0.000**
	Custom Charges ($/ea.)	**0.280**	**5.867**	**0.000**
	Shipping distance (miles)	**0.155**	**5.337**	**0.000**
	Container weight (lbs./container)	**0.100**	**3.533**	**0.000**
	Average daily Volume (containers/day)	**-0.145**	**-3.029**	**0.003**
	Backhaul volume factor	**0.085**	**2.983**	**0.003**
	Container quantity per pallet (tote/pallet)	-0.023	-0.800	0.424
	Peak volume factor	-0.013	-0.473	0.637
	Return rate (percent/year, RPC)	-0.003	-0.094	0.925

※ *Note: Dependent variable: reusable packaging system cost – expendable packaging system cost*

Statistically, based on the initial observations, not all factors are significantly contributing the system cost differential. Container cost ratio (reusable container cost / expendable container cost) is the largest cost contributor based on the standardized coefficients (Betas) results, which is a similar result to Mollenkopf, et al. (2005). The positive relationship with the dependent variable, *the cost differential*, suggests that as the relative cost of the reusable container increases, the expendable container systems are more economically viable.

Designed container life, cycle time, custom charge, shipping distance, container weight, and backhaul volume factor also have positive Beta value, meaning as these factors increase, the EXPS is more economically viable.

Designed container life is the second important variable in determining which container system to use. This factor has negative value along with container quantity per pallet and average daily volume, meaning RPCS is more viable option as RPCS has longer designed container life, more container quantity per pallet and more average daily volume than EXPS.

Cycle time is the third most important variable, but still significant impact on determining packaging systems. But it is interestng to note that shipping distance is less statistically significant than cycle time. A longer cycle time tends to increase the number of containers in the system, so it is a more important factor to contribute to the total cost of reusable packaging systems.

Custom charges rank fourth in importance. Custom charges largely depend on the value of the products (not a package), and it is unavoidable for whatever types of packaging system used during forward transportation. However, it is a significant factor for RPCS and RENS because it contributes to the cost of returns. Container quantity per pallet, peak volume factor and return rate were statistically not significant factors in this scenario.

In Table 39, reusable (RPCS) and rental (RENS) packaging systems are compared. Interestingly, cycle time and cost ratio are not only the most important factors that could impact on packaging system decision, but they impact on the system in opposite way.

From the analysis, if cycle time increases, rental is a more viable option because a company which operates RPCS has to invest more money to purchase reusable containers.

On the other hand, cost ratio has a negative correlation with the dependent variable which suggests that as reusable container costs increase, RENS is also economically less desirable option. Because RENS essentially use RPCs, increasing container purchasing cost is likely increase RPC rental cost.

Table 39: Base regression analysis results comparing between reusable packaging system and rental packaging system costs

RPCS – RENS	Variables	Standardized coefficients (Beta)	t	Sig.
R: .862 R Square .743 Adjusted R Square.733	(Constant)		-1.004	0.316
	Cycle time (days)	**0.601**	**19.940**	**0.000**
	RPC / REN	**-0.610**	**-19.876**	**0.000**
	Designed container life (year, RPC)	**0.183**	**6.072**	**0.000**
	Container weight (lbs./container)	**-0.088**	**-2.911**	**0.004**
	Return rate (percent/year, RPC)	**0.061**	**2.016**	**0.045**
	Backhaul volume factor	0.048	1.577	0.116
	Shipping distance (miles)	-0.041	-1.314	0.190
	Container quantity per pallet (tote/pallet)	-0.022	-0.734	0.463
	Custom Charges ($/ea.)	-0.029	-0.564	0.573
	Average daily Volume (containers/day)	-0.024	-0.483	0.630
	Peak volume factor	0.010	0.317	0.751

※ *Note: Dependent variable: reusable packaging system cost – rental packaging system cost*

Table 40 compares the EXPS and RENS. In this case, too, container cost ratio and cycle time are two most important factors and impact opposite way as Table 40, meaning longer cycle time favors EXPS, and larger cost difference favors RENS.

Table 40: Base regression analysis results comparing between expendable packaging system and rental packaging system costs

EXPS - RENS	Variables	Standardized coefficients (Beta)	t	Sig.
R: .928 R Square: .861 Adjusted R Square: .855	(Constant)		-0.259	0.796
	EXP / REN	**-0.673**	**-30.234**	**0.000**
	Cycle time (days)	**0.629**	**28.315**	**0.000**
	Custom Charges ($/ea.)	**0.134**	**3.595**	**0.000**
	Shipping distance (miles)	**0.061**	**2.740**	**0.007**
	Backhaul volume factor	**0.061**	**2.737**	**0.007**
	Average daily Volume (containers/day)	**-0.086**	**-2.318**	**0.021**
	Designed container life (year, RPC)	-0.015	-0.667	0.506
	Container weight (lbs./container)	0.010	0.444	0.657
	Return rate (percent/year, RPC)	0.009	0.404	0.686
	Container quantity per pallet (tote/pallet)	-0.008	-0.341	0.734
	Peak volume factor	0.000	0.011	0.991

※ *Note: Dependent variable: expendable packaging system cost-rental packaging system cost*

While these results are interesting in themselves, the three packaging systems are further analyzed to have better understanding of the sensitivity of the cost differential and impact of each variable. This process also can help to generalize research results (Mollenkopf, *et al.* 2005).

6.3. Results of regression analysis scenarios

Eleven scenarios are developed by altering the values of the independent factors such as distance, cycle time (doubled and halved), custom clearance charge, container quantity, average daily volume, backhaul volume factor, designed container life, and combination of factors. Results of the sensitivity analysis are presented in from Table 41 to 74 to illustrate the impacts on the relative cost of packaging systems.

6.3.1. Scenario 1: Distance doubled

It is considered that distance is one of the most important factors to decide between EXPS and RPCS. For every system, while container purchasing cost ratio is still the most important factor, designed container life, shipping distance, cycle time, and custom charge remains the most important variables to determine total packaging system cost. Distance contributes to cycle time greatly and becomes very important for RPCS and RENS as expected. Table 41 through Table 43 show the results of the regression analysis when the distance is doubled.

Table 41: Variations in the regression analysis as compared to the Base Analysis between reusable and expendable packaging system costs (Scenario 1: Distance doubled)

RPCS-EXPS	Variables	Standardized coefficients (Beta)	t	Sig.
R: .894 R Square: .799 Adjusted R Square: .795	(Constant)		-3.827	0.000
	RPC / EXP	**0.605**	**29.551**	**0.000**
	Designed container life (year, RPC)	**-0.272**	**-13.285**	**0.000**
	Shipping distance (miles)	**0.272**	**13.147**	**0.000**
	Cycle time (days)	**0.226**	**11.129**	**0.000**
	Custom Charges ($/ea.)	**0.327**	**9.915**	**0.000**
	Average daily Volume (containers/day)	**-0.196**	**-5.922**	**0.000**
	Backhaul volume factor	**0.104**	**5.091**	**0.000**
	Container weight (lbs./container)	**0.077**	**3.749**	**0.000**
	Return rate (percent/year, RPC)	-0.010	-0.512	0.609
	Peak volume factor	-0.007	-0.339	0.735
	Container quantity per pallet (tote/pallet)	-0.001	-0.046	0.963

Table 42: Variations in the regression analysis as compared to the Base Analysis between reusable and rental packaging system costs (Scenario 1: Distance doubled)

RPCS – RENS	Variables	Standardized coefficients (Beta)	t	Sig.
R: .867 R Square .751 Adjusted R Square: .745	(Constant)		-1.112	0.267
	Cycle time (days)	**0.614**	**27.096**	**0.000**
	RPC / REN	**-0.608**	**-26.634**	**0.000**
	Designed container life (year, RPC)	**0.185**	**8.118**	**0.000**
	Container weight (lbs/container)	**-0.064**	**-2.811**	**0.005**
	Return rate (percent/year, RPC)	**0.050**	**2.189**	**0.029**
	Backhaul volume factor	0.026	1.128	0.260
	Shipping distance (miles)	-0.020	-0.868	0.386
	Container quantity per pallet (tote/pallet)	0.012	0.535	0.593
	Peak volume factor	-0.007	-0.294	0.769
	Average daily Volume (containers/day)	-0.004	-0.108	0.914
	Custom Charges ($/ea)	-0.004	-0.103	0.918

Table 43: Variations in the regression analysis as compared to the Base Analysis between expendable and rental packaging system costs (Scenario 1: Distance doubled)

EXPS - RENS	Variables	Standardized coefficients (Beta)	t	Sig.
R: .932 R Square: .868 Adjusted R Square: .865	(Constant)		-0.902	0.368
	EXP / REN	**-0.632**	**-38.285**	**0.000**
	Cycle time (days)	**0.608**	**36.906**	**0.000**
	Shipping distance (miles)	**0.150**	**8.991**	**0.000**
	Custom Charges ($/ea.)	**0.194**	**7.271**	**0.000**
	Backhaul volume factor	**0.067**	**4.056**	**0.000**
	Average daily Volume (containers/day)	**-0.098**	**-3.667**	**0.000**
	Container quantity per pallet (tote/pallet)	0.014	0.835	0.404
	Peak volume factor	-0.012	-0.749	0.454
	Return rate (percent/year, RPC)	0.009	0.537	0.592
	Container weight (lbs./container)	0.007	0.395	0.693
	Designed container life (year, RPC)	0.001	0.082	0.934

As shown in Table 41 and Table 43, all values of the standardized coefficients (Betas) for container purchasing cost ratio, cycle time, shipping distance, custom charges, backhaul volume, and average daily volume decreased since doubling shipping distance favors EXPS. Doubling shipping distance is not critical factor of choosing between RPCS and RENS as much as deciding between RPCS and EXPS or between RENS and EXPS.

6.3.2. Scenario 2: Cycle time doubled

Shipping distance is directly related to cycle time and the cycle time contributes only for reusable and rental packaging systems because EXPS does not have the return process. Thus, Scenario 2 doubled the cycle time for both RPCS and RENS as shown in Table 44 through Table 46. As expected, container cost ratio and cycle time are generally the most important variables. Note that designed container life is an important factor when comparing between RPCS and EXPS and RPCS and RENS, but this does not contribute much for between EXPS and RENS. This is because the RENS is usually based on the unit rental price per certain rental period rather than designed container life. In many cases, unit rental price is directly based on the purchasing cost of the container although the higher cost of container does not always guarantee the longer use life of the container. Shipping distance and custom charge are more important factors and show positive value, meaning as cycle time increases, EXPS is more economical option.

Table 44: Variations in the regression analysis as compared to the Base Analysis between reusable and expendable packaging system costs (Scenario 2: Cycle time doubled)

RPCS – EXPS	Variables	Standardized coefficients (Beta)	t	Sig.
R: .917 R Square: .840 Adjusted R Square: .837	(Constant)		-2.345	0.019
	RPC / EXP	**0.625**	**34.230**	**0.000**
	Designed container life (year, RPC)	**-0.429**	**-23.511**	**0.000**
	Cycle time (days)	**0.389**	**21.444**	**0.000**
	Custom Charges ($/ea.)	**0.204**	**6.940**	**0.000**
	Shipping distance (miles)	**0.123**	**6.666**	**0.000**
	Average daily Volume (containers/day)	**-0.098**	**-3.315**	**0.001**
	Backhaul volume factor	**0.056**	**3.088**	**0.002**
	Container weight (lbs./container)	**0.049**	**2.683**	**0.008**
	Return rate (percent/year, RPC)	-0.019	-1.036	0.301
	Peak volume factor	0.000	-0.011	0.991

Table 45: Variations in the regression analysis as compared to the Base Analysis between reusable and rental packaging system costs (Scenario 2: Cycle time doubled)

RPCS – RENS	Variables	Standardized coefficients (Beta)	t	Sig.
R: .866 R Square .750 Adjusted R Square: .744	(Constant)		-0.964	0.336
	Cycle time (days)	**0.616**	**27.109**	**0.000**
	RPC / REN	**-0.610**	**-26.652**	**0.000**
	Designed container life (year, RPC)	**0.186**	**8.121**	**0.000**
	Return rate (percent/year, RPC)	**0.050**	**2.204**	**0.028**
	Container weight (lbs./container)	-0.038	-1.654	0.099
	Backhaul volume factor	0.025	1.110	0.268
	Shipping distance (miles)	-0.020	-0.874	0.383
	Peak volume factor	-0.007	-0.310	0.756
	Container quantity per pallet (tote/pallet)	-0.006	-0.253	0.800
	Custom Charges ($/ea.)	-0.004	-0.099	0.921
	Average daily Volume (containers/day)	-0.003	-0.090	0.928

Table 46: Variations in the regression analysis as compared to the Base Analysis between expendable and rental packaging system costs (Scenario 2: Cycle time doubled)

EXPS - RENS	Variables	Standardized coefficients (Beta)	t	Sig.
R: .902 R Square: .814 Adjusted R Square: .810	(Constant)		-0.684	0.494
	Cycle time (days)	**0.686**	**35.025**	**0.000**
	EXP / REN	**-0.579**	**-29.458**	**0.000**
	Shipping distance (miles)	**0.060**	**3.018**	**0.003**
	Custom Charges ($/ea.)	**0.094**	**2.960**	**0.003**
	Backhaul volume factor	0.032	1.613	0.107
	Return rate (percent/year, RPC)	0.026	1.303	0.193
	Average daily Volume (containers/day)	-0.025	-0.786	0.432
	Designed container life (year, RPC)	0.015	0.752	0.452
	Peak volume factor	-0.009	-0.472	0.637
	Container weight (lbs./container)	-0.003	-0.163	0.870
	Container quantity per pallet (tote/pallet)	-0.001	-0.026	0.979

6.3.3. Scenario 3: Custom charges removed

As mentioned earlier, custom clearance charges are depending on the value of the product for forward transportation, and many countries exempt import taxes if reusable shipping containers are returned to the origin. However, custom charges becomes an important issue if the containers are not properly documented.

In this scenario, all custom charges for containers are removed assuming that the company received tax exemptions or each export and import countries have a mutual agreement (e.g. Free Trade Agreement) for their returning containers.

Tables 47 to Table 49 show that both cost ratio and cycle time are consistently most important factors regardless of simulation scenarios. When comparing RPCS and EXPS, cost ratio and cycle time are positive values, meaning that EXPS is better option as cost ratio and cycle time increase. Cost ratios are negative for both RPCS-RENS and EXPS-RENS, meaning RPCS and EXPS are still heavily favored in this scenario compared to RENS.

Table 47: Variations in the regression analysis as compared to the Base Analysis between reusable and expendable packaging system costs (Scenario 3: Custom charges removed)

RPCS – EXPS	Variables	Standardized coefficients (Beta)	t	Sig.
R: .872 R Square: .760 Adjusted R Square: .755	(Constant)		-2.500	0.013
	RPC / EXP	**0.686**	**30.704**	**0.000**
	Designed container life (year, RPC)	**-0.307**	**-13.710**	**0.000**
	Average daily Volume (containers/day)	**-0.303**	**-13.613**	**0.000**
	Cycle time (days)	**0.261**	**11.748**	**0.000**
	Shipping distance (miles)	**0.163**	**7.234**	**0.000**
	Container weight (lbs./container)	**0.091**	**4.069**	**0.000**
	Backhaul volume factor	**0.075**	**3.357**	**0.001**
	Return rate (percent/year, RPC)	-0.012	-0.548	0.584
	Peak volume factor	-0.007	-0.295	0.768
	Container quantity per pallet (tote/pallet)	-0.003	-0.129	0.897

※ For models with dependent variable RPCS-EXPS, the following variables are constants or have missing correlations: Custom Charges ($/ea). They are deleted from the analysis.

