TRANSPORT OPTIMIZATION:
A CASE STUDY OF VEHICLE MANUFACTURER

By
SUPHANIDA LEEKIJWIRIDHPOL

Submitted in Partial Fulfillment of the Requirements for the Degree of
MASTER OF SCIENCE IN SUPPLY CHAIN MANAGEMENT

Martin de Tours School of Management
Assumption University
Bangkok, Thailand

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Declaration of Authorship Form

I, Suphanida Leekijwiridhpol, declare that this project and the works presented in it are my own and had been generated by me as the result of my own original research.

TRANSPORT OPTIMIZATION:
A CASE STUDY OF VEHICLE MANUFACTURER

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ADVISOR'S STATEMENT

I confirm that this project has been carried out under my supervision and it represents the original work of the candidate.

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(Dr. Srobol Smutkupt)

Date 29 Aug 16

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Suphanida Leekijwiridhpol
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ABSTRACT

This study is about battery transportation of Vehicle Manufacturer that was found to have inefficient space utilization in the truck container. This problem has negatively affected the profit and opportunity of the company. Therefore, the consideration to apply GRASP is proposed to develop and improve the problem substantially.

In this research, Vehicle Manufacturer focused on its battery export by transporting it with commercial vehicles. As purchase is contracted to only one supplier, it is important to investigate the cost and eliminate the risk. To solve the problem, data were collected by interviewing personnel, observing actual operation, and historical data were analyzed. The result showed that the container truck utilized only 68% of its space. Thus, it impacted in two areas: high number of transportation trips and high spending on transportation cost. The conceptual framework of the research is to find the causes of battery transportation problem as well as implement GRASP methodology to the solution.

GRASP methodology is a heuristics approach of allocating the right space. This methodology is widely applied in vessel container business. It can be useful in related field such as truck container following the research consequence. The objective of this research is to build a significant tool to enhance on space utilization for loading battery.

The result indicates that the proposed solution can be accomplished and solve space utilization. According to this research the company should implement a tower rack to stack batteries on pallets and change the truck size from six wheels to ten wheels. These will provide cost saving, customer satisfaction, and collaboration which raises competitiveness in the industry.

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I, Joseph Philip Chan II, have proofread this graduate project entitled

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A Case Study of Vehicle Manufacturer

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CHAPTER I

GENERALITIES OF THE STUDY

1.1 Introduction

The automotive industry in Thailand has developed from an inward-oriented import-substitution industry into a competitive export driven industry. Multinationals, in particular the Japanese, have been instrumental in driving growth. Export has increased dramatically according to economic condition and changes in customer demand. Nowadays the automotive manufacturers are rationalizing the supply base, defining new supply requirements, and increasing their outsourcing as a strategic alternative. In response, the automotive supply industry is experiencing consolidation and restructuring by creating tier suppliers along with third party logistics service providers. As a result it provides challenges and opportunities that contribute to the automotive company in terms of cost and time. To become efficient in supply chain, automotive manufacturers know that it is necessary to achieve lean principle on processes and activities. It is important to identify customer value, value stream, develop the capability of production, reduce all waste in the production system to zero, measure on quality, cost, and delivery time (Womack & Jones, 1996). In regards to automotive supply chain, road transportation is a significant area which creates cost to the company in many factors. Examples are the high frequency of usage, geographic matters, different types of products, transport optimization, infrastructure, and energy. Most automotive manufacturers select to implement outsourcing for their cost saving.

To find improvement for automotive supply chain, this study is concentrated on transport optimization of vehicle fill. Maximized vehicle fill is a key level in optimizing the use of transport by utilizing all available vehicle load weight and cube (ECR, 2007). To optimize container load is often not achievable due to weight limitation, operator's experience, type of road transportation, different product types,

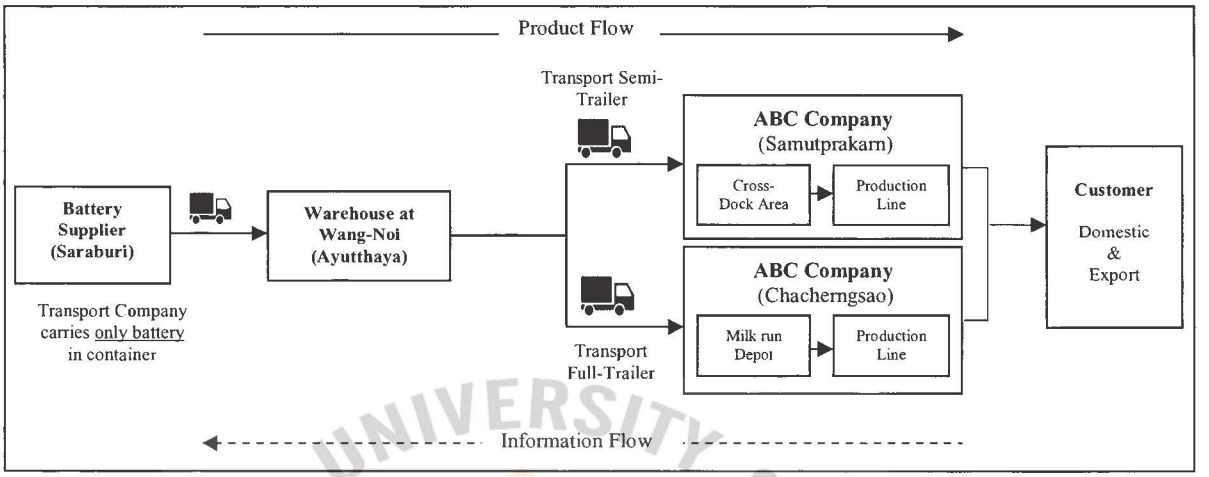
and low innovation response. The expectation is to analyze the case study and provide recommendation to Vehicle Manufacturer in order to enhance their utilization value and competitiveness in the long run.

1.2 Background of the Research

Vehicle Manufacturer is a global automotive company which was established in Thailand in 1966. The company is registered as a global automotive company selling commercial vehicles in both domestic and international markets. Currently they have been outsourcing both inbound (Supply) mostly local concentration and outbound (Transportation) under cost consideration policy. This research is focused on battery which is an important part that is required in every vehicle. Nowadays, Vehicle Manufacturer purchases batteries to be installed in vehicles for domestic sales and for export. Batteries for domestic vehicles are purchased from four well-known brand companies in the market such as 3K, GS, Panasonic, and FB. The purchase allocation used is volume sharing by percentage for each brand which is reviewed every three months. The sharing volume by percentage is based on supplier evaluation but the main criteria are concentrated on cost, performance, and collaboration. Batteries for export are purchased only from FB because in the previous years the volume of exported vehicles was not high. Also, the supplier has sufficient capacity as well as high performance in quality, fast delivery, cost saving, and collaboration.

As to transportation, Vehicle Manufacturer has a contract with a private transport company who provides transporting and warehousing. The trucks used in transportation are owned by the transport company. Vehicle Manufacturer acts as the operation controller of both battery supplier and the transport company, aside from paying for the transport cost.

Figure 1.1: Supply Chain of Vehicle Manufacturer on Battery Transportation



Source: Vehicle Manufacturer

Figure 1.1 shows the supply chain of Vehicle Manufacturer for batteries in transport vehicle. Vehicle Manufacturer emphasizes between the supplier and the transport company to succeed on mutual cooperation. The term for the supply side is called "the supplier" and the term for the transport service provider is called "the transport company". Vehicle Manufacturer has applied the milk run concept to solve the vehicle routing problems following the milk run system to minimize cost. Typically, the transport company will directly pick the batteries from the supplier factory, following a confirmation date and time. After that the picked up lot will be temporarily placed at the transport company's warehouse to be consolidated with other components. Then the batteries will be delivered to Vehicle Manufacturer's plant at both Samutprakarn and Chacherngsao for customized production as demanded by all customers, domestic and export destinations.