Table 48: Variations in the regression analysis as compared to the Base Analysis between reusable and rental packaging system costs (Scenario 3: Custom charges removed)

RPCS – RENS	Variables	Standardized coefficients Beta	t	Sig.
R: .867 R Square .751 Adjusted R Square.746	(Constant)		-1.164	0.245
	Cycle time (days)	**0.614**	**27.129**	**0.000**
	RPC / REN	**-0.608**	**-26.669**	**0.000**
	Designed container life (year, RPC)	**0.185**	**8.126**	**0.000**
	Container weight (lbs./container)	**-0.064**	**-2.815**	**0.005**
	Return rate (percent/year, RPC)	**0.050**	**2.192**	**0.029**
	Backhaul volume factor	0.026	1.130	0.259
	Shipping distance (miles)	-0.020	-0.867	0.387
	Container quantity per pallet (tote/pallet)	0.012	0.536	0.592
	Peak volume factor	-0.007	-0.294	0.769
	Average daily Volume (containers/day)	-0.001	-0.044	0.965

Table 49: Variations in the regression analysis as compared to the Base Analysis between expendable and rental packaging system costs (Scenario 3: Custom charges removed)

EXPS - RENS	Variables	Standardized coefficients Beta	t	Sig.
R: .929 R Square: .863 Adjusted R Square: .860	(Constant)		0.227	0.821
	EXP / REN	**-0.661**	**-39.254**	**0.000**
	Cycle time (days)	**0.635**	**37.838**	**0.000**
	Average daily Volume (containers/day)	**-0.153**	**-9.076**	**0.000**
	Shipping distance (miles)	**0.082**	**4.809**	**0.000**
	Backhaul volume factor	**0.048**	**2.822**	**0.005**
	Container quantity per pallet (tote/pallet)	0.013	0.793	0.428
	Peak volume factor	-0.012	-0.730	0.466
	Return rate (percent/year, RPC)	0.009	0.546	0.585
	Container weight (lbs./container)	0.009	0.510	0.610
	Designed container life (year, RPC)	0.004	0.256	0.798

A negative relationship with the dependent variable, standardized coefficients, suggests that the average daily volume increases, RPCS becomes more viable. However, if the logistics provider is required to pay significant amount of the custom charges or deposits when they ships back empty containers from the oversea, establishing international RPCS or RENS should be very difficult to operate.

6.3.4. Scenario 4: Quantity of containers on a pallet halved

Scenario 4 addresses the issue of container quantity on a pallet. A pallet is generally regarded as a basic unit of international transportation, so more containers on a pallet means the container is smaller and more economical in distribution process.

Even if average container quantity on a pallet halved, container cost ratio is still the most important contributor on packaging system cost. Like previous scenarios, designed container life and cycle time and are also significantly related to all packaging systems. Table 50 through Table 52 show the impact of the quantity of containers on a pallet.

Table 50: Variations in the regression analysis as compared to the Base Analysis between reusable and expendable packaging system costs (Scenario 4: Container Q on a pallet halved)

RPCS – EXPS	Variables	Standardized coefficients (Beta)	t	Sig.
R: .887 R Square: .787 Adjusted R Square: .782	(Constant)		-3.823	0.000
	RPC / EXP	**0.674**	**31.914**	**0.000**
	Designed container life (year, RPC)	**-0.302**	**-14.274**	**0.000**
	Cycle time (days)	**0.252**	**12.023**	**0.000**
	Custom Charges ($/ea.)	**0.273**	**8.017**	**0.000**
	Shipping distance (miles)	**0.163**	**7.643**	**0.000**
	Container weight (lbs./container)	**0.088**	**4.153**	**0.000**
	Average daily Volume (containers/day)	**-0.136**	**-3.995**	**0.000**
	Backhaul volume factor	**0.074**	**3.511**	**0.000**
	Return rate (percent/year, RPC)	-0.011	-0.518	0.605
	Peak volume factor	-0.006	-0.271	0.786
	Container quantity per pallet (tote/pallet)	-0.004	-0.198	0.843

Table 51: Variations in the regression analysis as compared to the Base Analysis between reusable and rental packaging system costs (Scenario 4: Container Q on a pallet halved)

RPCS – RENS	Variables	Standardized coefficients (Beta)	t	Sig.
R: .860 R Square: .739 Adjusted R Square: .733	(Constant)		-1.369	0.172
	Cycle time (days)	**0.613**	**27.046**	**0.000**
	RPC / REN	**-0.607**	**-26.573**	**0.000**
	Designed container life (year, RPC)	**0.185**	**8.105**	**0.000**
	Container weight (lbs./container)	**-0.063**	**-2.779**	**0.006**
	Return rate (percent/year, RPC)	**0.049**	**2.154**	**0.032**
	Container quantity per pallet (tote/pallet)	**0.048**	**2.108**	**0.036**
	Backhaul volume factor	0.027	1.163	0.246
	Shipping distance (miles)	-0.020	-0.855	0.393
	Peak volume factor	-0.006	-0.261	0.794
	Average daily Volume (containers/day)	-0.005	-0.141	0.888
	Custom Charges ($/ea.)	-0.004	-0.109	0.913

Table 52: Variations in the regression analysis as compared to the Base Analysis between expendable and rental packaging system costs (Scenario 4: Container Q on a pallet halved)

EXPS - RENS	Variables	Standardized coefficients (Beta)	t	Sig.
R: .933 R Square: .870 Adjusted R Square: .867	(Constant)		-1.017	0.310
	EXP / REN	**-0.656**	**-39.977**	**0.000**
	Cycle time (days)	**0.628**	**38.369**	**0.000**
	Custom Charges ($/ea.)	**0.153**	**5.763**	**0.000**
	Shipping distance (miles)	**0.083**	**5.006**	**0.000**
	Backhaul volume factor	**0.048**	**2.939**	**0.003**
	Container quantity per pallet (tote/pallet)	**0.042**	**2.554**	**0.011**
	Average daily Volume (containers/day)	**-0.060**	**-2.254**	**0.025**
	Peak volume factor	-0.011	-0.680	0.497
	Return rate (percent/year, RPC)	0.009	0.549	0.583
	Container weight (lbs./container)	0.008	0.505	0.614
	Designed container life (year, RPC)	0.003	0.195	0.846

6.3.5. Scenario 5: Average daily volume doubled

Scenario 5 addresses the issue of average daily volume. See Table 53 to Table 55. When average daily volume doubled, cost ratio is consistently the most important contributors on each packaging system. Designed container life and cycle time are also significantly important for RPCS. Shipping distance is one of contributors for the cost of EXPS compared to RPCS and RENS while container weight and return rate is more important when comparing RPCS and RENS.

Table 53: Variations in the regression analysis as compared to the Base Analysis between reusable and expendable packaging system costs (Scenario 5: Average daily Volume doubled)

RPCS – EXPS	Variables	Standardized coefficients Beta)	t	Sig.
R: .881 R Square: .777 Adjusted R Square: .772	(Constant)		-3.992	0.000
	RPC / EXP	**0.725**	**33.549**	**0.000**
	Designed container life (year, RPC)	**-0.320**	**-14.828**	**0.000**
	Cycle time (days)	**0.274**	**12.771**	**0.000**
	Custom Charges ($/ea.)	**0.165**	**4.745**	**0.000**
	Shipping distance (miles)	**0.099**	**4.520**	**0.000**
	Container weight (lbs./container)	**0.094**	**4.346**	**0.000**
	Average daily Volume (containers/day)	-0.064	-1.831	0.068
	Backhaul volume factor	0.035	1.623	0.105
	Return rate (percent/year, RPC)	-0.011	-0.500	0.617
	Container quantity per pallet (tote/pallet)	-0.004	-0.204	0.839
	Peak volume factor	-0.003	-0.162	0.871

Table 54: Variations in the regression analysis as compared to the Base Analysis between reusable and rental packaging system costs (Scenario 5: Average daily Volume doubled)

RPCS - RENS	Variables	Standardized coefficients (Beta)	t	Sig.
R: .867 R Square: .751 Adjusted R Square: .745	(Constant)		-1.110	0.268
	Cycle time (days)	**0.614**	**27.097**	**0.000**
	RPC / REN	**-0.608**	**-26.635**	**0.000**
	Designed container life (year, RPC)	**0.185**	**8.118**	**0.000**
	Container weight (lbs./container)	**-0.064**	**-2.811**	**0.005**
	Return rate (percent/year, RPC)	**0.050**	**2.189**	**0.029**
	Backhaul volume factor	0.026	1.128	0.260
	Shipping distance (miles)	-0.020	-0.869	0.386
	Container quantity per pallet (tote/pallet)	0.012	0.535	0.593
	Peak volume factor	-0.007	-0.294	0.769
	Average daily Volume (containers/day)	-0.004	-0.116	0.908
	Custom Charges ($/ea.)	-0.004	-0.113	0.910

Table 55: Variations in the regression analysis as compared to the Base Analysis between expendable and rental packaging system costs (Scenario 5: Average daily Volume doubled)

EXPS - RENS	Variables	Standardized coefficients (Beta)	t	Sig.
R: .934 R Square: .873 Adjusted R Square: .870	(Constant)		-0.722	0.470
	EXP / REN	**-0.673**	**-41.462**	**0.000**
	Cycle time (days)	**0.644**	**39.797**	**0.000**
	Custom Charges ($/ea.)	**0.094**	**3.567**	**0.000**
	Shipping distance (miles)	**0.047**	**2.887**	**0.004**
	Backhaul volume factor	0.027	1.658	0.098
	Container quantity per pallet (tote/pallet)	0.013	0.794	0.428
	Average daily Volume (containers/day)	-0.020	-0.770	0.442
	Peak volume factor	-0.011	-0.662	0.508
	Return rate (percent/year, RPC)	0.010	0.635	0.526
	Container weight (lbs./container)	0.008	0.474	0.636
	Designed container life (year, RPC)	0.006	0.360	0.719

6.3.6. Scenario 6: Backhaul volume halved

Scenario 6 addresses the issue of backhaul volume factor. If a reusable container has a function to reduce its volume by any stacking methods such as collapsible, foldable, nesting, etc., it is assumed that this could be one of the saving factors for reusable and rental packaging systems since these systems require return process (backhaul logistics). See Table 56 through Table 58.

Table 56: Variations in the regression analysis as compared to the Base Analysis between reusable and expendable packaging system costs (Scenario 6: Backhaul volume halved)

RPCS – EXPS	Variables	Standardized coefficients (Beta)	t	Sig.
R: .884 R Square: .781 Adjusted R Square: .776	(Constant)		-3.914	0.000
	RPC / EXP	**0.715**	**33.393**	**0.000**
	Designed container life (year, RPC)	**-0.316**	**-14.777**	**0.000**
	Cycle time (days)	**0.270**	**12.704**	**0.000**
	Custom Charges ($/ea.)	**0.211**	**6.125**	**0.000**
	Shipping distance (miles)	**0.107**	**4.935**	**0.000**
	Container weight (lbs./container)	**0.093**	**4.319**	**0.000**
	Average daily Volume (containers/day)	**-0.073**	**-2.105**	**0.036**
	Backhaul volume factor	0.034	1.578	0.115
	Return rate (percent/year, RPC)	-0.011	-0.508	0.612
	Container quantity per pallet (tote/pallet)	-0.004	-0.195	0.846
	Peak volume factor	-0.004	-0.189	0.850

Table 57: Variations in the regression analysis as compared to the Base Analysis between reusable and rental packaging system costs (Scenario 6: Backhaul volume halved)

RPCS – RENS	Variables	Standardized coefficients (Beta)	t	Sig.
R: .867 R Square .751 Adjusted R Square: .745	(Constant)		-1.138	0.255
	Cycle time (days)	**0.614**	**27.106**	**0.000**
	RPC / REN	**-0.608**	**-26.636**	**0.000**
	Designed container life (year, RPC)	**0.185**	**8.118**	**0.000**
	Container weight (lbs./container)	**-0.064**	**-2.812**	**0.005**
	Return rate (percent/year, RPC)	**0.050**	**2.198**	**0.028**
	Backhaul volume factor	0.028	1.212	0.226
	Shipping distance (miles)	-0.020	-0.869	0.385
	Container quantity per pallet (tote/pallet)	0.012	0.533	0.594
	Peak volume factor	-0.007	-0.290	0.772
	Average daily Volume (containers/day)	-0.004	-0.109	0.913
	Custom Charges ($/ea.)	-0.004	-0.104	0.917

Table 58: Variations in the regression analysis as compared to the Base Analysis between expendable and rental packaging system costs (Scenario 6: Backhaul volume halved)

EXPS – RENS	Variables	Standardized coefficients (Beta)	t	Sig.
R: .935 R Square: .873 Adjusted R Square: .870	(Constant)		-0.713	0.476
	EXP / REN	**-0.669**	**-41.307**	**0.000**
	Cycle time (days)	**0.641**	**39.677**	**0.000**
	Custom Charges ($/ea.)	**0.117**	**4.478**	**0.000**
	Shipping distance (miles)	**0.052**	**3.159**	**0.002**
	Backhaul volume factor	0.028	1.719	0.086
	Average daily Volume (containers/day)	-0.025	-0.938	0.349
	Container quantity per pallet (tote/pallet)	0.013	0.794	0.427
	Peak volume factor	-0.011	-0.672	0.502
	Return rate (percent/year, RPC)	0.010	0.635	0.526
	Container weight (lbs./container)	0.008	0.467	0.641
	Designed container life (year, RPC)	0.006	0.341	0.733

When backhaul volume factor is halved, cost ratio and cycle time were still important factors, and custom charges and shipping distance are important for RPCS-EXPS and EXPS-RENS comparison. In RPCS-EXPS comparison, although reducing backhaul volume factor has little influence on the regression results, it contributes on average daily volume of containers.

6.3.7. Scenario 7: Designed container life doubled

It is expected that designed container life can impact greatly on container cost for a reusable packaging system. When the container life is doubled, cost ratio, designed container life, custom charges, shipping distance, cycle time, average daily volume, container weight and backhaul volume factor contribute significantly on RPCS and EXPS costs.

Again, increased container life does not affect RENS-EXPS cost comparison since RENS is based on the container rental cost in this scenario. See Table 59 through Table 61.

Table 59: Variations in the regression analysis as compared to the Base Analysis between reusable and expendable packaging system costs (Scenario 7: Container life doubled)

RPCS – EXPS	Variables	Standardized coefficients Beta)	t	Sig.
R: .846 R Square: .716 Adjusted R Square: .710	(Constant)		-4.239	0.000
	RPC / EXP	**0.667**	**27.411**	**0.000**
	Designed container life (year, RPC)	**-0.191**	**-7.850**	**0.000**
	Custom Charges ($/ea.)	**0.305**	**7.780**	**0.000**
	Shipping distance (miles)	**0.182**	**7.387**	**0.000**
	Cycle time (days)	**0.139**	**5.729**	**0.000**
	Container weight (lbs./container)	**0.110**	**4.518**	**0.000**
	Average daily Volume (containers/day)	**-0.156**	**-3.954**	**0.000**
	Backhaul volume factor	**0.082**	**3.383**	**0.001**
	Peak volume factor	-0.009	-0.383	0.702
	Container quantity per pallet (tote/pallet)	-0.005	-0.211	0.833
	Return rate (percent/year, RPC)	-0.005	-0.189	0.851

Table 60: Variations in the regression analysis as compared to the Base Analysis between reusable and rental packaging system costs (Scenario 7: Container life doubled)

RPCS – RENS	Variables	Standardized coefficients (Beta)	t	Sig.
R: .860 R Square .740 Adjusted R Square.734	(Constant)		-0.744	0.457
	Cycle time (days)	**0.676**	**29.161**	**0.000**
	RPC / REN	**-0.545**	**-23.364**	**0.000**
	Designed container life (year, RPC)	**0.099**	**4.237**	**0.000**
	Container weight (lbs./container)	**-0.072**	**-3.075**	**0.002**
	Return rate (percent/year, RPC)	**0.045**	**1.928**	**0.054**
	Backhaul volume factor	0.025	1.055	0.292
	Shipping distance (miles)	-0.020	-0.860	0.390
	Container quantity per pallet (tote/pallet)	0.015	0.652	0.514
	Peak volume factor	-0.005	-0.224	0.823
	Custom Charges ($/ea.)	-0.006	-0.148	0.882
	Average daily Volume (containers/day)	-0.003	-0.076	0.939

Table 61: Variations in the regression analysis as compared to the Base Analysis between expendable and rental packaging system costs (Scenario 7: Container life doubled)

EXPS - RENS	Variables	Standardized coefficients (Beta)	t	Sig.
R: .933 R Square: .870 Adjusted R Square: .867	(Constant)		-0.733	0.464
	EXP / REN	**-0.657**	**-40.029**	**0.000**
	Cycle time (days)	**0.629**	**38.447**	**0.000**
	Custom Charges ($/ea.)	**0.153**	**5.781**	**0.000**
	Shipping distance (miles)	**0.083**	**5.005**	**0.000**
	Backhaul volume factor	**0.048**	**2.905**	**0.004**
	Average daily Volume (containers/day)	**-0.059**	**-2.221**	**0.027**
	Container quantity per pallet (tote/pallet)	0.013	0.802	0.423
	Peak volume factor	-0.012	-0.717	0.473
	Return rate (percent/year, RPC)	0.010	0.586	0.558
	Container weight (lbs./container)	0.008	0.475	0.635
	Designed container life (year, RPC)	0.003	0.193	0.847

Note cycle time is less significant for RPCS-EXPS comparison in this case. While positive value of cycle time shows that longer cycle time is still one of the disadvantages for RPCS, but longer container life can reduce the negative impact of using reusable containers.

6.3.8. Scenario 8: Reusable and rental costs doubled

Table 62 through Table 65 shows that the impact of reusable and rental packaging costs compared to expendable packaging costs. When reusable container cost and rental rate are doubled compared to EXPS, cost ratio and cycle time are still the most important cost contributors for any scenario. Note return rate becomes more important than other scenarios because of the high cost of reusable packaging containers. It is no surprise that more effective container management is necessary since the container owner has to invest more money on purchasing or leasing the containers.

Table 62: Variations in the regression analysis as compared to the Base Analysis between reusable and expendable packaging system costs (Scenario 8: Reusable cost doubled)

RPCS – EXPS	Variables	Standardized coefficients (Beta)	t	Sig.
R: .917 R Square: .841 Adjusted R Square: .838	(Constant)		-2.284	0.023
	RPC / EXP	**0.621**	**34.097**	**0.000**
	Designed container life (year, RPC)	**-0.433**	**-23.759**	**0.000**
	Cycle time (days)	**0.392**	**21.681**	**0.000**
	Custom Charges ($/ea)	**0.203**	**6.925**	**0.000**
	Shipping distance (miles)	**0.122**	**6.645**	**0.000**
	Average daily Volume (containers/day)	**-0.097**	**-3.297**	**0.001**
	Container weight (lbs/container)	**0.058**	**3.180**	**0.002**
	Backhaul volume factor	**0.056**	**3.054**	**0.002**
	Return rate (percent/year, RPC)	-0.020	-1.089	0.277
	Peak volume factor	0.000	-0.015	0.988
	Container quantity per pallet (tote/pallet)	0.000	0.001	0.999

Table 63: Variations in the regression analysis as compared to the Base Analysis between reusable and rental packaging system costs (Scenario 8: Reusable cost doubled)

RPCS – RENS	Variables	Standardized coefficients Beta)	t	Sig.
R: .878 R Square .771 Adjusted R Square.766	(Constant)		-1.861	0.063
	RPC / REN	**-0.697**	**-31.802**	**0.000**
	Cycle time (days)	**0.447**	**20.540**	**0.000**
	Designed container life (year, RPC)	**0.353**	**16.129**	**0.000**
	Return rate (percent/year, RPC)	**0.058**	**2.635**	**0.009**
	Container weight (lbs/container)	**-0.052**	**-2.385**	**0.017**
	Backhaul volume factor	0.027	1.219	0.224
	Shipping distance (miles)	-0.018	-0.828	0.408
	Peak volume factor	-0.009	-0.423	0.673
	Container quantity per pallet (tote/pallet)	0.005	0.252	0.801
	Average daily Volume (containers/day)	-0.006	-0.168	0.867
	Custom Charges ($/ea)	0.000	-0.006	0.995

Table 64: Variations in the regression analysis as compared to the Base Analysis between reusable and rental packaging system costs (Scenario 8: Rental cost doubled)

RPCS - RENS	Variables	Standardized coefficients (Beta)	t	Sig.
R: .860 R Square .739 Adjusted R Square: .733	(Constant)		-0.602	0.547
	Cycle time (days)	**0.678**	**29.178**	**0.000**
	RPC / REN	**-0.547**	**-23.384**	**0.000**
	Designed container life (year, RPC)	**0.099**	**4.239**	**0.000**
	Container weight (lbs/container)	**-0.046**	**-1.972**	**0.049**
	Return rate (percent/year, RPC)	**0.045**	**1.942**	**0.053**
	Backhaul volume factor	0.024	1.039	0.299
	Shipping distance (miles)	-0.020	-0.865	0.388
	Peak volume factor	-0.006	-0.238	0.812
	Custom Charges ($/ea)	-0.005	-0.145	0.885
	Container quantity per pallet (tote/pallet)	-0.002	-0.101	0.920
	Average daily Volume (containers/day)	-0.002	-0.061	0.952

Table 65: Variations in the regression analysis as compared to the Base Analysis between expendable and rental packaging system costs (Scenario 8: Rental cost doubled)

EXPS - RENS	Variables	Standardized coefficients Beta)	t	Sig.
R: .902 R Square: .814 Adjusted R Square: .810	(Constant)		-0.685	0.494
	Cycle time (days)	**0.686**	**35.025**	**0.000**
	EXP / REN	**-0.579**	**-29.458**	**0.000**
	Shipping distance (miles)	**0.060**	**3.018**	**0.003**
	Custom Charges ($/ea)	**0.094**	**2.960**	**0.003**
	Backhaul volume factor	0.032	1.612	0.108
	Return rate (percent/year, RPC)	0.026	1.303	0.193
	Average daily Volume (containers/day)	-0.025	-0.786	0.432
	Designed container life (year, RPC)	0.015	0.752	0.452
	Peak volume factor	-0.009	-0.472	0.637
	Container weight (lbs/container)	-0.003	-0.164	0.870
	Container quantity per pallet (tote/pallet)	-0.001	-0.026	0.979

6.3.9. Scenario 9: Return rate 20 percent dropped

Table 66 through Table 68 show that if the return rate of reusable and rental containers are dropped by 20 percent, cost ratio and cycle time are still the most important cost contributors for any scenario. Designed container life of a reusable container is a key cost contributor for reusable packaging system, so it shows when RPCS is compared with EXPS.

Table 66: Variations in the regression analysis as compared to the Base Analysis between reusable and expendable packaging system costs (Scenario 9: Return rate 20 percent dropped)

RPCS – EXPS	Variables	Standardized coefficients Beta)	t	Sig.
R: .896 R Square: .802 Adjusted R Square: .798	(Constant)		-3.893	0.000
	RPC / EXP	**0.670**	**32.927**	**0.000**
	Designed container life (year, RPC)	**-0.329**	**-16.160**	**0.000**
	Cycle time (days)	**0.281**	**13.875**	**0.000**
	Custom Charges ($/ea)	**0.261**	**7.970**	**0.000**
	Shipping distance (miles)	**0.157**	**7.633**	**0.000**
	Average daily Volume (containers/day)	**-0.130**	**-3.962**	**0.000**
	Container weight (lbs/container)	**0.080**	**3.913**	**0.000**
	Backhaul volume factor	**0.071**	**3.512**	**0.000**
	Return rate (percent/year, RPC)	-0.007	-0.329	0.743
	Peak volume factor	-0.005	-0.250	0.803
	Container quantity per pallet (tote/pallet)	-0.003	-0.128	0.898

Table 67: Variations in the regression analysis as compared to the Base Analysis between reusable and rental packaging system costs (Scenario 9: Return rate 20 percent dropped)

RPCS – RENS	Variables	Standardized coefficients Beta)	t	Sig.
R: .869 R Square .755 Adjusted R Square: .749	(Constant)		-1.030	0.304
	RPC / REN	**-0.626**	**-27.573**	**0.000**
	Cycle time (days)	**0.593**	**26.340**	**0.000**
	Designed container life (year, RPC)	**0.211**	**9.344**	**0.000**
	Container weight (lbs/container)	**-0.061**	**-2.681**	**0.008**
	Return rate (percent/year, RPC)	**0.046**	**2.038**	**0.042**
	Backhaul volume factor	0.026	1.129	0.259
	Shipping distance (miles)	-0.020	-0.885	0.376
	Container quantity per pallet (tote/pallet)	0.011	0.487	0.626
	Peak volume factor	-0.007	-0.300	0.764
	Average daily Volume (containers/day)	-0.003	-0.094	0.925
	Custom Charges ($/ea)	-0.002	-0.066	0.947

Table 68: Variations in the regression analysis as compared to the Base Analysis between expendable and rental packaging system costs (Scenario 9: Return rate 20 percent dropped)

EXPS - RENS	Variables	Standardized coefficients Beta)	t	Sig.
R: .933 R Square: .870 Adjusted R Square: .867	(Constant)		-0.831	0.406
	EXP / REN	**-0.657**	**-40.031**	**0.000**
	Cycle time (days)	**0.630**	**38.445**	**0.000**
	Custom Charges ($/ea)	**0.154**	**5.787**	**0.000**
	Shipping distance (miles)	**0.083**	**4.996**	**0.000**
	Backhaul volume factor	**0.048**	**2.915**	**0.004**
	Average daily Volume (containers/day)	**-0.059**	**-2.214**	**0.027**
	Container quantity per pallet (tote/pallet)	0.013	0.797	0.426
	Peak volume factor	-0.012	-0.712	0.477
	Return rate (percent/year, RPC)	0.011	0.693	0.489
	Container weight (lbs/container)	0.008	0.476	0.634
	Designed container life (year, RPC)	0.003	0.189	0.850

For the case of RENS, return rate does not affect the cost much in this scenario since a pool company should have responsibility for returning containers. The cost of RENS may vary depending on whether the cost of returning containers is included in the contract between a pool user and a pool company.

6.3.10. Scenario 10: Cycle time halved

Table 69 through Table 71 show that the impact of the cycle time changes. Cost ratio, designed container life and cycle time are still the most important cost contributors for any scenario. It should be noted that custom charges are statistically more important factors than designed container life and cycle time when RPCS is compared EXPS. Because of increased frequency of delivery due to shorter cycle time and shipping distance, reducing custom charges should be very important for RPCS. Compare to basic analysis, changing cycle time does not impact much on RPCS-RENS and RENS-EXPS.

Table 69: Variations in the regression analysis as compared to the Base Analysis between reusable and expendable packaging system costs (Scenario 10: Cycle time halved)

RPCS – EXPS	Variables	Standardized coefficients Beta)	t	Sig.
R: .846 R Square: .716 Adjusted R Square: .710	(Constant)		-4.240	0.000
	RPC / EXP	**0.667**	**27.411**	**0.000**
	Custom Charges ($/ea)	**0.305**	**7.780**	**0.000**
	Designed container life (year, RPC)	**-0.191**	**-7.850**	**0.000**
	Shipping distance (miles)	**0.182**	**7.388**	**0.000**
	Cycle time (days)	**0.139**	**5.729**	**0.000**
	Container weight (lbs/container)	**0.110**	**4.519**	**0.000**
	Average daily Volume (containers/day)	**-0.156**	**-3.953**	**0.000**
	Backhaul volume factor	**0.082**	**3.382**	**0.001**
	Peak volume factor	-0.009	-0.383	0.702
	Container quantity per pallet (tote/pallet)	-0.005	-0.211	0.833
	Return rate (percent/year, RPC)	-0.005	-0.188	0.851

Table 70: Variations in the regression analysis as compared to the Base Analysis between reusable and rental packaging system costs (Scenario 10: Cycle time halved)

RPCS – RENS	Variables	Standardized coefficients Beta)	t	Sig.
R: .869 R Square .754 Adjusted R Square: .749	(Constant)		-1.406	0.160
	Cycle time (days)	**0.609**	**27.044**	**0.000**
	RPC / REN	**-0.603**	**-26.573**	**0.000**
	Designed container life (year, RPC)	**0.184**	**8.104**	**0.000**
	Container weight (lbs/container)	**-0.116**	**-5.115**	**0.000**
	Return rate (percent/year, RPC)	**0.049**	**2.154**	**0.032**
	Container quantity per pallet (tote/pallet)	**0.048**	**2.109**	**0.035**
	Backhaul volume factor	0.026	1.163	0.245
	Shipping distance (miles)	-0.020	-0.857	0.392
	Peak volume factor	-0.006	-0.263	0.793
	Average daily Volume (containers/day)	-0.005	-0.141	0.888
	Custom Charges ($/ea)	-0.004	-0.109	0.914

Table 71: Variations in the regression analysis as compared to the Base Analysis between expendable and rental packaging system costs (Scenario 10: Cycle time halved)

EXPS – RENS	Variables	Standardized coefficients Beta)	t	Sig.
R: .935 R Square: .874 Adjusted R Square: .872	(Constant)		-0.558	0.577
	EXP / REN	**-0.716**	**-44.359**	**0.000**
	Cycle time (days)	**0.497**	**30.919**	**0.000**
	Custom Charges ($/ea)	**0.226**	**8.657**	**0.000**
	Shipping distance (miles)	**0.109**	**6.701**	**0.000**
	Backhaul volume factor	**0.067**	**4.131**	**0.000**
	Average daily Volume (containers/day)	**-0.103**	**-3.933**	**0.000**
	Container quantity per pallet (tote/pallet)	0.032	1.959	0.051
	Container weight (lbs/container)	0.023	1.418	0.157
	Peak volume factor	-0.014	-0.889	0.374
	Return rate (percent/year, RPC)	-0.014	-0.868	0.386
	Designed container life (year, RPC)	-0.014	-0.849	0.396

6.3.11. Scenario 11: Combination of Distance Doubled, Return rate 20 percent dropped and Cycle time doubled

Scenario 11 is a combination of worst cases for RTPS and RENS to see how the combination of important factors such as distance, return rate and cycle time impact on the systems. Cost ratio and cycle time are still the most important cost contributors for any scenario (Table 72 through Table 74).