1.3 Statement of the Problems

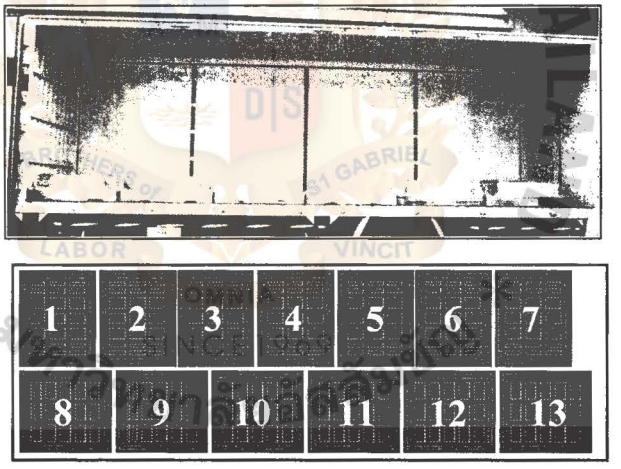
The research is concentrated on the transportation of batteries for export vehicles because the export vehicles' volume had dramatically increased from 81,143 units to 101,191 units (25%) from 2014 to 2015. It shows that export business is highly expanding. This means that the battery specification attached in every vehicle unit

needs to be reviewed for better improvement. Knowing that battery for export vehicle is purchased by monopoly, it is appropriately selected for a case study. This is a case of high volume purchase with high cost saving after the implementation of the solutions. There are obvious problems in battery transportation, especially for export production, such as space utilization, loading, and unloading the trucks. These problems usually bring high transportation cost.

1.3.1 Problems on Container Space Utilization

Space utilization is the core problem in filling the vehicles. The problems are in packaging and operation capability area. The problem is expressed in the figure below.

Figure 1.2: Inefficient Container Space Utilization



Source: Vehicle Manufacturer

Figure 1.2 shows inefficient container space utilization. Battery is a special product among transporters because of its sensitivity during transportation. Batteries that are handled improperly might have poor impact in their performance. Nowadays, Vehicle Manufacturer is facing a problem of poor packaging design. They cannot be stacked properly, especially the battery parts. Then the battery for export vehicles transportation are usually loaded at only one level of the container floor, calculated by 13 pallets or 195 pieces per trip. So the batteries loaded are often less than the actual

container capacity and creates empty spaces as seen in the figure. Moreover, the loading staff usually lacks management skill in loading operation, space management, and initiative to do any change. To emphasize on packaging, there are problems in dimension design as some packages are fully protected but not efficient in terms of weight limit. There are also some packages with moderate protection but they provide troubles to loading staff because their particular design makes it difficult to consolidate with other parts.

1.3.2 Problem on Truck Loading Capacity

Truck loading capacity relies on container utilization which is measured on weight maximization. Therefore, low container utilization provides poor utilization of truck capacity. The problem is explained below.

Table 1.1: Inefficient Truck Loading Capacity

Detail	Current
Routing Pick up Battery	Battery Supplier to Transport Company Warehouse
Truck Type	6 Wheels-Diesel
Total Truck Capacity (Kg.)	6,200
Actual Truck Load with Battery (Kg.)	4,250
Total Truck Load by Percentage (%)	68%

Source: Vehicle Manufacturer

Table 1.1 shows Vehicle Manufacturer has utilized the truck load capacity by only 68%. Vehicle Manufacturer used six wheels trucks in battery transportation, by allocating two daily pick up of batteries from the supplier to the transport company's warehouse. The number of transport trips is four trips per day. In each pick up operation the trucks only carry a load of 4,250 kilograms compared to its capacity of up to 6,200 kilograms. This is obviously an inefficient use of container space. This problem has become very obvious because the export of vehicles is growing. Furthermore, the battery transportation is operated by the transport company which is

under Vehicle Manufacturers contract. This situation allows the transport company to pay low attention and initiative regarding cost benefit to Vehicle Manufacturer. Vehicle Manufacturer is aware of the Inland Transportation Department's regulation on truck specification, limitations on truck operation, environmental and safety concerns.

1.3.3 Transportation Cost

Maximizing container space utilization is a significant transportation concept that brings competitive advantage to the company. The reason behind the need of four trips a day in transporting the batteries is from space utilization problem. To complete the deliveries of all the batteries ordered, the transport company limits the batteries into the container and this results in having four trips instead of two trips. As a consequence there is high transportation cost on the part of Vehicle Manufacturer and opportunity loss due to the empty spaces during transportation.

This study aims to answer the research question: **"How can Vehicle Manufacturer Optimize Battery Transportation?"**

1.4 Research Objectives

The main purpose of the study is to provide optimization in transporting batteries for Vehicle Manufacturer. The concept is focused on enhancing transport practices. The major objectives are as follow:

1.4.1 To study how the company can utilize container space utilization and maximize on truck load capacity

1.4.2 To examine how the company can reduce battery transportation cost

1.5 Scope of the Research

To provide efficiency and effectiveness for Vehicle Manufacturer's supply chain, the research is concentrated on battery transportation for export vehicles. This area is particularly a loss for Vehicle Manufacturer and improvement is necessary. The research hopes to contribute effective transportation cost, a critical consideration in supply chain. The major scopes of the study are as follow:

1.5.1 The research is a case study of Vehicle Manufacturer focusing on battery transportation. It starts from the battery supplier's factory to the transport company's warehouse. The research will use battery transportation cost in January-December, 2015 to analyze and compare after improvement.

1.5.2 The researcher will interview logistics department and relevant people in transportation process to understand the loading operation. Moreover, the researcher will observe the operation of truck loading in order to understand loading operation and help solve the problems.

1.5.3 The parties involved in this research are Vehicle Manufacturer, the battery supplier, and the transport company. The battery supplier is a monopoly supplier for export vehicles and shares some for domestic vehicles. The transport company is a monopoly transporter for Vehicle Manufacturer.

1.5.4 The research is based on Greedy Randomized Adaptive Search Procedure or GRASP which will be applied to solve the space utilization problem. Thus, GRASP can be implemented for transport optimization significantly.

1.6 Significances of the Research

The research considers applying GRASP methodology. GRASP is defined as a heuristics approach to maximize loading space utilization. In solving the problem, this methodology is expected to be effective in the space utilization of the truck to full

load capacity. It can increase the number of loaded battery pallets to minimize battery transportation cost. Furthermore, the operation staff can enhance their capabilities in loading and they bring value added in the process. Vehicle Manufacturer will have opportunities in applying this method with other suppliers or other areas in the company that need improvement.

1.7 Limitations of the Research

The research is concentrated on battery transportation for export vehicles only because the battery for export vehicles is purchased from only one supplier and the export business has shown a significant increase. Therefore it is appropriate to start improving the battery transportation to cut high cost. The research is mainly to improve the truck loading problem. It will not provide a common practice to be applied in different operations and procedures in the company. Additionally, the research does not cover all the causes of the problem and related impact such as operating time, manpower, etc.

1.8 Definition of Terms

Container utilization	This is to determine a feasible arrangement of a subset of boxes in the container to consider ways that the stowed volume is maximized and the constraints for loading are met (Dyckhoff & Finke, 1992; Gehring & Bortfeldt, 1997).
Lean	The concept is defining a seven waste elimination described in terms of transportation, inventory, motion, waiting, overproduction, over-processing, and defects (Ohno, 1988).