Table 72: Variations in the regression analysis as compared to the Base Analysis between reusable and expendable packaging system costs (Scenario 13: Combination of Distance Doubled, Return rate 20 percent dropped and Cycle time doubled)

RPCS – EXPS	Variables	Standardized coefficients Beta)	t	Sig.
R: .918 R Square: .842 Adjusted R Square: .839	(Constant)		-2.502	0.013
	RPC / EXP	**0.574**	**31.602**	**0.000**
	Designed container life (year, RPC)	**-0.428**	**-23.568**	**0.000**
	Cycle time (days)	**0.391**	**21.650**	**0.000**
	Shipping distance (miles)	**0.201**	**10.952**	**0.000**
	Custom Charges ($/ea)	**0.238**	**8.118**	**0.000**
	Average daily Volume (containers/day)	**-0.139**	**-4.731**	**0.000**
	Backhaul volume factor	**0.077**	**4.270**	**0.000**
	Container weight (lbs/container)	0.035	1.902	0.058
	Return rate (percent/year, RPC)	-0.009	-0.520	0.603
	Container quantity per pallet (tote/pallet)	0.002	0.108	0.914
	Peak volume factor	-0.001	-0.051	0.960

Table 73: Variations in the regression analysis as compared to the Base Analysis between reusable and rental packaging system costs (Scenario 13: Combination of Distance Doubled, Return rate 20 percent dropped and Cycle time doubled)

RPCS – RENS	Variables	Standardized coefficients Beta)	t	Sig.
R: .868 R Square .754 Adjusted R Square: .748	(Constant)		-0.886	0.376
	RPC / REN	**-0.627**	**-27.590**	**0.000**
	Cycle time (days)	**0.595**	**26.352**	**0.000**
	Designed container life (year, RPC)	**0.212**	**9.348**	**0.000**
	Return rate (percent/year, RPC)	**0.047**	**2.059**	**0.040**
	Container weight (lbs/container)	-0.034	-1.511	0.131
	Backhaul volume factor	0.025	1.112	0.267
	Shipping distance (miles)	-0.020	-0.891	0.374
	Peak volume factor	-0.007	-0.316	0.752
	Container quantity per pallet (tote/pallet)	-0.007	-0.310	0.757
	Average daily Volume (containers/day)	-0.003	-0.076	0.940
	Custom Charges ($/ea)	-0.002	-0.062	0.951

Table 74: Variations in the regression analysis as compared to the Base Analysis between expendable and rental packaging system costs (Scenario 13: Combination of Distance Doubled, Return rate 20 percent dropped and Cycle time doubled)

EXPS - RENS	Variables	Standardized coefficients Beta)	t	Sig.
R: .903 R Square: .815 Adjusted R Square: .811	(Constant)		-1.006	0.315
	Cycle time (days)	**0.679**	**34.756**	**0.000**
	EXP / REN	**-0.571**	**-29.149**	**0.000**
	Shipping distance (miles)	**0.098**	**4.956**	**0.000**
	Custom Charges ($/ea)	**0.119**	**3.764**	**0.000**
	Backhaul volume factor	**0.044**	**2.220**	**0.027**
	Return rate (percent/year, RPC)	0.030	1.534	0.126
	Average daily Volume (containers/day)	-0.047	-1.491	0.137
	Designed container life (year, RPC)	0.014	0.691	0.490
	Peak volume factor	-0.009	-0.485	0.628
	Container weight (lbs/container)	-0.004	-0.188	0.851
	Container quantity per pallet (tote/pallet)	0.000	-0.005	0.996

Note that container weight becomes less significant factor for RPCS-EXPS comparison, but other factors remain constant in terms of weight of importance.

6.4. Summary of comparative regression analysis results

By breaking down each analysis, major findings from eleven scenarios are summarized as below.

a. Container cost ratio and cycle time are the most significant and consistent cost drivers for all scenarios. In other words, container cost and cycle time are major cost contributors in this model. This is a similar result found by (Mollenkopf, Closs, *et al*. (2005, 191-192). Shipping distance and designed container life are also consistently more important factors than other variables such as peak volume factor, return rate, backhaul volume factor.

b. Secondary to container cost ratio, cycle time is the most significant cost factor to choose a packaging system. Time is more important than physical distance since it requires an increased number of containers. Therefore, EXPS is more economical option for prolonged supply chains.

c. Designed container life is constantly the third most important factor after cost ratio when reusable and expendable packaging system costs are compared. Although expensive containers do not always guarantee the better quality and durability of the reusable container, longer container life usually increases unit purchasing cost. Setting an optimum cost vs. container durability for RPC should be critical to save total packaging and logistics costs.

d. Custom charges for forward transportation should not be a factor for this research because the custom charges is based on a product, not a package. However, custom charges can be a decisive factor if a company wants to implement a reusable packaging system internationally since this is one of the most important cost drivers for RPCS and RENS. Proper documentation and mutual agreement by both parties and governments are necessary to avoid any unnecessary customs duties and the like and delays due to customs formalities.

Although this regression analysis is meaningful since this can help to identify important cost factors and impacts on other variables, the problem of this analysis is that this result does not represent a real world scenario. This calculation limits itself showing simple relationships with each other variables. It is hard to include the activity and time factors that the packaging system consumed. An international supply chain environment is far more complicated and dynamic, so this type of analysis can only useful to analysis domestic and simple logistical distribution environment. Mollenkopf (2005) also noted that the dynamic simulation method would be suitable for more complicated and real world solution.

The next chapter attempts to solve this problem with a dynamic simulation model. Based on each activity cost, the total cost of an activity, process, and system cost are calculated. Depending on various packaging system types, the results of activity cost simulation model show that the total costs can be changed by various supply chain activities and can show more realistic cost model for an international supply chain.

CHAPTER 7

DYNAMIC SIMULATION MODELING

A dynamic simulation model can help measure quantitative performance of a supply chain; cost minimization is the most widely used objective. Cost can be analyzed for entire supply chain or for the particular manufacturing or distribution processes (Beamon, 1998).

This study is trying to cover the complete supply chain from the inbound logistics activities at the distribution warehouse to the oversea manufacturing center of H automotive company. Arena Rockwell software by Rockwell Inc. is used for the development of supply chain model.

The findings from the simulation show that the model calculates activity-based costs of each different packaging type in a predictable manner. The results are different depending on different cycle time and material costs.

This model can be utilized to study the total packaging system cost of an existing supply chain and to find the opportunities to improve overall financial performance.

7.1 Simulation model

Figure 10 shows the structure of the simulation model created by using Arena software.

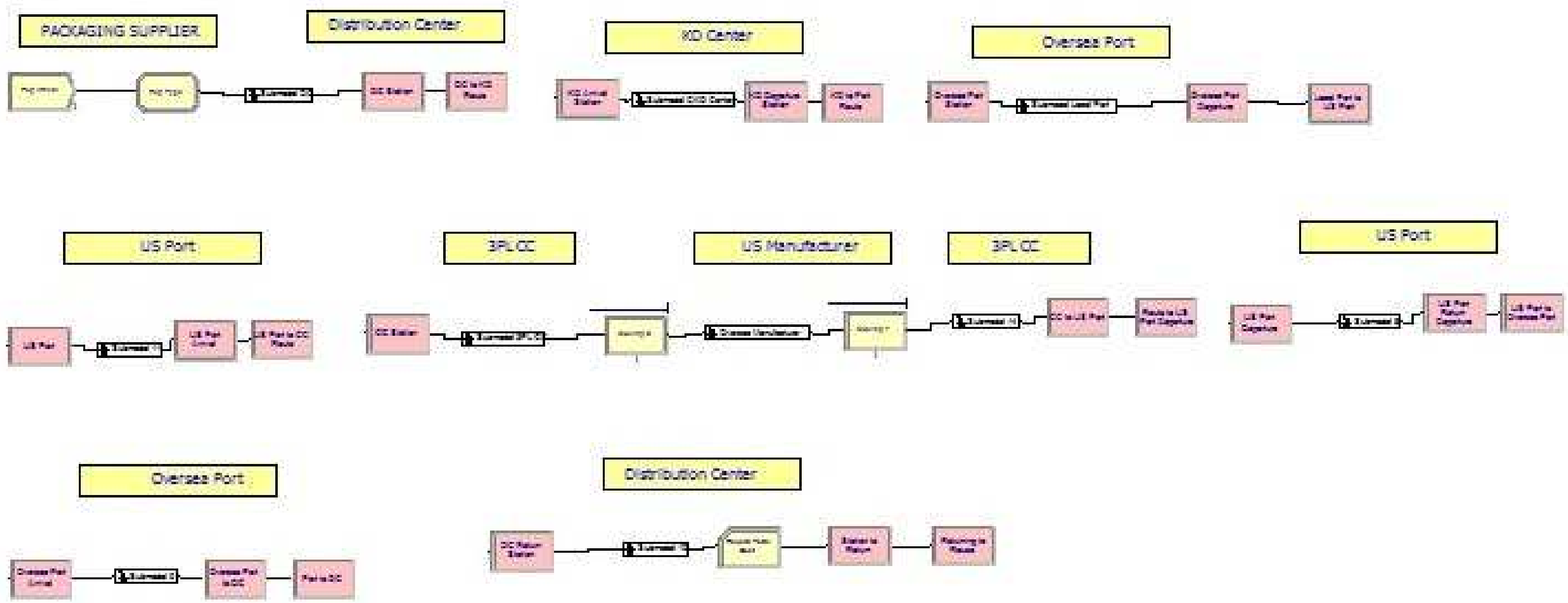

Figure 10: Simulation model for an international automotive part packaging system

The model represents the international packaging supply chain process of automotive part manufacturing from receiving packages (containers). The model was divided into ten main sub-modules. The operation of each sub-model is described next.

The starting point of this simulation is assigning entity types for three different packaging systems, i.e., expendable, reusable, and rental shipping containers. Three entity types are created and assigned their types and variables. Following sub-models contain each activity (for example, loading/unloading, moving, palletizing/unpalletizing, sorting, etc.) at each destination. Upon arrival, packages are processed at a 3PL distribution center (Figure 11: the first sub model) in South Korea. The second sub model (Figure 12) is a set of activities in KD center where automotive parts are packaged and shipped to the port.

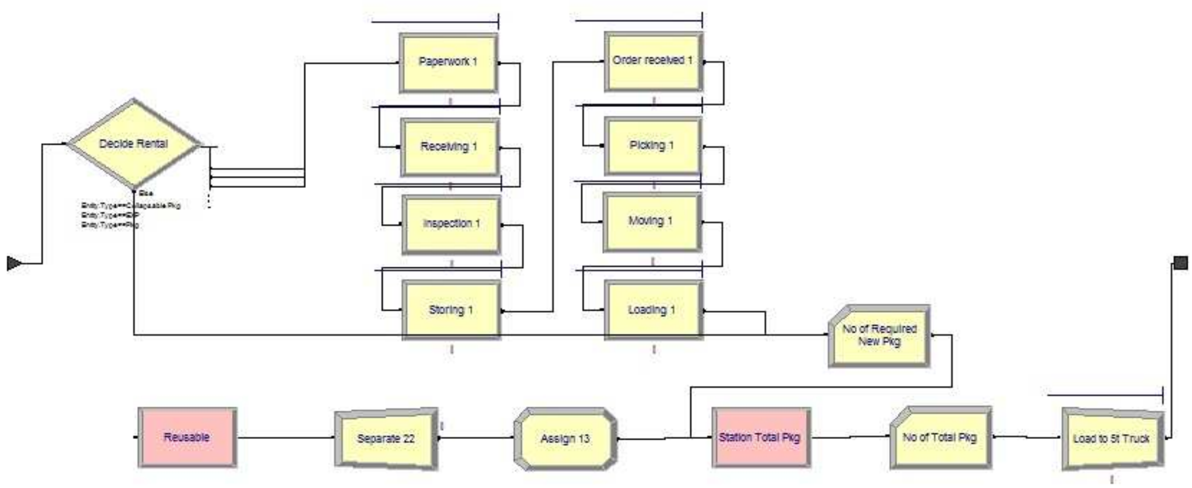

Figure 11: The first sub model: processes at a 3PL distribution center

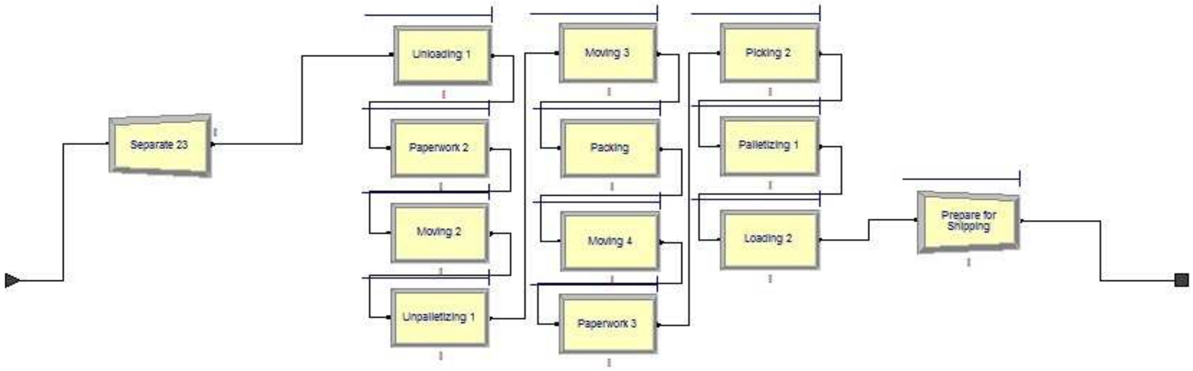

Figure 12: The second sub model: processes at a Knock Down center

After port processing (Figure 13: third sub model), packaged automotive parts are shipped to the US port (Figure 14: fourth sub model) at a certain route time (days). All parts go to 3PL consolidation center and are prepared to feed the assembly line of the car manufacturer (Figure 15: fifth sub model). After being emptied and disassembled at the manufacturing process (Figure 16: sixth sub model), all containers are shipped back to the 3PL consolidation center.

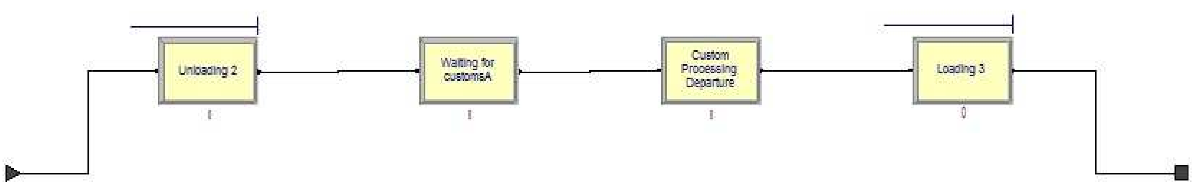

Figure 13: The third sub model: processes at an international port

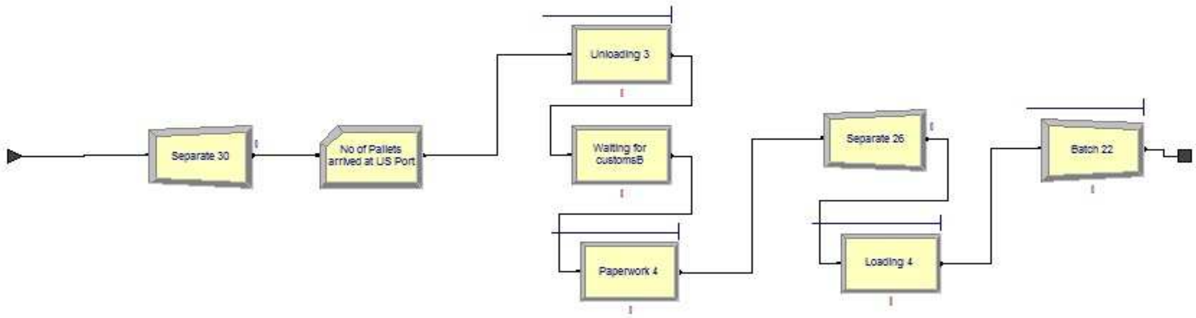

Figure 14: The fourth sub model: processes at a port in the US

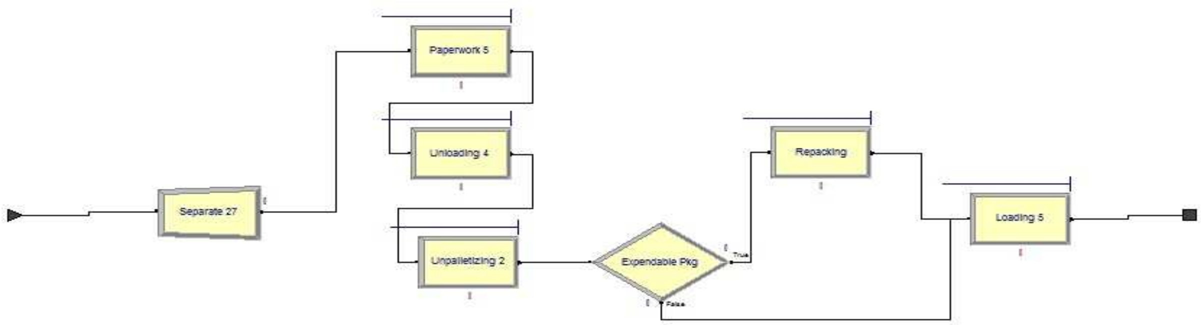

Figure 15: The fifth sub model: processes at consolidation center in the US

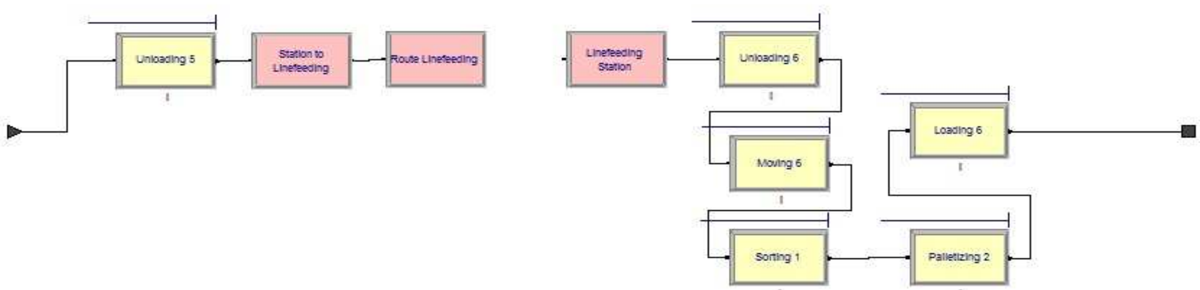

Figure 16: The sixth sub model: line feeding and disassembling at the manufacturing plant

At the 3PL consolidation center, the containers are separated out into different process by “N-way by chance” distribution.   If the containers are reusable or rented, they follow a TRIA distribution (80, 90, 95) to be reused.   For containers that are not suitable to be reused by damages, loss, etc., they are sorted by “2-way by chance” distribution; 90 percent for recycle and 10 percent disposal.   Reused containers are also separated by “2-way by chance” distribution if they feature different type; straight wall and collapsible types (Figure 17: seventh sub model).

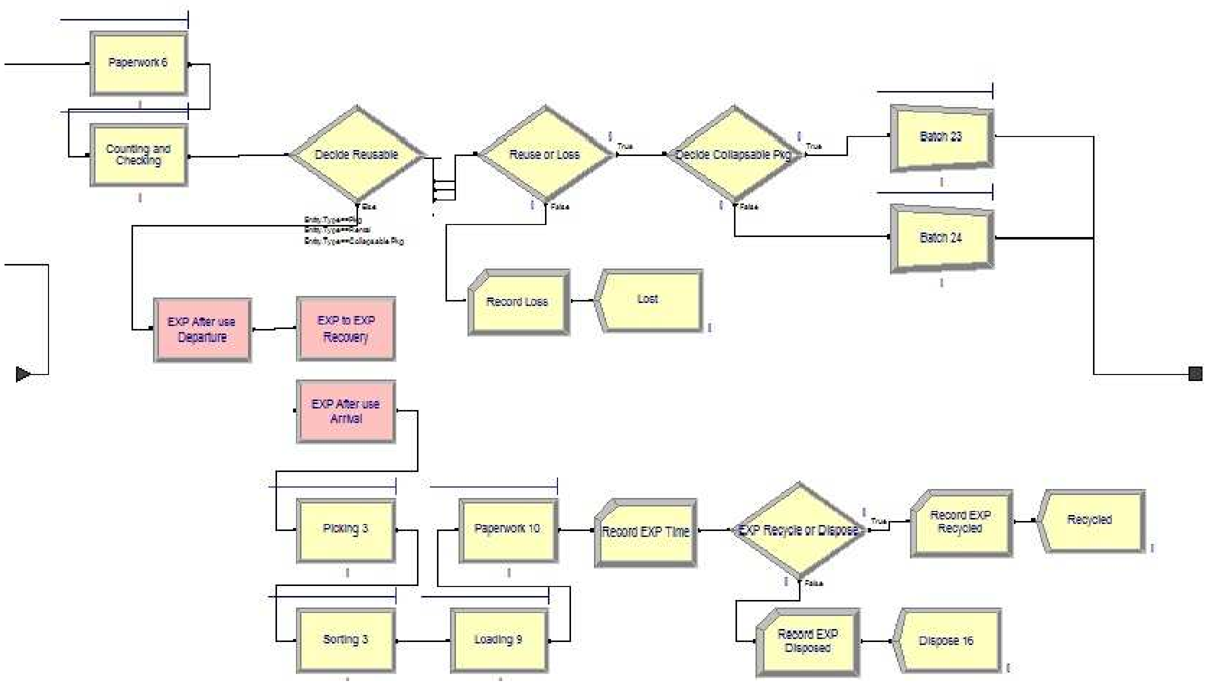

Figure 17: The seventh sub model: returning process at 3PL consolidation center

If the containers are expendable, 90 percent are recycled and 10 percent are disposed.   Recycled and disposed containers are transferred to the recycling plant. Only reusable containers are shipped back to the distribution center (Figure 20: tenth sub model) via port and shipping process (Figure 18 and 19: eighth and ninth sub model).

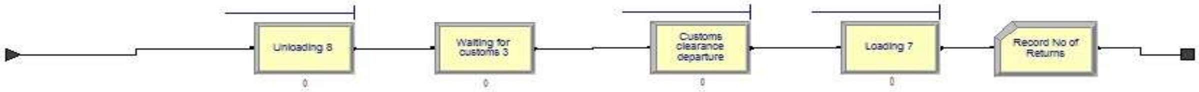

Figure 18: The eighth sub model: Shipping process of reusable containers (at the US)

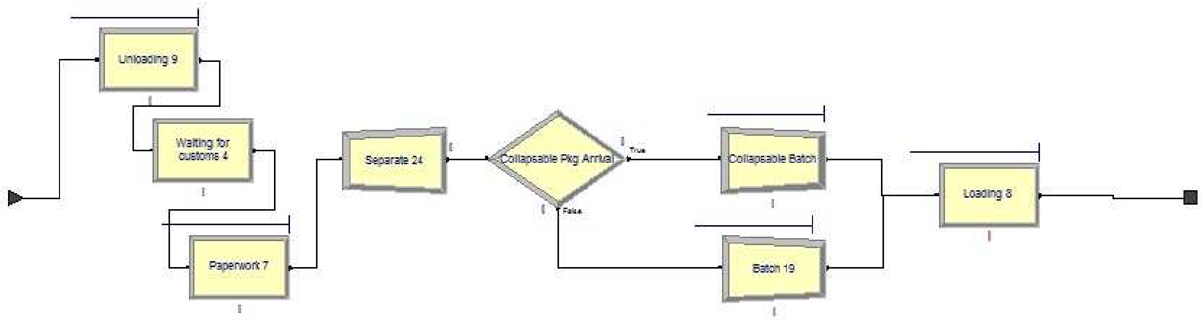

Figure 19: The ninth sub model: Shipping process of reusable containers (at the oversea port)

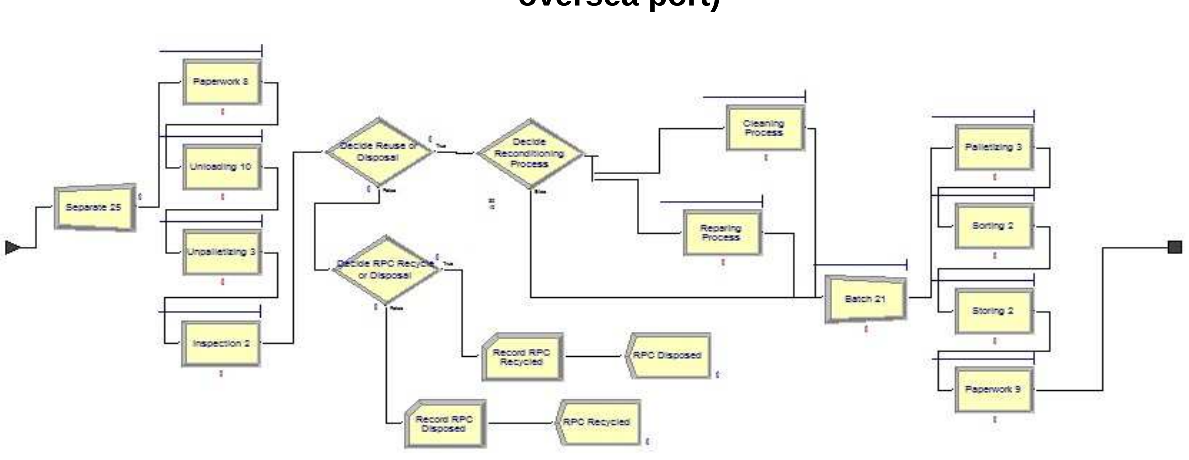

Figure 20: The tenth sub model: reconditioning and repairing of reusable containers

All data are based on the activity cost model which was developed in Chapter 5. For simplification, although the entity is a package (or container), it is measured as a pallet load of containers. For example, if 150 pallet loads of containers arrive every day and each pallet contains 30 containers, this means 4,500 containers are received every day.

The Simulation model collects statistics in each area on entity, transfer time and transfer cost, process and resource utilization. More importantly, this model calculates the number of total containers required and the number of reused containers that are returned to the 3PL distribution center.

To reduce unnecessary variation of uncertainty of simulation, process time and resources for each activity are predetermined from actual measurement and data from ABC analysis (for example, loading/unloading, moving, palletizing/unpalletizing, and sorting, etc.). However, to demonstrate the random nature of simulation, transfer time follows a triangular (TRIA) distribution. Each independent simulation runs is set to 5 because the results are not significantly different after 5 replications, as shown in Table 75. Law and McComas (1991) recommended making at least 3 to 5 independent runs for each case. As shown in the Table 75, comparing 1, 5 and 100 runs shows 5 runs is enough since data from 5 runs to 100 runs are almost identical and statistically insignificant.

Based on the observation, the following parameters were specified:

(i) Length of each simulation run= 260 days (per year).

(ii) Number of independent simulation runs = 5

Table 75: Data comparison based on the number of replications

EXP	1 run (A)	5 runs average (B)	A/B, percent	100 runs average (C)	A/C, percent
No of Required New Pkg	39,260	39,260.00	100.0percent	39,260.00	0.0percent
No of Total Pkg	39,260	39,260.00	100.0percent	39,260.00	0.0percent
Disposed	3,543	3501	101.2percent	3522	0.0percent
Recycled	31,065	31193	99.6percent	31120	0.0percent
REN	1 run (A)	5 runs average (B)	A/B, percent	100 runs average (C)	A/C, percent
No of Required New Pkg	16,681	16,515.00	101.0percent	16553	0.0percent
No of Total Pkg	44,491	44,539.00	99.9percent	44554	0.0percent
Loss	4,588	4546	100.9percent	4554	0.0percent
No of Returns	712	715.6	99.5percent	715	0.1percent
Disposed	179	150.8	118.7percent	148	0.8percent
Recycled	1,327	1333.8	99.5percent	1337	0.1percent
RPC	1 run (A)	5 runs average (B)	A/B, percent	100 runs average (C)	A/C, percent
No of Required New Pkg	16,490	16550	99.6percent	16563	0.0percent
No of Total Pkg	44,350	44,466.00	99.7percent	44602	0.0percent
Loss	4,548	4515.4	100.7percent	4555	0.0percent
No of Returns	709	714	99.3percent	716	0.1percent
Disposed	159.0000	150	106.0percent	147	0.7percent
Recycled	1295.00	1302.6	99.4percent	1329	0.1percent

7.2. Results of simulations

No computational model will ever be fully verified, guaranteeing 100 percent error-free implementation. Verification is concerned with building the model correctly. It is utilized in the comparison of the conceptual model to the computer representation that implements that conception. Verification is done to ensure that:

– The model is programmed correctly

– The algorithms have been implemented properly

– The model does not contain errors, oversights, or bugs

As Kelton et al (2010, p. 555) suggested, the best way to verify the simulation model is comparing the results from my model to the results from the real packaging system. In this study; comparisons between the simulation and exiting results are made. The associated parameters are set constant for calculating the packaging system costs by using deterministic data. This includes fixed cost data and activity cost data.

7.2.1. Simulation 1: Impact of expected life of reusable containers

Although unit cost of EXPS (Expendable Packaging System) is cheapest, we need to take account that the reusable packaging system (either RPCS or RENS) has value over the years of operation. One question is what would be a break-even point of the reusable container system if this can be operated for extended period of time, e.g. 10 years.

Assuming the loss and damaged reusable containers are replenished during the operation, the expected useful life of the reusable containers are up to the end of days of operations, the working days are 260 days per year, and the results of the simulation are shown in Table 76.

Table 76: Impact of expected useful life of reusable containers

	EXP				**REN**				**RPC**			
	1yr	2yr	3yr	10yr	1yr	2yr	3yr	10yr	1yr	2yr	3yr	10yr
Required new pkg	39,260	78,520	117,780	392,600	16,515	24,781	32,351	86,321	16550	24,840	32,390	87,360
Total pkg	39,260	78,520	117,780	392,600	44,539	93,241	141,361	478,241	44,466	92,080	141,390	483,410
Disposed	3,543	7,542	11,508	38,961	151	425	631	2,154	150	386	602	2,058
Recycled	31,065	66,282	101,580	349,071	1333.8	3,307	5,166	18,444	1303	3,186	5,113	18,722
Loss					4546	10,327	15,990	55,106	4515	10,166	15,858	55,697

※ *Note: Loss rate: 5 percent for every cycle*

From Table 76, For example, REN requires only 16,550 containers per year although total accumulated containers are 44,466 containers to run the first year of operation. This means that the containers are reused for 2.67 times (44,466 / 16,550=

2.67) per year.

For one year of the operation, the number of required containers for expendables is 39,260, but 16,515 for rental and 16,550 for reusable system. The number difference is even larger over the time. For 10 years of operations, EXPS requires 392,600 containers, but RENS requires 86,321 and RPCS requires 87,360 containers.

For this particular system, the break-even point of reusable packaging system is about 2.2 years compared to the expendable system (see Figure 21). Interestingly, rental system is almost equal or cheaper than reusable packaging system, but the cost rate increases much faster over the time and passes after 6.6 years of operations. This means if a company expects the useful life of a reusable container is less than about 6.6 years, it would be beneficial to use rental system, but if the expected useful life is longer than 6.6 years, they should consider having their own reusable packaging system.

The biggest difference between EXPS, RENS and RPCS is the number of containers used. As a result of the larger number of total containers used, total cost of EXP system is $98.9 million US dollars after 10 years' operation (Table 77).