Milk-run logistics	This is a generic name for a logistics procurement method that uses routing to consolidate goods by the buyer. It is a method of goods collection in which the user such as car assembly manufacturer dispatches one truck at a specified time to visit various suppliers (Brar & Saini, 2011).
Vehicle fill	This is optimizing the use of transport by aiming to utilize the available vehicle, available cube, and tertiary transport items (ECR, 2007).
Logistics of packaging	A carton, case, box, bin, bottle or bag which is used to protect the products from incidence of damage, spoilage, and misplaced goods during movement through the distribution channel (Speece & Silayoi, 2004).

CHAPTER II

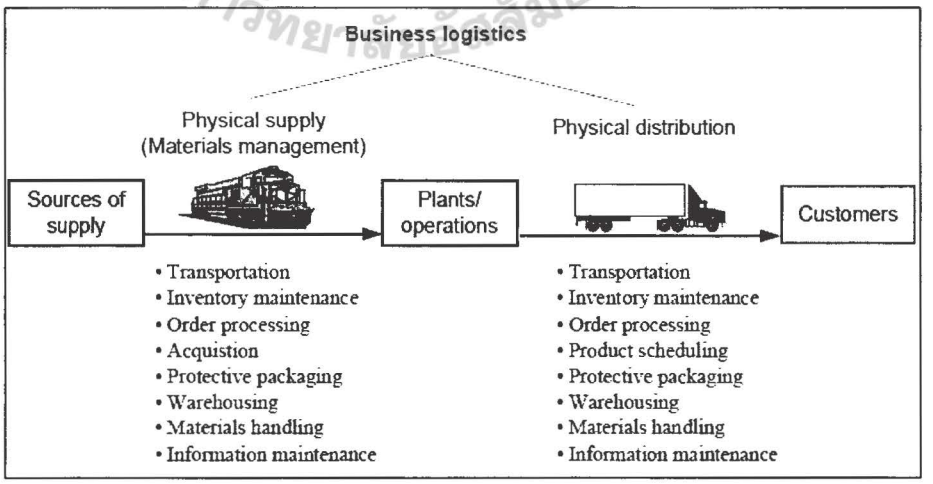
REVIEW OF RELATED LITERATURE

The objective of this study is to discuss the relevant theories and concepts to enhance the study of optimization in transportation in order to analyze the root cause focusing on vehicle fill. The case study of Vehicle Manufacturer provides a valuable knowledge and logical analysis. Moreover, literature and previous studies have provided guide in finding solution. So the scope of this chapter is literature, concentrated on logistics and supply chain, logistics activities, vehicle fill, and optimized implementation in supply chain.

2.1 Logistics Activities

The logistics activities will identify key implications that are important in planning, analysis, control, and meeting customer requirements. All activities are important to create value added in the supply chain.

Figure 2.1: Logistical Activities



Source: Ballou, 2004

Figure 2.1 shows logistics management emphasized on "logistics activities" consisting of key decision areas to be practically achieved (Ballou, 2004). *Inventory* is a measure on stock holding, a major work in logistics management. The inventory or stock holding cost is costly in doing logistics. Therefore determining the level of inventory is associated with cost. To sustain customer demand needs the consideration of inventory location, quantity sufficiency, and frequency of replenishment. *Facilities* are to be determined based on warehouse number, location, size, and design. Majority of all decisions in companies are fixed and in short term, rather than long term, to bring the company cost down.

Communication in physical distribution is focused on communication between customer and supplier, referred as "ordering process". These activities rely on the efficiency of demand and supply forecasting, documentation, and system support to reach customer satisfaction with cost benefits. *Utilization* is defined as packaging the goods by considering the packing size and material. It refers to loading capacity, movement and storage, providing influence in the cost of transportation, handling, and warehousing. *Transportation* is a major concern in making decision on the mode of transportation, selection criteria, owning transport or hiring transport from service providers. Transportation plays an important role in logistics. It affects delivery time, cost, customer satisfaction, and competitive advantage.

Materials handling is providing effective logistics management in terms of standard operation that matches customer demand during production. *Production scheduling* becomes efficient by requiring minimum inventory level in respond with production schedule, following the concept of just-in-time to balance the supply and demand while also trying to minimize transportation cost, the level of inventory, and related wastes that occur in the process. *Customer service standard* is setting the level of output and degree available that logistics must response. Using maintained information becomes a support to all activities in logistics in order to do planning, monitoring, leading, and controlling.

2.2 The Transportation in Logistics

Logistics is to provide efficient and effective flow of goods, service, financial and information from point of origin to point of consumption. Logistics efficiency is also critical and successful in supply chain but it must involve efficient time, optimal quantity, transportation and related utilities that coordinate the flow of materials and activities.

Tracey (2004) stated an outstanding execution regarding transportation as a foundation of overall logistics and supply chain. The ultimate objective in logistics is underlining the rapid and effective respond in moving materials, service, and information within a crucial short period and transportation is the key element in making this to happen. The element of transportation is classified by two major roles.

First, *Inbound Transportation (INBTRN)*. The fundamental role is moving inbound materials from supplier site to manufacturer site which encompasses transit time, reliability, and consistency. In supply chain, integration requires high level of collaboration in order to provide effective communication, performance, and satisfaction enhancement.

Second, *Outbound Transportation (OUTBTRN)*. The fundamental role is focused on moving a finished product from manufacturer to distributor or end customers by ensuring that the products arrive at the right time, right location, and right customer. Inbound and outbound transportation contribute efficiency or even provide impacts to parties concerned. The effects in inbound and outbound transportation are examined in terms of time utility which replies to organization's capacity to achieve on quality, cost, availability, and responsiveness for overall activities.

2.3 The Vehicle Fills in Transport Optimization

Overall supply chain optimization is an elusive and attainable goal for organization but different characteristics and operation drive a different business direction in supply chain. Currently, lack of specification and unit load design criteria are limiting

transport efficiency or vehicle utilization. Therefore, ECR (2007) explained key improvement areas to solve this problem. "Vehicle fill" is a key improvement for truck loading because it is a key in realizing transport utilization on available loading weight and cube. The available weight per vehicle is considered in maximum vehicle weight with empty vehicle weight. The available cube per vehicle defines physical dimension with fixed equipment and transport item to fit in space. Transport items such as pallets and racks are usually maximizing mechanisms in vehicle loading and they also minimize risks of product damage. To achieve vehicle fill, the items need density fulfillment, weight, and volume balance that match with vehicle capacity represented by efficient lead time, quality, and cost.

2.4 The Packaging in Logistics

Logistics is becoming a key strategic function for organizations in order to achieve competitive advantages on cost reduction management and service improvement. According to Paine (1991) this strategy underlines a relationship between packaging and logistics and developed to be "packaging logistics" because the types of packaging are usually subject to consideration on cost reduction.

Livingstone (1994) stated a hierarchy of packaging that is widely used following three categories. First is *primary packaging*, also called as sales packaging. This category is mostly used with consumer products. Second is *secondary packaging* which supports the primary packaging. Examples are plastic sheets and cardboard boxes. Secondary packaging is purposely used in marketing and protection. Third is *tertiary packaging* or transport packaging. It facilitates the movement of goods, handling of goods, and protecting goods in transit. Examples are container, crates, cardboard boxes, and pallets. Transportation unit and stacking ability are directly affecting transport and transport packaging is specially a major concentration on transportation cost (Lambert, 1998).

Kye, Lee and Lee (2013) explored that improving the efficiency of supply chain must reduce logistics cost which is by direct and indirect packaging, building the efficiency

of freight transportation (EOT) which represent transport cost reduction through unit loading (ULS). To define packaging logistics (PL) a research was made on palletization that functions in loading and stacking on boxes or product. Ge (1996) also proposed that inefficient palletization lead to poor usage of pallet space, reduce efficiency in transport, and increase its cost.