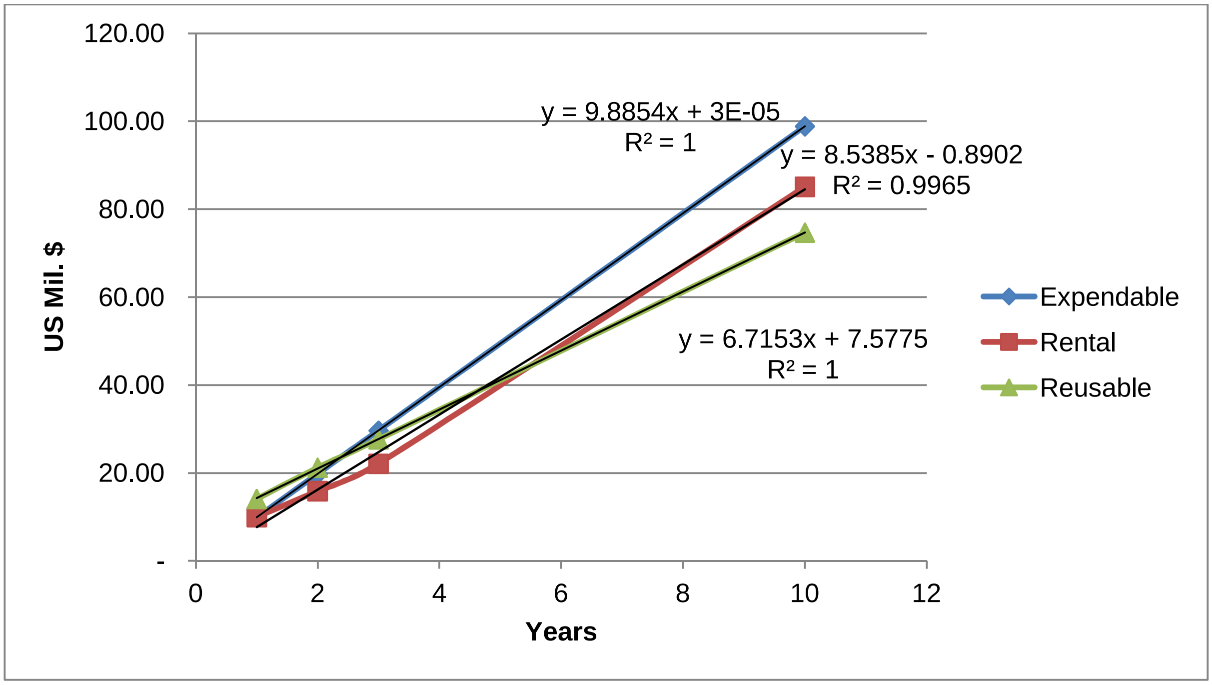

Figure 21: Total cost comparison of different packaging systems depending on the different expected useful life of the container

Table 77: Unit and total cost comparison of three types after simulating 1st to 10th years of operations

	Expendable				*Reusable*				*Rental*			
Days	1st year	2nd year	3rd year	10th year	1st year	2nd year	3rd year	10th year	1st year	2nd year	3rd year	10th year
Total Pallet used	39,260	78,520	117,780	392,600	32,980	49,680	64,780	174,720	33,362	49,562	64,702	172,642
Containers on pallet	30	30	30	30	30	30	30	30	30	30	30	30
CC	1.44	1.44	1.44	1.44	4.79	4.79	4.79	4.79	0.72	1.44	2.16	7.2
AC	0.27	0.297	0.297	0.297	0.30	0.374	0.374	0.374	0.27	0.348	0.348	0.348
FTC	4.59	4.593	4.593	4.593	4.59	4.593	4.593	4.593	4.59	4.593	4.593	4.593
BTC	-				2.02	2.019	2.019	2.019	2.02	2.019	2.019	2.019
WC	2.1	2.073	2.073	2.073	2.55	2.478	2.478	2.478	2.35	2.274	2.274	2.274
AUC	0.44	0.438	0.439	0.440	0.02	0.018	0.018	0.019	0.02	0.018	0.019	0.019
UC	8.84	8.393	8.393	8.393	14.27	14.253	14.253	14.253	9.97	10.673	11.393	16.433
TC (US Mil $)	9.9	19.8	29.7	98.9	14.1	21.2	27.7	74.7	10.0	15.9	22.1	85.1

※ *Note: CC: Container cost, AC: Administration cost, FTC: Forward transportation cost, BTC: Backhaul transportation cost, WC: Warehousing cost, AUC: After use cost, UC: Unit cost, TC: Total cost*

For RPCS and RENS, total costs of 10 years' operation are $74.7 and $85.1 million US dollars, respectively. Due to the high initial investment cost for purchasing containers, the RPC system requires longer period to reach the break-even point than RENS, but it gains more financial benefits for long term operation.

7.2.2. Simulation 2: Impact of distance (port to port comparison) – for 2 years of operations

The Impact of distance between two ports is examined. There is great relationship between distance and route time (shipping from port A to port B), so route time is pre-determined depending on the distance difference. Relationships between distance and route time are compared in Table 78.

Table 78: Distance vs. route time (port to port)

Distance (miles)	Route Time (day, port to port)		
	Min.	Avg.	Max.
8,000	25	30	35
500	1	1.5	2
5,000	10	15	20
10,000	30	35	40

The most notable data is route time. From Table 79, for shipping distance of 500 miles, the route time of RPCS varies ranging from 3.19 days to 184.84 days. Even average route time is 25.59 days compared to 2.34 days for EXPS. If the shipping distance extends up to 10,000 miles, the average route time is about 194 days for both RPCS and RENS, but the maximum route time can be reached up to 513.46 days for RPC and 512.79 days for RENS. This could happen in many reasons: a company could have very poor container management system, a product has very slow inventory turnover, a company uses container for their warehouse inventory purpose, etc.

Consequently, more containers are required due to these non-productive activities although shipping distance remains same.

Table 79: Impact of shipping distance changes on route time and the number of packages required

	EXP			RPC			REN		
miles	500	5000	10000	500	5000	10000	500	5000	10000
Avg. Time	2.34	15.67	35.88	25.59	131.57	194.53	25.15	132.38	194.01
Min. Time	1.55	10.99	30.86	3.19	23.17	63.17	3.31	22.40	62.05
Max. Time	3.68	21.25	41.20	184.84	515.37	513.46	185.57	509.71	512.79
Required New Pkg	78,520	78,520	78,520	14,981	20,201	25,731	14,640	20,270	26,060
Total Pkg	78,520	78,520	78,520	89,701	95,761	91,101	86,820	94,410	92,870
Loss				10,355	10,709	9,892	10,173	10,717	10,046
Disposed	7,638	7,605	7,231	377	404	322	400	359	333
Recycled	70,602	68,523	65,873	3,515	3,607	3,081	3,450	3,492	3,166

The Table 80 compares the unit costs and total costs of each case and shows the impact of shipping distance on three packaging types. Unit cost is the combined cost to deliver a product including a container cost and other costs associated to logistical activities such as administration, transportation, warehousing, etc.

Table 80: Unit cost comparison of three when shipping distance changed

	EXP			*RPC*			*REN*		
Miles	500	5000	10000	500	5000	10000	500	5000	10000
CC	1.44	1.44	1.44	4.79	4.79	4.79	1.44	1.44	1.44
AC	0.30	0.30	0.30	0.35	0.35	0.35	0.37	0.37	0.37
AUC	0.44	0.44	0.44	0.02	0.02	0.02	0.02	0.02	0.02
BTC	0.00	0.00	0.00	0.71	1.49	2.37	0.71	1.49	2.37
FTC	2.72	3.84	5.09	2.72	3.84	5.09	2.72	3.84	5.09
WC	2.07	2.07	2.07	2.48	2.48	2.48	2.27	2.27	2.27
UC	6.959	8.083	9.333	11.060	12.972	15.096	7.531	9.443	11.567
TC (US Mil $)	16.4	19.0	22.0	9.9	15.7	23.3	6.6	11.5	18.1

※ *Note: CC: Container cost, AC: Administration cost, FTC: Forward transportation cost, BTC: Backhaul transportation cost, WC: Warehousing cost, AUC: After use cost, UC: Unit cost, TC: Total cost*

According to the simulation result, RPC becomes the most expensive option when the route distance is extended to 10,000 miles. REN also becomes more expensive and less attractive option with longer travel time. From the linear regression expressed on Figure 22, total cost of RPC equals with total cost of EXP when the shipping distance is 7,824 miles. When the distance is up to 14,682 miles, total cost of REN equals to that of EXP.

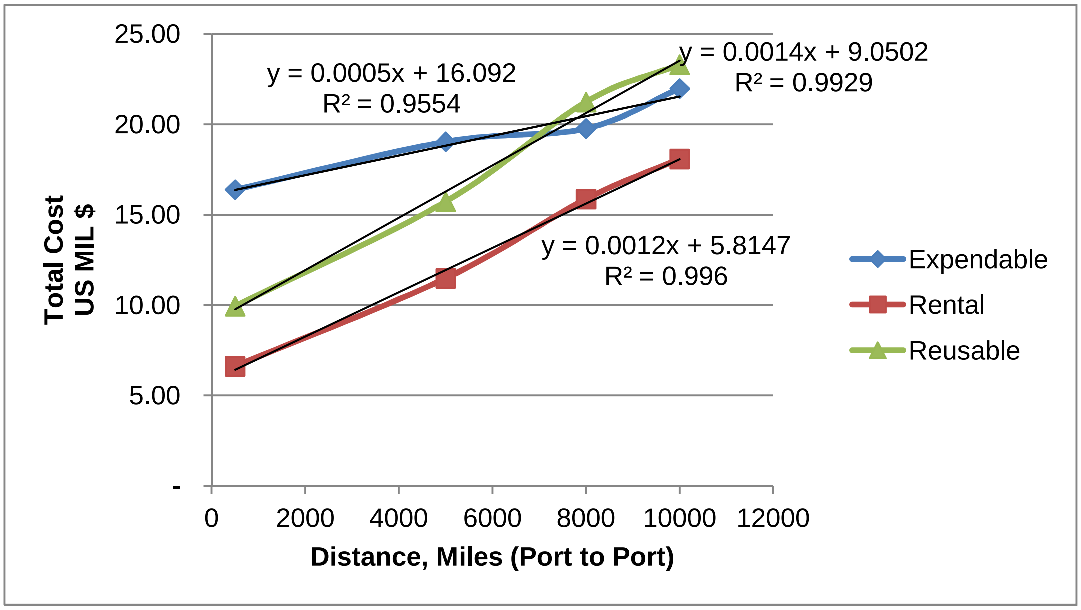

Figure 22: Total cost comparison of different packaging systems depending on the different route (shipping) time of the container

7.2.3. Simulation 3: Impact of loss rate (return rate) of reusable containers

Losing reusable containers clearly impact on the total cost of the container operation for both RPC and REN. As shown in Table 81, unit cost does not change, but the total cost changes because the total number of new packages needed increases as loss rate increases. In case of RPCS, the packager needs only 20,840 new RPCs with average loss rate of 5 percent (TRA[2] (90, 95, 99)), but the packager needs 29,520 new packages when 20 percent of containers are lost (TRA (70, 80, 90)).

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[2] TRA: Triangular Distribution (low, medium, high)

Table 81: Cost comparison of RPC and REN when loss rate changed

	RPC			REN		
Loss rate	TRA(70, 80, 90)	TRA(80, 90, 95)	TRA(90, 95, 99)	TRA(70, 80, 90)	TRA(80, 90, 95)	TRA(90, 95, 99)
New Pkg	29,520	24,840	20,840	29,201	24,781	20,981
Total Pkg	88,630	92,080	97,730	87,931	93,241	98,681
Loss	16,652	10,166	4,865	16,509	10,327	4,936
UC	14.25	14.25	14.25	10.72	10.72	10.72
TC (US Mil. $)	25.24	21.23	17.81	18.78	15.94	13.49

※ *Note: UC: Unit cost, TC: Total cost*

This difference is compared to EXPS graphically as shown in Figure 23.

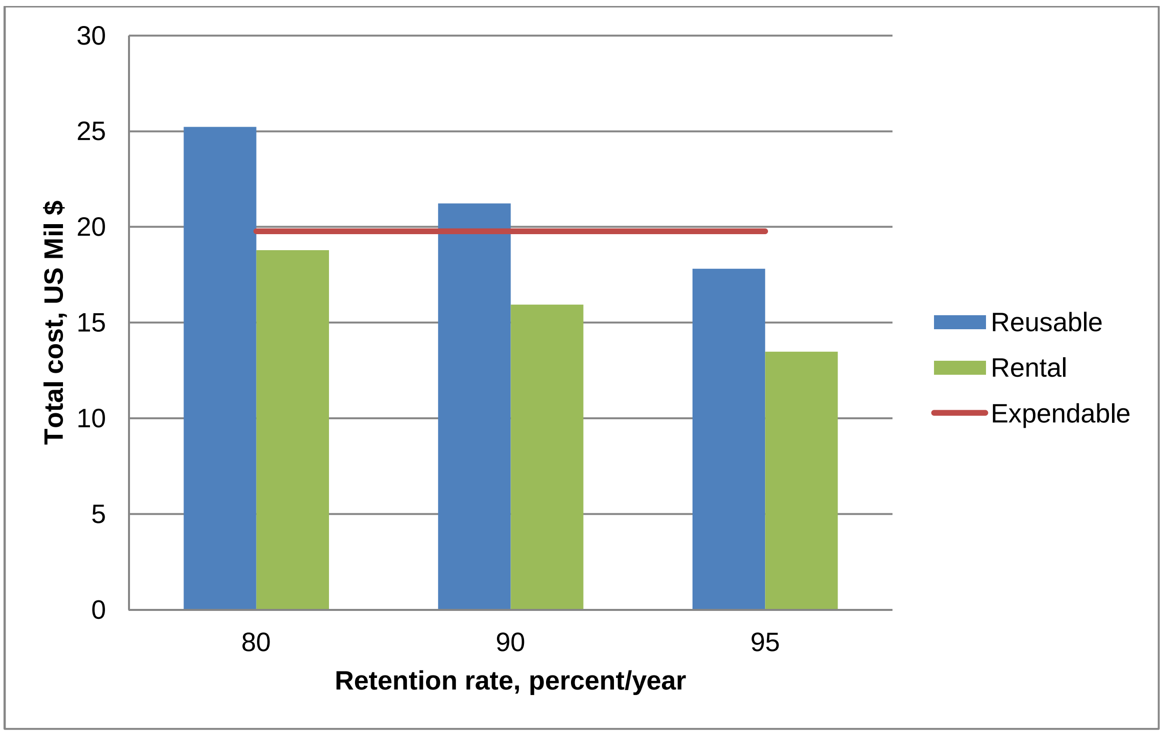

Figure 23: Total cost comparison of different packaging systems depending on the different loss rate of the container

The total cost of RPCS is already exceeding EXPS when the loss rate is up to 10 percent (TRA (80,90,95)) and the total cost of REN is also approaching rapidly to that of EXPS. When the total cost of EXPS is 19.77 million US for 2 years of operations and only the loss rate is considered, the minimum threshold of RPCS and

RENS should be less than 8.23 percent and 22.5 percent respectively based on the linear regression result. (Linear regression equation of RPC is y = -0.4813x + 63.939, R^2 = 0.9791 and Linear regression equation of REN is y = -0.3428x + 46.35, R^2 = 0.9787)

7.2.4. Simulation 4: Impact of container cost for 2 years of operations

Container costs impact directly on unit costs, and it is the most significant reason to increase reusable packaging costs. Since most RPCS and RENS containers are generally more expensive than expendables, relative container cost should be always considered as the most important factor to decide the packaging type.

As shown in Table 82, as the rental period increases, total REN cost increases dramatically. Rental cost for 100 days is similar with RPCS, but the rental cost for 300 days is almost double of RPCS cost. This simulation shows that packaging and logistics managers should take account of the relationships between rental period and container purchasing cost as well as long term total cost impacts.

Table 82: Cost comparison when container costs changed

	Expendable			Reusable			Rental (100 days)			Rental (300 days)		
CC	0.5	1.5	3	2	5	10	2	5	10	6	15	30
	0.30	0.30	0.30	0.35	0.35	0.35	0.37	0.37	0.37	0.37	0.37	0.37
FTC	4.59	4.59	4.59	4.59	4.59	4.59	4.59	4.59	4.59	4.59	4.59	4.59
BTC	-	-	-	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02
WC	2.07	2.07	2.07	2.48	2.48	2.48	2.27	2.27	2.27	2.27	2.27	2.27
AUC	0.44	0.44	0.44	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
UC	7.90	8.90	10.40	11.46	14.46	19.46	11.28	14.28	19.28	15.28	24.28	39.28

※ *Note: CC: Container cost, AC: Administration cost, FTC: Forward transportation cost, BTC: Backhaul transportation cost, WC: Warehousing cost, AUC: After use cost, UC: Unit cost, TC: Total cost*

7.2.5. Simulation 5: Average daily volume

Average daily volume (ADV) explains the number of packaging containers needed. In this case, EXPS is competitive when the ADV is low, but the RPCS and RENS systems are more competitive when ADV is increased.

The RENS has competitive advantage over both EXPS and RPCS regardless of average daily volume because a company can reduce reconditioning activities (cleaning, repairing, etc.) for packaging containers. See Table 83 and Figure 24.