Abdou and Yang (1994) explained the factors influencing palletization in transport by box size, weight, orientation, and density. The box size is based on different products and sizes resulting in pallet pattern. The box weight is based on quantity of the products. The box orientation affects the layout and density or pallet especially the impact on loading stability. The box stability is a significant consideration and desirable in transport and product size. Furthermore, the study summarized the advantage of palletization in transport by providing cost reduction in transport and inventory, reducing loading and unloading operation times, facilitates freight handling, and reducing the number of damage, lost, and stolen items.

2.5 Pallet Loading Problem in Truck Transportation

The transport unit and stackability is directly affecting transportation because the transport unit is a function of unit load based on weight and height while stacking boxes on a pallet is also related to cost reduction (Hellstrom & Saghir, 2007). The pallet loading problem (PLP) is defined as involving the interlocking of boxes on a pallet with character by two dimensional, rectangular, identical item-packaging problem. "The determination of an optimal is loading a set of identical boxes to be loaded on pallet. High pallet utilization is emphasized in loading stability". It is an important concept for research and development (Kocjan & Holmstrom, 2010).

Moreover, Pennington and Tanchoco (1988) also addressed PLP in loading multiple size boxes on pallet that are able to maximize space usage on the pallet and transport packaging, resulting in increased efficiency and reduce transport cost. The loading of boxes on a standard pallet and the loading of pallet on truck and developed utilization to evaluate the economic performance of unit load system.

Bischoff and Downland (1982) studied distribution management by one of the many application areas in pallet loading. A sustainability of pallet stacks in transport is definitely a major concentration. The assumption is testing pallet and boxes randomly while identifying rectangle packing. All pallets must have the same dimensions in loading, considered as layers of boxes in storage and distribution activities. Each box is affected to a position of stacking especially during transport. This makes loading subjected to dynamic force and this aspect is much considered in transportation. The consideration in this study was focused on "stability and clampability". These two methods are used in general pallet stack, called as pallet-loading algorithms to produce a maximum layer pattern for any box and pallet combination. Stability is to maintain the stack positioning balance with force during transportation by adjusting the layer and lead to a potential low damage. Investigating its relative importance is done by four criteria. The first criteria require that each box must have at least a two-box base each column in order to see the instability during transport. The second criteria require each box to have its base area in contact with the layer to eliminate falling and box crushing problem. The third criteria investigate a possible problem associated with pallet stack in vertical direction. The fourth criteria is a part of clampability concerning clamp truck loading which is applied in transportation and storage. This clampability requires at least one pair of opposite stack side to be flat and all box edges must be parallel to the plane for the clamping. The result of testing pallet loading system showed that all criteria is able to reach practical stackability, calculated by 40% success of pallet combination. The implementations need to take into account the maximal layout differences and stable pattern in transport.

Moura and Oliveira (2005) explained that most of the transport loading problems are usually subject to pallet loading. The major concern is Vehicle Manufacturer's pallet packing problem and the distributor's pallet packaging problem resulting from different packaging size and pallet orientation. Therefore the study provided a methodology "The Single Pallet Algorithm" by linking the container loading problem with pallet loading problem based on greedy procedure. The concept of single pallet algorithm was considered a potential loading pattern generated from block of boxes. It also considered a single tier rectangular arrangement to identify boxes of the same

orientation. This experiment was meant to increase the stability in transport with high degree of packing efficiency as well as to easily convert to multi-pallet or new pallet patterns in the future.

Morabito, Morales and Widmer (2000) found out that pallets and truck loading are the usual problems in manufacturer's pallet loading because the products cannot be stacked. This examination is not only the loading of products on pallets, but also loading of pallets on trucks in order to enhance economic performance in supply chain. Therefore, the study is emphasized in loading the pallets in the truck and balancing the pallets and the truck. The case study is from a Brazilian distributor with an issue on truck load that required increase number of daily delivery trip. To maximize utilization, a relationship approach requires that all pallets loaded must be assumed identical and vertically shaped to gain optimization in transport. The advantages of palletization enhancement are cost reduction of transportation and inventories, decrease of loading as delivery trip decrease, and reduce the number of damage and lost. However, the cost of palletization and equipment requirement for special handling should be considered in the implementation.

2.6 Constraints in Truck Loading

Bischoff and Ratcliff (1995) provided constraint in the container or truck fill in four areas. First, stability constraint in loading boxes requires support from container bottom or other upper box surface. The stability is evaluated into two different ways, "the horizontal interval limit in which the center of gravity of the container must fall in both transverse and longitudinal plane and by the maximum angle of inclination in which the center of gravity of the container should fall within its base in both transverse and longitudinal planes". Second, orientation constraint may not be used as a height related box positioning. Third, stacking constraint considers placing weight during transport. Stability loading in vertical or static stability prevents items from falling when the truck is not moving while horizontal is endurable because the items will not move while the truck is moving (Rachman, Dhini & Mustafa, 2009).

Fourth, weight constraint is determined on weight limitation for transport vehicle and container constructive technique.

2.7 Greedy Randomized Adaptive Search Procedure (GRASP)

Festa and Resende (2002) introduced the generic of GRASP by an iterative multi-start algorithm. Each of the iterations consisted of two phases. First is a greedy adaptive randomized construction phase. Second is local search phase which started from the feasible solution built during the greedy adaptive randomized construction phase. For local search the emphasis is on optimum local search being founded. Moreover, the heuristics is adaptive due to the consideration of beneficial association that every element is updated. The iteration of construction phase can be a reflected change by selecting the previous element. Local implementation is by using either the best improvement or providing the first improvement strategy. The first improvement comes as soon as the strategy is applicable while the best improvement is to evaluate the best alternative as current solution. GRASP methodology has attractive characteristics. First, it is a simple structure and it can be easily implemented. Second, it is linked with the construction of greedy algorithm. It can be a basic version for adjustment. And third, it is able to optimize problem in wide range of combination.

Tamarit and Oliveira (2008) explained that minimization on empty space inside the container is not only an economic requirement but also an ecological issue. It gives impact in transportation cost and global effect on human activities in our planet's sustainability. The literature allows GRASP to implement a container loading problem as solution of space search strategy. To define GRASP, it is an iterative procedure that combines constructive phase and improvement phase. The constructive phase concept is to build a solution step by step to match with the problem. Added to this element comes a greedy function and randomizing strategy being emphasized in the methodology. Along with improvement phase is providing a simple local search which usually follow a constructive phase. In constructive phase, it is selecting the type of package and configuration for packing to build a layer. The

major purpose is to find the best increase of volume or allocate the best fit in the space. In improvement phase, the solution built in constructive phase focuses in procedure to be improved. After implementing GRASP with container loading problem, it contributes good result on empty space filled twice. It is not guaranteed to have cargo stability and not relevant to have packing sequence.

Moura and Oliveira (2005) stated that container loading problem is similar in the area of pallet loading problem. These problems arise in practice when containers have to be filled with container space and need to be maximized. Additionally, ecological issue can be fulfilled by the minimization of empty space in container to bring efficient transport and logistics activities. Consequently, developing Greedy Randomized Adaptive Search Procedure (GRASP) algorithm can achieve volume utilization and load stability, by maximal space approach that explains the efficiency of algorithm. The algorithm is defined by two different steps. The first step is constructive heuristic. This is building a layer and filling a free space based on wall building, "the container is filled with transversal walls and the depth of layer is determined by the first box placed in the layer" (George & Robinson, 1980). The second step is improvement with local search algorithm. This is formulating a maximizing solution, especially space allocation. Ultimately developing algorithm provides good results due to three main reasons. First is the use of maximal space by analyzing the space in which the products can fit in the pallet. Second is the way that space can be filled in the container. And third is the combination of randomized and allocated strategy. All of these measures provide an obvious improvement and capable address for future aspect.