Table 83: Cost comparison when average daily volume of containers changed

	Expendable			Reusable			Rental		
Daily volume	1500	3000	7500	1500	3000	7500	1500	3000	7500
Total Pallet used	78,520	156,520	390,520	49,562	89,182	208,382	49,680	90,220	208,060
No of Containers on pallet	30	30	30	30	30	30	30	30	30
CC	1.44	1.44	1.44	4.79	4.79	4.79	1.44	1.44	1.44
AC	0.297	0.297	0.297	0.374	0.374	0.374	0.348	0.348	0.348
FTC	4.593	4.593	4.593	4.593	4.593	4.593	4.593	4.593	4.593
BTC				2.019	2.019	2.019	2.019	2.019	2.019
WC	2.073	2.073	2.073	2.478	2.478	2.478	2.274	2.274	2.274
AUC	0.438	0.438	0.438	0.018	0.018	0.018	0.018	0.018	0.018
UC	8.832	8.832	8.832	14.271	14.271	14.271	10.691	10.691	10.691
Total Cost (US Mil $)	20.8	41.5	103.5	21.2	38.2	89.2	15.9	28.9	66.7

※ *Note: CC: Container cost, AC: Administration cost, FTC: Forward transportation cost, BTC: Backhaul transportation cost, WC: Warehousing cost, AUC: After use cost, UC: Unit cost, TC: Total cost*

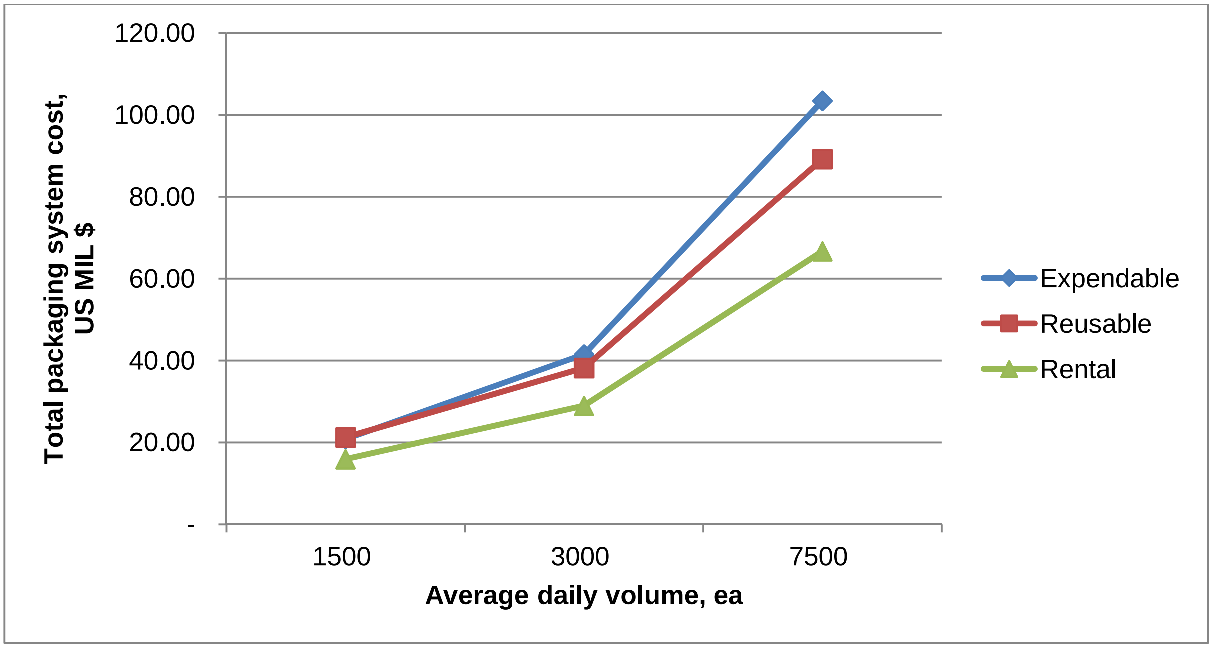

Figure 24: Total cost comparison of different packaging systems depending on the different average daily volume of containers used

7.2.6. Simulation 6: Number of containers on a pallet

In this simulation, pallet size for each type of containers is considered the same, but the size and number of containers on a pallet are changed. Regardless of container types, the number of containers on a pallet impacts greatly on the unit logistics cost as shown in Figure 25. Note that the graph is nonlinear, and unit cost drops significantly when the number of containers on a pallet increases from 20 to 60.

This simulation illustrates a company could utilize the best cost efficient option when it designs a container size to fit on a pallet or a sea container perfectly. This result also implies the important of unit load standardization. A well-designed container should be a perfect fit to a unit load and standard size of base pallets, sea containers, cargos, trucks and other loading devices.

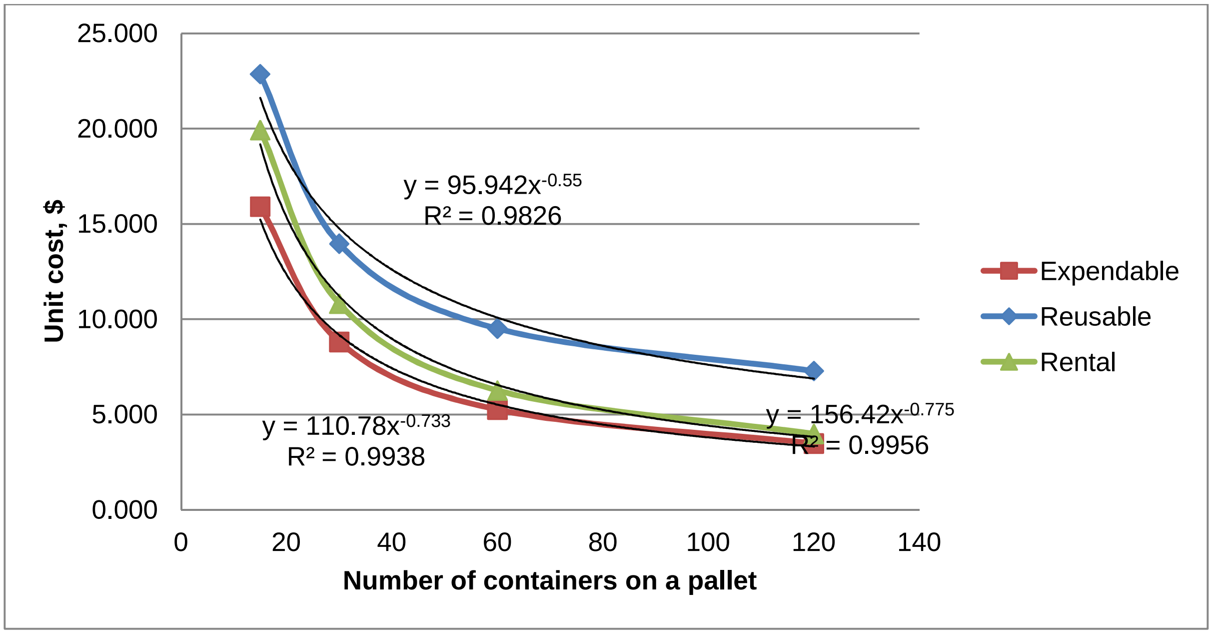

Figure 25: Unit cost comparison of different packaging systems depending on the different number of containers on a pallet

7.2.7. Simulation 7: Comparison of transportation cost between straight wall and collapsible container types

Reusable plastic containers vary depending on their function and customers' needs. Collapsible and nesting features of RPCs especially contribute to reducing backhaul volume. As shown in Table 84, container quantity per pallet during backhaul transportation process should be dramatically increased and will reduce backhaul packaging system cost.

Consequently, the simulation result is similar to Simulation 6 although the total cost difference is not significant. Adding the fact that the relative RPC unit cost with collapsible and nesting features is usually higher while packing quantity is usually less than straight-wall RPCs, backhaul volume reduction by adding collapsible or nesting functions on RPCs does not provide a significant cost saving in terms of total packaging system cost.

Table 84: Comparison of total packaging system cost between straight wall and collapsible container types for 1 year

Cost	Reusable			Rental		
	BVF			BVF		
	1	0.7	0.5	1.0	0.7	0.5
Container cost	4.79	4.79	4.79	1.44	1.44	1.44
Administration cost	0.35	0.35	0.35	0.37	0.37	0.37
Forward transportation cost	0.02	0.02	0.02	0.02	0.02	0.02
Backhaul transportation cost	0.71	0.49	0.35	0.71	0.49	0.35
Warehousing cost	2.72	2.72	2.72	2.72	2.72	2.72
After use cost	2.48	2.48	2.48	2.27	2.27	2.27
Unit cost	11.06	10.85	10.71	7.53	7.32	7.18
Cost difference, percent	100	98	97	100	97	95
Total cost (for 1 year)	9.9	9.8	9.6	6.6	6.4	6.3

7.3. Summary of scenarios

By breaking down each analysis, major findings from 7 different scenarios are summarized as below.

a. The dynamic simulation provides more realistic and real-time situation at each logistical phase which can be used to inform packaging and logistics decisions. By showing realistic material flow throughout supply chain, a packaging or logistics manager can identify possible activities that cause bottlenecks in its supply chain such as long lead time at the ports.

b. This dynamic simulation was used to estimate the break-even point of each packaging system in terms of total packaging system costs. Such analysis can be used by packaging and logistics managers to decide a better packaging option that may be beneficial for their company. For example, if a company estimates the break-even point of reusable packaging system that is 2 years, but this company changes the product's outside dimension every 1.5 years, this company may not get any cost savings by using a reusable packaging system. Contrary, if the company tends to keep product dimension and does not need to change packaging specifications beyond the break-even point for reusable packaging system, the company may save total packaging system costs over the years.

c. Distance is an important factor when reusable packaging system is considered and it is directly related to transportation cost and cycle time which are critical factors for implementing returnable packaging system. Longer cycle time means more containers required within the loop. Longer cycle time is usually associated with poor container management that can easily slow down inventory turnover, replenishment speed, etc. It is notable that RPC is a worse option for long distance delivery than EXP and REN because the average route time (194 days) is too long to own containers. However, both RPCS and RENS are much economical for shorter distance and cycle time delivery (e.g. 500 miles with less than 30 days).

d. Losing reusable containers during return process cause a significantly important, but unnecessary and non-value added activity: purchasing and replenishing new containers. RPCS with good management (average loss rate of 5 percent) can save 29.4 percent of total packaging system costs compared to poor container management case (average loss rate of 20 percent).

e. Container cost is the most important factor, regardless of packaging options, and this should be the first thing to consider when reusable packaging system is considered. Especially, for long distance when high loss rate is expected, EXP or cheaper RPC container should be considered foremost. A packaging or logistics manager should try to reduce loss rate by implementing proper container fleet management system, and determine the optimum investment level before make a packaging decision.

f. When the average daily volume of container used is considered, economy of scale is in favor for RPC and REN options compared to EXP. Initial cost of implementing RPC and REN (e.g. new mold cost for RPC, basic contract cost for REN, etc.) is a significant barrier for packagers and logistics managers, but this can be compensated when numbers of required containers are large.

g. Like above, economy of scale is an important cost factor for the number of containers on a pallet.

h. The general expectation is that the total packaging system costs with collapsible and nestable containers should be much lower than the straight wall containers. This is a true statement, but the total cost difference is not significant because a container with collapsible and nestable features is usually more expensive while losing inside volume significantly compared to the container with straight wall.

Finally, the findings and conclusions of the study are discussed in the Chapter 8 of this paper.

CHAPTER 8

CONCLUSIONS AND DISCUSSION

8.1. Importance of the study

Total packaging costs cannot be measured and justified without understanding logistics costs and performance interrelationships between packaging components and logistics activities. In many cases in industry, the packaging cost is only considered as a material cost. It is important to include packaging cost in total supply chain cost, so that packaging managers can evaluate and compare packaging options and identify the value of packaging in the supply chain.

Packaging is more than a material cost, but is related to many business activities such as logistics and marketing. Improper use of packaging and packaging design could cause numerous unnecessary logistics activities and costs. Furthermore, reducing packaging cost does not necessarily reduce logistics cost. Without identifying accurate packaging and logistics activity costs and their interactions, managers have a hard time to identify the cause and effect of packaging changes on total logistics costs.

This study explored whether reusable packaging can be a viable option to replace expendable packaging in a global supply chain. This research demonstrates the importance of using a scientific approach in assessing the financial performance of reusable packaging, using a combination of case studies, ABC method, regression analysis and dynamic simulation, so the industry can significantly reduce its risk when making such packaging decisions. By analyzing results and comparing possible options, key opportunities and constraints for implementing a reusable packaging system for international trade have been discovered.

8.2. ABC analysis

First, this research develops a framework for visualizing packaging costs in a supply chain using the ABC method. Logistics activities are very labor intensive, so ABC analysis can lead to identifying, removing, replacing or reducing non-value activities. ABC can help to show the interaction of each activity and to guide better packaging and logistics decisions.

This method identifies packaging activities, measures packaging costs, and quantifies the total packaging costs as well as logistics costs. This study breaks down each process into activities and determined the cost of each activity.
By breaking down cost drivers to find out cost generator, ABC shows the resources and costs movement (up and down) throughout supply chain, so it helps firms to identify non-value added activities. As Dubiel (1996) pointed out, it may be almost impossible to identify packaging cost from total supply chain cost in traditional accounting systems, but this can be achieved using ABC method.

Three packaging system costs (expendable, reusable, and rental packaging systems) were established using ABC. For each packaging system, five cost types were categorized based on the logistics processes and activities involved in an automotive company shipping overseas: container purchasing cost, administration cost, transportation (outbound and inbound) cost, warehousing cost, and after use cost/revenue. Each process, activity, cost driver and cost unit of the cost driver was identified based on each process in the cost type.

Because activity cost drivers can be measured quantitatively and used to calculate total packaging costs, this is used for analysis comparing three packaging system options, namely expendable, reusable and rental packaging system. The results can also be used to analyze and remove excessive resource-consumption patterns or to develop alternatives to reduce overall cost in the future. For example, company provided data for this study neglected many warehousing activities and repacking activities that consume resources and increase total system costs.

8.3. Regression analysis

Second, this research developed a static simulation to reveal interrelationships between the packaging and supply chain costs.

Based on the activity cost calculations, a comparative and static simulation demonstrated the relative importance of various factors when evaluating the cost of container system alternatives. The developed simulation model was used to evaluate the relative influence of the various factors and perform a comparative analysis of reusable and expendable packaging systems.

Eleven scenarios were tested to learn how relative cost changes in one or more of the variables would influence the total cost. The use of regression model does not provides relative cost advantages one over the other, but it is useful to bring the general idea of interactions among each factors. Overall, container cost ratio and cycle time were found to be decisive factors in determining the packaging system and it was a similar result found by (Mollenkopf, *et al*. (2005, 191-192).

It was found that cycle time is more important factor than shipping distance, meaning that time is more important than physical distance since it requires an increased number of containers. Therefore, expendable packaging is more economical option for prolonged supply chains.

Setting an optimum cost vs. container durability for RPCS should be critical to save total packaging and logistics costs. Custom charges were an important factor for company-owned as well as rented reusable packaging.

Although this regression model is based on a certain logistical route by a specific automotive company and a logistics provider, using the factor ranges and the generalized relationships among each factor could help other business sectors to use this regression analysis method.

8.4. Dynamic simulation

Third, this research evaluated reusable and expendable shipping containers using a dynamic simulation method. The dynamic simulation shows real-time status of packaging inventory and helps a packaging and logistics managers to understand the control of containers as assets. A packager and logistics manager should know not only how many containers are being shipped, but also they need to know when ordered containers should arrive. They need real-time transit data for efficient container management, so they can reduce a number of containers being used in a reusable packaging system and prevent loss of containers due to poor management.

For the reusable packaging system, two options (company-owned and rental) were compared. Employee interviews, current supply chain flows and cost data provided by the company are used to construct the simulation model. Variables considered include costs of shipping containers, distance and transport time required for minimum 2-year operation. The results for a 2-year analysis of the operation of the reusable shipping containers reveal packaging system costs over time. The results show the expected performance of different packaging types and operation options.

ARENA software was used to calculate the number of RPCs and costs for three international supply chain routes of a company.