Alonson, Valdes, Tamarit and Parreno (2015) implemented GRASP algorithm to develop pallet building and truck loading in an inter-depot transportation problem. The main purpose is minimizing the number of trucks which will become a reduction in transportation cost. In this literature there is a classified problem by two interrelated phases. First is pallet building phase because an outstanding problem on multi pallet loading response was found to be impacting the loading operation. Second is truck loading phase that is restricting maximum weight of loading on axle

support. Therefore the solution is to design to put the products on the pallet and load the pallets in the truck by restricted constraint to ensure that they do not exceed the dimension of the pallet and the truck. To approach GRASP, the researcher followed two steps, constructive phase and improvement phase. In constructive phase, the emphasis is on pallet problem by adding related constraint to build a potential pallet in loading. The constraints in pallet composition are orientation, support priority, and stackability. Improvement phase is realized by increasing the percentage of truck fill which is measured in volume and weight. But the result obtained by GRASP produced a good optimization in truck loading. It provided result in short computing times. To be sustainable for improvement, it has to be applied on related problem and implement additional constraint to apply with different pallet and truck type.

2.8 Chapter Summary

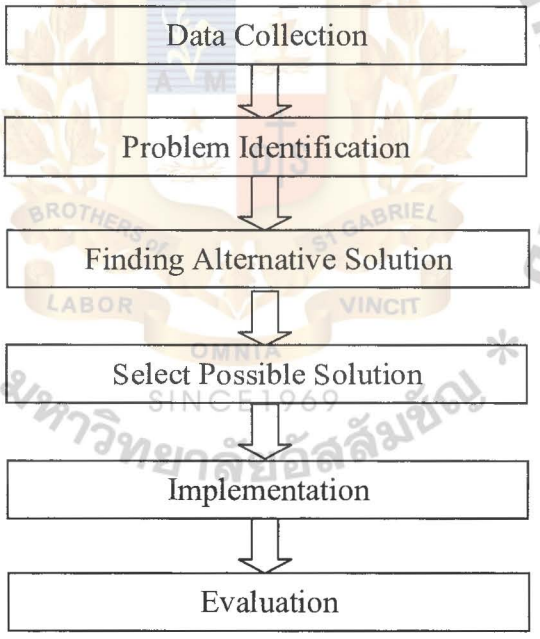
After reviewing the common practices in battery transportation, the researcher found little practical information. The researcher knows that the battery product is a specific vehicle component and each company has different designs on packaging and transport operations. Actually, in this case study Vehicle Manufacturer relied on the research and development team from the company headquarters to mutually develop solution their transportation problem. However, there is no exact literature that provides optimization in battery transportation. Therefore, this research tried to apply similar concept which emphasizes on space utilization and truck loading. The best solution according to the many literatures is to use GRASP methodology to solve space utilization and loading problem, usually with container. Most results showed that it provides a significant improvement and it utilized wide free spaces. Hence, this research considers implementing GRASP methodology, using constructive phase and improvement phase. Other related constraints can be supported in battery transport optimization. The major concentration is to enhance pallet loading and truck loading to contribute beneficially in transportation cost and efficiency in operation.

CHAPTER III

RESEARCH METHODOLOGY

This research is a case study on the battery transportation of Vehicle Manufacturer. The conceptual framework of this research is to investigate data and select an appropriate solution to provide transport optimization. This chapter presents the methodology and related tools for improvement and enhancing on competitive advantages.

Figure 3.1: Framework of Research Methodology



Source: Author

3.1. Data Collection

For data collection, the researcher used three methods to collect which are interview, observation, and historical data. The purpose is using data to support the analysis and implementation.

3.1.1 Interview

The researcher interviewed personnel in logistics department. They are the Production / Planning manager and the Logistics officer. The data from logistics department explained the current transportation of battery for export vehicles and operation flow. Related data is about the department concerns, container and truck, loading carrier, pallet and battery. The interview questions are below.

Question 1: What do you think about the current battery transportation and do you have any suggestions?

The Production and Planning manager: "The company has a problem in loading battery that cannot be achieved on fully utilized truck space and always resulting in high transportation cost. The root causes of the problem should be reviewed, especially in transportation area where we should get more collaboration from our transport company. Also, the company should review the current internal operation flow, both the products and communication". (Interview: March 15, 2016).

Question 2: What important information do you think may contribute to the improvement of battery transportation?

The Logistics officer: "There are significant data that can help solve the problem. Firstly, you have to understand the current battery transportation e.g. transportation route and department concern. Second, it is important to understand the characteristics of the product and its packaging and the characteristics of the carrier.

Then, the overall collected information will be used to create improvement as value added in the process". (Interview: April 20, 2016)

3.1.2 Observation

The researcher observed the actual operation at the plant, especially the battery loading process. By observing the truck loading, both at the supplier's factory and at the transport company's warehouse, the researcher hopes to understand their management practices. The information obtained is how to load the battery into the truck, managing the space in the container, materials handling, and battery packaging that influences the loading process.

3.1.3 Historical Data

The researcher decided to use the battery transportation cost of the year 2015. The concern is in battery for export vehicles only. The data was used to compare the improvement after the implementation of the solution.

Assumptions:

i. All Batteries are Packed on Pallets for Transportation

Battery is a special product in transportation because it is classified as risk product. It contains dangerous chemicals e.g. lead, acid, etc. Moreover, Vehicle Manufacturer has a strict policy in product quality. It rejects all damaged battery products. Both physical product and good performance must ensure the company's standard to pass any customer inspection. Finally, the use of pallets as mechanism to support in the loading and protection from damage make the products in excellent condition.

ii. All Pallets have Square Dimension

Because batteries have standard size, the pallets should be designed in a standard dimension. Vehicle Manufacturer has designed a pallet fit for batteries as well as emphasized on quality and security in transportation. Moreover, loading the standard pallets in the truck or container is useful in allocating and maximizing space.

iii. All Pallets with Battery are Loaded into a Container

Vehicle Manufacturer delivers its battery products via direct shipment from supplier factory and the batteries are mixed with other vehicle components. This allows transport loading to maximize the container space for more batteries in order to minimize the number of delivery trips and cut the cost of transportation.

3.2 Problem Identification and Analysis

Referring to Vehicle Manufacturer's data, it shows problems in three main areas. The first problem is in space utilization because of the poor initiative loading of the staff and less interest to improve, even though production volume has sharply increased compared with the past. Additionally, a visible problem is pallet loading that cannot be stacked because it needs quality protection and the container height has limitation. These make transport space utilization as less important than the actual truck loading capacity.

The second problem is the truck loading capacity which is under regulation from the Inland Transportation Department. As a result, loading correctly is highly considered in matching product type, pallet, weight of product and pallet, truck weight limit, and loading space in the truck.

The third problem is the high transportation cost that Vehicle Manufacturer is spending. It spends unnecessarily in transportation cost, labor cost, materials handling, and related operating cost with minimum product quantity transported.

Furthermore, trucking cost is a part of price per piece (PPP) structure. The average cost per piece is high and this brings opportunity loss to Vehicle Manufacturer. So it is important for Vehicle Manufacturer to find ways and means in order to solve these problems by setting the following objectives:

3.2.1 To study how the company can utilize container space utilization and maximize on truck load capacity

3.2.2 To examine how the company can reduce battery transportation cost

3.3 Finding and Selecting Alternative Solution

Part 1: To Study How the Company can Utilize Container Space Utilization and Maximize on Truck Load Capacity

Vehicle Manufacturer is searching for ways to save cost by maximizing space utilization through finding new alternative to replace its current operation practice and enhance the staff capability. Normally, truck loading is a complex problem because many criteria, e.g. space management, must be implemented. In attempting to solve this problem, one usually applies dynamic programming to allocate container. However this method cannot guarantee an optimal solution and it is not commonly applied. Consequently, this study is concentrated on heuristics approach that provides flexibility by applying a similar concept from GRASP to fully utilize truck loading as significant tool focusing on stacking ability. The concept to be supported is pallet loading into the container which will solve space utilization. The GRASP concepts that require two phases to implement are:

Phase 1: Constructive phase is "building." This concerns the pallet loading problem which refers to the batteries in transport that are usually placed on pallet and packed by plastic from the supplier factory. The purpose is to protect the product quality during transportation. Therefore, this research considers providing additional tool for loading capacity.

Phase 2: Improvement phase is "improving." This is a continuation from the phase one concept, or related improvement concern. The researcher continues to consider other truck loading problem to maximize transportation.

The consideration of loading balance is important following a restriction on road transportation, product quality concern, and production capacity. The study is to review the current truck of Vehicle Manufacturer. Export production volume is fluctuating depending on customer demand and economic situation. This fluctuation especially shows the impact on transportation so it is necessary that truck loading operation considers cost. As regards to the weight of truck or axle capacities, they are both limited. Furthermore it is also necessary to be concerned in environment and prevent any road accident. As a result, the significant objective is to select the right truck and the right product quantity in order to balance the weight and the volume. This adds up to efficient utilization of space, elimination of unnecessary cost, and having standardized system.

Part 2: To Examine How the Company can Reduce Battery Transportation Cost

The transport company actually has a number of cost expenses including labor, fuel, carrier cost, administrative, and operating cost. Transportation cost has two major costing which are fixed cost and variable cost. Fixed cost usually refers to infrastructure cost and others under negotiation in a contract. Variable cost usually refers to cost under fluctuation such as oil price, also called as fuel charge. Thus the company normally bears unstable conditions in transport activities. Furthermore, a significant transportation effect can be measured by geography which is related to distance expressed in terms of time, length, and economic cost. Also the type of product requires variation of packaging in transport, special handling and protection. Economies of scale in practice contributes to cost saving by bulky loading. Another important area is the mode of transportation and energy consumption as it is of primary consideration to match the volume with an appropriate carrier. Surcharge is an unexpected expense and the company has to ensure its collaboration. The company must study all the aspects before underlining the three strategies to improve

and drive down transportation cost which are process, people, and collaboration. For process, the operating strategy such as maximum space utilization, exact transport items to increase vehicle fill and useful material handling must be considered for transport optimization. For personnel, the right number of staff and emphasis on human development due to increasing staff duties means increasing efficiency in operation. Finally collaboration is becoming a primary strategy because it can be a value creator in terms of communication and operation with trust. As a result the company can realize these valuable transportation operations: on time delivery, quality assurance, low rate of accident, transportation cost elimination.

3.4 Implementation and Evaluation

The company considers testing the selected solution with historical data using the year 2015. Furthermore it will implement on current delivery with a maximized truck load. To calculate the result, they can use Excel spreadsheet to compare the volume and weight to improve on opportunity loss area while contributing a maximized profit to the company. The testing of the new solution with experiment for maximized truck load is defined as "Experimental".

The consideration is to implement the pilot study in May 2016 as trial period and simulate cost saving from June to December 2016. The experiment is based on feasibility study and research methodology.

To achieve the experiment, it is important to construct steps for the process and do calculation in Excel spreadsheet.

3.4.1 Prepare product and pallet dimension

3.4.2 Identify truck size and container dimension for loading

3.4.3 Prepare historical data of transportation cost before starting the testing

3.4.4 Define tower rack dimension and capacity to maximize stackability

3.4.5 Illustrate loading the products into the container by reaching the highest volume and weight constraint of truck loading

3.4.6 Arrange the product into the container based on staff experience

3.4.7 Explain the improvement by analyzing the volume and cost in battery transportation

To eliminate transportation cost in implementation, the company compares the improvement result with the original data. Then the company can analyze and evaluate the results before and after applying the selected methodology which will be shown later in Chapter 4.

3.5 Improvement Indicators

In order to evaluate the validity after implementing the selected solution, the company must have studied the key improvement indicators (Morabito & Morals, 1998) to analyze the results as follow.

3.5.1 Volume Utilization

The efficiency of the container loading can be measured by increasing the number of batteries and pallets stackable after adding a tower rack.

3.5.2 Truck Load Capacity

To determine the truck capacity, match it with the loaded volume. Concern must be placed in stackability, careful material handling, and truck type.

3.5.3 Transportation Cost

Using the company's financial database, especially PPP transportation cost, will directly affect truck utilization. Thereby the application of the solution is to achieve cost benefit which is measured in terms of clear transport cost reduction. As a result, measuring the loading efficiency as well as increasing the load volume will definitely decrease the cost per unit delivered.

3.6 Chapter Summary

This chapter provides a methodology to be implemented in the research. It also presents GRASP methodology to explain the process for improvement and analyzing data. The main problem is concentrated in battery transportation found in utilizing space, truck loading capacity, and resulting in high transportation cost. Then the researcher verifies the problem by using data from interview, historical data on transportation cost, and observing the loading operation as part of the analysis. The cause of the problem usually comes from poor loading practices related to packaging design. Also, affecting the truck loading capacity is often the fact that it is less than its capacity. Regarding the staff, the company should require their initiative and management skill. Their experience is one factor in improving the operation. Moreover, attention from concerned departments and collaboration for improvement are important in achieving cost saving. In solving the above problems, the researcher proposes providing the company with methodology, monitoring, and controlling in order to achieve the desired solution. The overall details of this research will be explored in the next chapter.

CHAPTER IV

PRESENTATION AND CRITICAL DISCUSSION OF RESULTS

This chapter presents the implementation of GRASP methodology. It is separated into two phases, constructive and improvement phases. Moreover, the results from implementation are also explained following the key indicators. The consequences can be used as efficient and effective contribution to Vehicle Manufacturer.

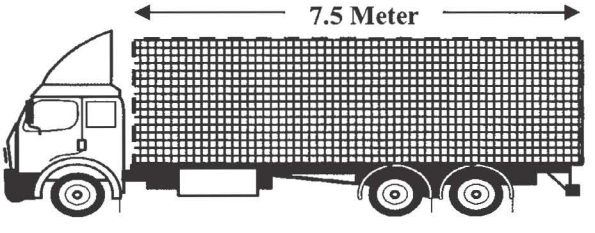
4.1 Data Implementation

According to the data collected from Vehicle Manufacturer, the company focuses on battery transportation (Chapter 3). The data is applied as a solution for three problems. First is to optimize the batteries transported in the container to utilize space. Second is to optimize the batteries transported by maximizing truck load capacity. Third is to minimize the transportation cost of batteries. The collected data is shown below.

4.1.1 Container and Truck Information

The information of container and truck was received from interviews made from the Vehicle Manufacturer's logistics department and the transport company. This information will be useful in understanding the current truck type and container in battery transportation.

Figure 4.1: Containers and Truck Picture



Source: Vehicle Manufacturer

Figure 4.1 shows a picture of container and truck for the current battery transportation. Normally, the container for truck transportation is designed to individually fit with truck dimension because it is permanently installed on the truck chassis. In case Vehicle Manufacturer uses container size 7.5 meters, it meets the standard of the Inland Transportation Department. They have to follow safety regulation and environmental concern. The truck in battery transportation used is six wheels truck for delivering batteries from the supplier factory to the transport company warehouse.