Total packaging system costs are carried out based on activity costs calculated by the ABC cost model and fixed costs provided by the company. The cost model calculates the values of system time and cost, resource utilization for the process and number of entities processed in the process. Express and Statistics functions of ARENA software are used for calculating the unit cost of each packaging system. The results of this simulation can help to analyze the interactive and coherent behavior of packaging and supply chain systems.

8.5. Validation

The dynamic simulation technique was used to verify the cost calculations of the static simulation and ABC based cost model. It visualizes actual cost flows depending on the packaging activities throughout the international supply chain.

Table 85 compares the company-provided data, the calculated ABC model and simulation for the first year of operation. Notably, the “Warehousing cost” calculated by the simulation model and ABC model are relatively higher than company data. The main reason is that the simulation and ABC model were taking account of time and activity together while the company-provided data is based on a simple allocation of costs. Compared to the company-provided data, all calculated data of ABC and simulation model are slightly higher. This may have happened due to using different metrics when converting the company-provided data to ABC and simulation models. There also could be a bottleneck in the simulation model that were not obvious in the company-provided data. Overall, total cost is little difference among the company-provided data, the ABC model and the dynamic simulation.

Table 85: Cost comparison based on the company-provided data, ABC model, and dynamic simulation

	Company-provided data			ABC model			Simulation model		
Container types	EXPS	RPCS	RENS	EXPS	RPCS	RENS	EXPS	RPCS	RENS
Container cost	1.44	4.79	0.72	1.44	4.79	0.72	1.44	4.79	0.72
Administration cost	0.22	0.27	0.26	0.17	0.28	0.25	0.27	0.30	0.27
Forward transportation cost	4.57	4.58	4.57	4.43	4.43	4.43	4.59	4.59	4.59
Backhaul transportation cost	0	2.12	2.12	-	2.12	2.12	-	2.02	2.02
Warehousing cost	1.86	1.96	2.11	2.7	2.98	2.66	2.1	2.55	2.35
After use cost	0.4	0.02	0.02	0.4	0.02	0.02	0.44	0.02	0.02
Unit cost	8.49	13.74	9.8	9.14	14.62	10.2	8.84	14.27	9.97
Unit cost difference from company data, percent	100	100	100	108	106	104	104	104	102

※ *Note: EXPS = Expendable packaging system cost, RPCS = Reusable packaging system cost, RENS = Rental packaging system cost*

8.6. Recommendations for reusable packaging optimization

The total costs estimated by the dynamic simulation cost model were generally higher than the company-provided data and ABC model. Interestingly, forward transportation costs were higher for the simulation model, but the backhaul transportation costs for reusable and rental container systems were lower than the company-provided data. This means that the company is underestimating the forward transportation cost, but overestimating the backhaul transportation cost.

Similarly, warehousing cost is significantly different. This is because the company data does not take account of cost of each activity while the ABC based simulation cost models handled every each activity cost and resource. It means the company is underestimates these costs.

However, unit cost is cheapest when a company uses an expendable packaging system while company-owned reusable packaging system cost is highest. Rented packaging cost is between these. This trend remains same with all cost models.

The total costs estimated by the dynamic simulation cost model were not significantly different from other models, but some cost elements (e.g. backhaul transport cost and warehousing cost) are significantly different. This is because the cost calculations based on company data and ABC analysis are static and more likely optimal conditions, so it does not present realistic situations. It is easy to assume that the time-related costs may vary in the actual supply chain situation due to unexpected delay such as loading and unloading time in the port or warehouse.

The result shows the possibility of using reusable shipping containers for international trade although there are several important points shown below that should be considered before selecting a packaging system.

8.6.1. Container cost

Whether it is a domestic or international operation, container purchasing cost is the most important factor to decide the profitability of reusable packaging system. As shown in Figure 22, RPCS need more than 2.2 years to reach the break-even point to EXPS, meaning the container life should last longer than 2.2 years in order to gain any benefit of using RPCS. Using RENS would be a good option for a company that does not have enough financial resources or distribution networks to operate RPCS.

8.6.2. Cycle time

Cycle time is directly related to the amount of containers in the reusable packaging system. Delays at the ports, plants or warehouse can also increase cycle time significantly.

8.6.3. Custom charges

Custom charges such as tariffs matter significantly depending on where products are shipped. In Korea, tariffs of pallets and packages imported are exempted if these are re-exported within one year. Custom charges can be removed if trading countries agree a free trade agreement.

This can promote using reusable packaging system in international trade only if country A and B can trade almost same amount of reusable shipping containers with each other. However, if a reusable shipping container is shipped to third country, C, the exporter cannot get the paid tariffs back.

8.6.4. Management options

Users may consider pooling or rental option for international operations. Management options for returnable shipping containers for international logistics vary considerably depending on the decision factors such as distance, types of contents, level of standardization, etc. Depending on the company's logistics strategy, an OEM (manufacturer) may own its containers or let a third party logistics provider handle the returnable packaging for it.

For the automotive industry, the trend varies depending on the level of standardization. In Europe, automotive manufacturers tend not to own the returnable packaging, but later to share the standard containers by pooling them. However, in

North America, the car manufacturer tends to own its returnable containers as assets; so generally, the standards vary depending on needs (Coia, 2013). Often, owning shipping containers can save money because the manufacturer can directly buy the containers and avoid any hidden purchasing costs or complexity of reimbursement of rental costs. Of course, the company must have high visibility on container fleet movements and excellent packaging management system. There are also a possibility to lose money by several non-valuable activities such as shipping the empty container back to the plants, cleaning and sorting containers for the line input, etc.

8.6.5. Geographical location

Because labor, land and material costs tend to be less in developing countries, where to handle returnable containers is also an important issue during international logistics process. For example, average labor cost in a developing country may be just $5 USD while it could be $40 USD in the US. It would be economical to do most cleaning, repairing and other reconditioning works in developing countries.

8.6.6. Freight balances between inbound and outbound freights

For example, China has a lot more outbound freight to the US, causing the US partners to ship empty containers back to China in order to balance. If in each direction a standard shipping container can be used for different products, there is more opportunity to balance out the number of containers.

For example, South Africa has many inbound containers for automotive parts, but not a lot of outbound ones. By using standardized containers, they can ship in with automotive parts and out with juice or rubber (Coia, 2013). This would be very difficult for an individual company to manage this, but it could be a good opportunity for global rental business.

8.6.7. Standardization

Various sizes, structures and processes due to lack of packaging standards lead to more complexity in supply chain process. Standardization of reusable packaging systems can boost international trade opportunities and logistical efficiency. Standards are being developed for dimensions, structures and procedures including:

- performance requirements, specification, and test methods.
- procedures for tracking and tracing of returnable packaging.
- improved overall quality control and management system providing harmonized standards for better communication, quality control, safety, sanitation, international trade and other relevant issues.
- contributing the environmental aspects of the packaging
- improving visibility of reusable packaging throughout the supply chain.

A global standard for returnable packaging system is a critical issue to facilitate an international logistics process. The fact that the standard pallet footprint in North America is imperial compared to the metric system in Europe and Asia, it requires additional work to regroup the unit load and is inefficient from logistical standpoint. International trade also requires a shipping container to fit both land (truck or railroad cars) and sea container. Table 86 shows relevant standards and guidelines that have been developed for reusable packaging.

Table 86: Standards and guidelines developed on returnable packaging

	Organizations	Standard titles
International standards or guidelines	ISO TC122	ISO 17364:2009: Supply chain applications of RFID -- Returnable transport items (RTIs) ISO 17350: Direct Marking on Plastic Returnable Transport Items (RTIs)
	CEN TC261	EN 13199 standards: Small Load Carrier Systems, Reusable EN 13117 standards: Rigid plastics distribution boxes
Regional / industrial standards or guidelines	ASTM	ASTM D6179-07: Standard Test Methods for Rough Handling of Unitized Loads and Large Shipping Cases and Crates ASTM D6881/D6881M-03(2008)e1: Standard Classification for Standard Plastics Industry Bulk Box/Pallet Unit Size Classified By Bulk Density
	EPCglobal, RTI Interest Group	RTI(Pallet tagging) Interest Group Guideline
	Korean Standards	KS T 1081: Plastic Returnable Containers KS T 1347, 1348 - Reusable, rigid plastics distribution boxes — Part 1: General purpose application, Part 2: Testing methods
	ISTA 7 Series (under development)	Project 7A: Open Reusable Transport Containers for Loads of 60 lb (27 kg) or Less and Unitized for Shipment on a Pallet - compression and shock testing Procedure 7B: Closed Reusable Transport Containers for Loads of 150 lb (68 kg) or Less - fixed displacement or random vibration, shock testing, compression and atmospheric pre-conditioning Procedure 7C: Reusable Intermediate Bulk Containers - atmospheric conditioning, compression, random vibration and shock testing
	AIAG	Returnable Containers Transported by Truck Guideline Standard Returnable Fastener Container System
	Joint Automotive Industry Forum (JAIF)	Global Guideline for Returnable Transport Items Identification

The International Organization for Standardization (ISO) Technical Committee 122 (Packaging) approved Working Group 13 for the Returnable Transport System and two new work item proposals for reusable rigid plastics distribution containers have been accepted (International Organization for Standardization, 2012).

The two new work item proposals (NWIP 18616 Part 1 and 2) are based on existing European standard (EN 13117 series on Reusable, rigid plastics distribution boxes. Part 1: Transport packaging - Reusable, rigid plastics distribution boxes -

General purpose application, Part 2: Transport packaging - Reusable, rigid plastics distribution boxes - General specifications for testing) and should be in the committee draft stage as of November 2014. Key difference from existing EN standards should be that these standard shipping container dimensions are based on the modular area 600 mm×400 mm, 600 mm×500 mm, 550 mm×366 mm and subdivisions of it in order to comply with the guideline from ISO 3394:2012- Packaging -- Complete, filled transport packages and unit loads -- Dimensions of rigid rectangular packages. In addition to NWIP 18616 Part 1 and 2, ISO TC122 / WG13 will develop series of returnable packaging standards as follows.

- Packaging - Small load carrier systems - Common requirements and test methods
- Packaging - Small Load Carrier Systems - Part 2: Column Stackable System (CSS)
- Packaging. Small load carrier systems. Bond Stackable System (BSS)
- Returnable flat pallets: Principal requirements and test methods
- Returnable large plastic containers: Principal requirements and test methods
- Returnable large mesh containers: Principal requirements and test methods
- Returnable Transport System for Packaging: Guideline for RTIs Tracking and Tracing
- Returnable Transport System for Packaging: Guideline for RTIs Safety Requirements in handling
- Other standards regarding handling and managing RTIs

Developing international standards can reduce technological, economic and social barriers for international trade. For a company to have a reusable packaging system, development of international standards and conforming to the guidelines set by international standard organizations such as ISO can certainly help to improve business productivity and logistics efficiency throughout its supply chain. (International Organization for Standardization, 2013).

8.7. Key trade-offs

Last, this research identifies key trade-offs for implementing a reusable packaging system for an international supply chain. While the benefits are numerous, applying reusable packaging system is not for every supply chain. The results of this research show the great possibility of using reusable packaging systems depending on following conditions.

8.7.1. Cost ratio between expendable and reusable containers

Because of relatively longer cycle time and distance, number of reusable containers are required. Even if collapsible or nestable features of containers can save significant volume during returning process, container purchasing costs should be the first thing to be considered. Reusable packaging may last longer, but reduction of container costs is necessary.

8.7.2. Cycle time

A quick turnaround times of containers with great frequency is essential. Avoiding unnecessary logistical activities during trans-shipment and custom process should be critical.

8.7.3. Standardization

Standardization is an essential element to reduce material costs while improving operational efficiency throughout supply chain. It does look easy, but it is actually not when different countries and logistics environments are involved. Production lines, loading/unloading docks, and even pallet sizes can be a big obstacle to apply for international routes.

8.7.4 Risk assessment:

Uncertainty is always greater during international trades and is also important element to determine an international packaging system. Free Trade Agreement and other policy changes can affect the cost greatly. Risk of product or production line changes can limit the uses of reusable container system.

In conclusion, this research tries to provide the most financially sound packaging solutions for the target industries such as global manufacturing companies, packaging and logistics providers, and other involved parties. It advances the use of a multi-methodology that combines case studies, ABC and simulation, as a new tool for packaging research that can be generalized to other packaging applications.

As shown in Figure 26, any elements of either logistics or packaging processes will cause changing each activity, cost driver, each cost and eventually other costs. This study concerned with economic impact by adopting different packaging systems in the international supply chain.

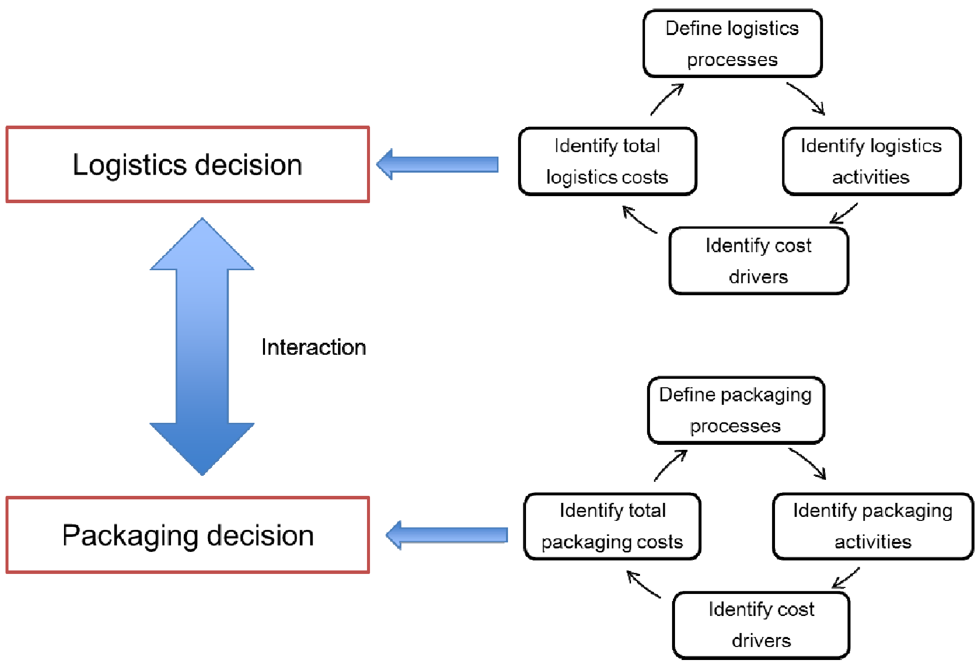

Figure 26: Cost identification loops and interaction between logistics and packaging decision

8.8. Limitations and recommendations for future research

ABC based cost simulation and dynamic simulation modeling can allow the user to analyze the future performance of the network and to understand the complex relationship between the parties involved. The present simulation model has been tested by using current automotive part logistics system between Korea and the US. The model can be further modified for simulating different logistical networks and parties involved to help improve the international supply chain performance.

This research contributes to the knowledge base in reusable packaging management by proposing a simulation modeling approach under a realistic scenario. This study shows the usefulness of using a simulation to save time and money while analyzing the effects and contribution of each variable at different conditions. It can be used to determine areas were the performance is above and below the expected level of operations in terms of choosing right packaging types and systems. This research contributes to optimize overall network performance by changes in impact variables such as packaging types, routes, distance and other logistics services.

This research has some limitations, providing opportunity for further research. First, this cost model is focused on an automotive part supply chain from a single supplier to a single customer, and back. It is assumed that reusable containers are shipped back to the supplier as being empty. Return transportation costs should be a lot lower if the company can fill the containers with other products.

In addition, other aspects of reusable packaging needs to be considered in future study. Environmental performance such as packaging waste generated and greenhouse gas emissions should be taken account in the model. Ergonomics for handling, hygiene and cleaning issues for food product containers, safety and fatigue of reusable containers during handling and stacking are also important subjects for successful establishment of reusable packaging system internationally.

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