Table 4.1: Container and Truck Dimension

Container Description	Container Basis			Truck Basis
	Depth (MM)	Width (MM)	Height (MM)	Weight (KG)
6 Wheels Truck Container	7,500	2,300	2,400	6,200
10 Wheels Truck Container	7,500	2,300	2,400	15,000

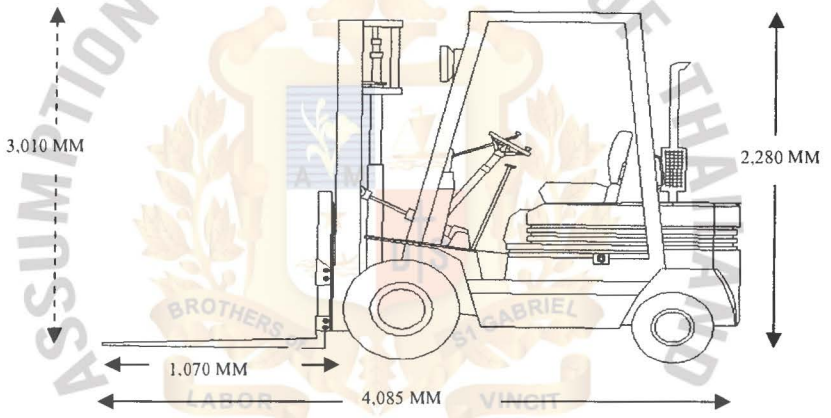
Source: Vehicle Manufacturer

Table 4.1 shows the actual dimension of the container and the truck in battery transportation. The data is provided by the transport company which is the truck owner. In the table, it describes two types of container and truck. The container is described by dimension in depth, width, and height. The container dimension is common between six and ten wheels truck with depth of 7,500 millimeters, width of 2,300 millimeters, and height of 2,400 millimeters. The reason why the containers have the same dimension is because they have the same length of chassis, both for six or ten wheels truck. The difference is the added wheels which increase weight support, from six to ten wheels. Trucking is concentrated on maximum truck load capacity. The Inland Transportation Department approved 6,200 kilograms weight load for six wheels truck and 15,000 kilograms weight load for ten wheels truck.

4.1.2 Loading Carrier Information

In loading operation, loading carrier is an important equipment to support the staff and to save loading time. Due to the weight of the batteries and the pallets, it is difficult to move and load them using manpower. If it is possible to load them, loading time will be long and expensive. So loading carrier is useful in improving the transportation of batteries.

Figure 4.2: Loading Carrier Picture



Source: Vehicle Manufacturer

Figure 4.2 shows a picture of a loading carrier from Vehicle Manufacturer. It is widely used in truck loading. To understand loading carrier, also called "forklift", this research provides definition and function. "Fork" means an activity to carry or take up a thing while "lift" is a vertical movement, up and down. Functionally, "forklift" is classified as a material handling equipment which is used in many industries. The advantages are to enhance human capacity, add up speed and flexibility, controllable quality, eliminate damage, and safe loading. All these aspects are significant in the operating cost of Vehicle Manufacturer.

Table 4.2: Loading Carrier Dimension

Description	Forklift Vehicle Dimension				Fork and Lift Dimension	
	Total Length (MM)	Total Width (MM)	Total Height (MM)	Maximum Loading Weight (KG)	Maximum Fork Length (MM)	Maximum Lift Length (MM)
Engine Forklift	4,085	1,360	2,280	4,000	1,070	3,010

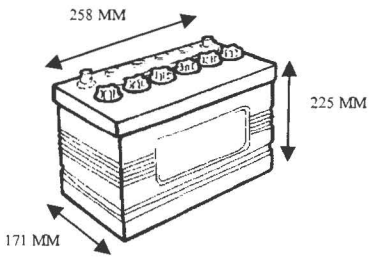
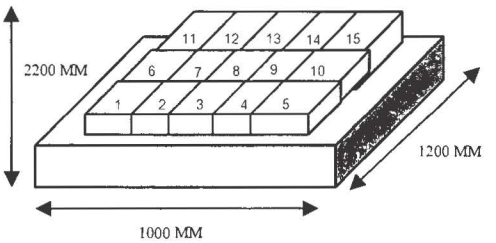
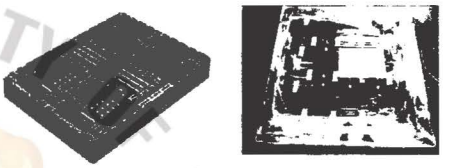
Source: Vehicle Manufacturer

Table 4.2 shows the loading carrier dimension that was observed from the current truck loading in Vehicle Manufacturer. Loading carrier or forklift truck has two types, battery forklift truck and engine forklift truck. The difference is power supply to the forklift's engine. Battery forklift truck uses power supply from charged battery, whereas engine forklift truck uses power supply from diesel oil. Vehicle Manufacturer uses engine forklift truck because of its higher performance and convenience for maintenance. The dimension of engine forklift truck is described by forklift vehicle dimension, fork, and lift dimension. The information shows fork has a maximum length of 2,280 millimeters to pick and move the batteries while lift can be straight upward 3,010 millimeters to support loading into the containers. The overall forklift vehicle has a total length of 4,085 millimeters, total width of 1,360 millimeters, and a total height of 2,280 millimeters. The maximum loading weight is 4,000 kilograms and this forklift specification has the highest capacity and performance.

4.1.3 Product and Pallet Information

This research is to provide optimization on battery transportation. Therefore, both the batteries and pallets are important in analyzing and implementing the solution. The collected data will be described in dimension and actual usage of battery and pallet as a part of the implementation.

Figure 4.4: Product and Pallet Pictures

Type	Product Basis	Pallet Basis
Virtual		
Actual		

Source: Vehicle Manufacturer

Figure 4.4 shows pictures of the battery product and pallet in this research. The product is battery for export vehicle in its finished goods form from the supplier factory. Its function is a major power supply for vehicle electric component. It is a needed part to be installed in every vehicle unit. The pallet's material is made of plastic because of its durability and concern for reuse. Regarding safety concern, plastic is a nonflammable substance so it will not be a risk in production line and transportation. In the picture it shows the battery's physical character and battery packed on pallet from the supplier factory. The number of batteries per pallet is 15 units maximum as used by Vehicle Manufacturer. The pallet dimension is also designed to fit in transportation as well as delivery into the production line.

Table 4.3: Product and Pallet Dimension

Description	Depth (MM)	Width (MM)	Height (MM)	Weight (KG)
Battery	258	171	225	20
Pallet with Battery	1,000	1,200	2,200	305

Source: Vehicle Manufacturer

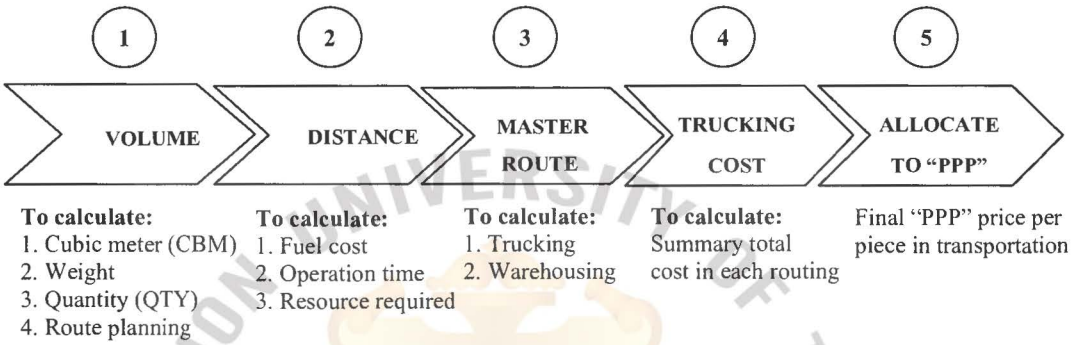
Table 4.3 shows the dimensions of the battery and pallet. The table explains the dimension of battery only and pallet with battery. The battery's depth is 258 millimeters, width is 171 millimeters, height is 225 millimeters, and weight is 20 kilograms. Actually, Vehicle Manufacturer uses the highest battery specification installed in export vehicle due to the vehicle's electricity consumption. The pallet's dimension is significant as it affects efficiency in transport, e.g. space allocation and quality protection. The table also shows pallet with battery because it is packed from the supplier factory. Each battery in the pallet is wrapped in plastic to protect the batteries in the loading process and during transportation. Totally the pallet with 15 batteries has a depth of 1,000 millimeters, width of 1,200 millimeters, height of 2,200 millimeters, and weight of 305 kilograms. These table dimensions were collected by visiting the supplier factory and the transport company warehouse.

4.1.4 Price Structure Information

The transportation cost of Vehicle Manufacturer is calculated in two different ways. The first is calculating transportation cost by a number of trips and this method is a big concern on the part of Vehicle Manufacturer. It emphasizes on number of delivery trips in agreement along with contingency negotiation, in case of less trips or extra trips due to fluctuation in production volume. The second is calculating transportation cost by a number of pieces and this method is applied for small part of direct delivery to Vehicle Manufacturer. To get the actual product cost by piece does not have much influence in production volume. Battery transportation cost is

calculated by the second structure because battery is classified as small part and uses just in time (JIT) delivery system. The technical term of this calculation is called price per piece (PPP) which is shown below.

Figure 4.5: Price Structure by Price Per Piece (PPP)



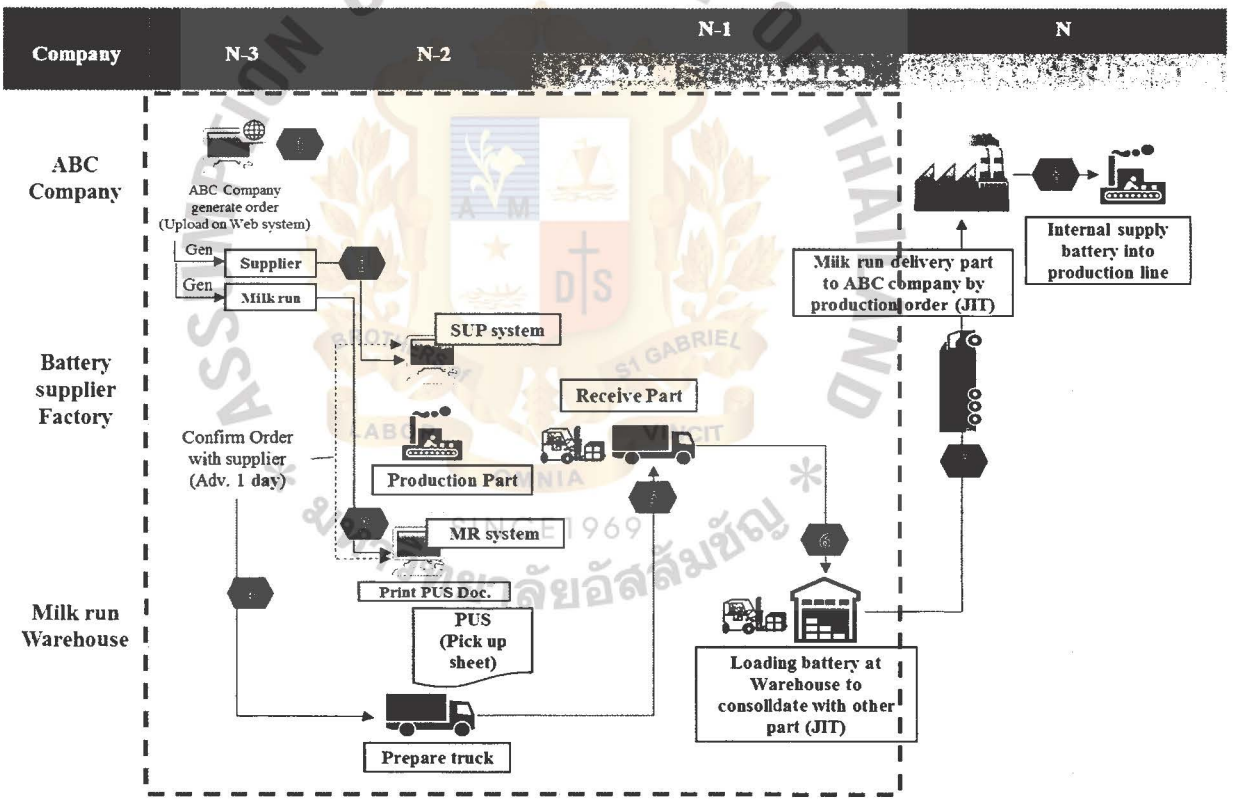
Source: Vehicle Manufacturer

Figure 4.5 shows the price structure to calculate battery transportation cost. To explain price per piece, it refers to the cost of battery per unit in each transport trip. This pricing method is applied following the trend of production volume which is appropriate in calculating the actual transported units rather than by container. There are four factors to this which are volume, distance, master route, and trucking cost. Starting from volume it is calculated by cubic meter "CBM" measured on space utilization in container. Weight is also an important criterion as it impacts transport limitation. The second is distance which involves fuel cost and manpower with emphasis on fuel cost as unpredictable factor. In fact fuel cost fluctuates so it usually creates additional expenses in transportation cost. Manpower is calculated by staff's operation time and the number of staff in the process. The third is master route which is a cost from the trucking and warehousing services by the transport company. It is a part of the price structure. The fourth is concentrated on trucking cost which is truck usage, waiting time, and maintenance cost. Thus, price per piece formulation is logical from the part of the transport company.

4.1.5 Battery Transport Operation

Battery transportation involves three departments in transporting activities. According to standard operation, operation flow is necessary for working instruction to specify on communication, operation time, related documents, and relationship of each function. Vehicle Manufacturer has created a battery transportation flow to create understanding among cooperators and to monitor time in providing value added operation.

Figure 4.6: Battery Transportation Flow



Source: Vehicle Manufacturer

Figure 4.6 shows a particular overview of battery transportation for the export vehicle. The operation process starts from the supplier factory until it is delivered to the production line. The issuing order of Vehicle Manufacturer is automatically generated four days in advance following the company ordering system. Then the

supplier and the transport company will have their preparation lead time from this information. The details of the processes and responsibilities are explained by eight steps below.

Step 1: Vehicle Manufacturer is responsible in setting an initial issue of order (AS400 system) and uploads it into its website. The supplier and the transport company who have access system to Vehicle Manufacturer extract the order by themselves.

Step 2: The supplier, after receiving the order, will plan its production to meet with the customer demand and be able to deliver on time because most of the materials are for just in time (JIT) production.

Step 3: The transportation company, after receiving the order, will have to prepare the truck capacity that matches with the order in due time. They will prepare and print a pick up sheet "PUS" document. This PUS document provides order number, due time, party name, quantity, supplier name, destination point, etc. The transportation company system provides tracking for goods delivered each trip.

Step 4: The transportation company will reconfirm with the supplier one day in advance before picking up the batteries from the supplier factory.

Step 5: The transportation company's truck will go to pick up the batteries at the supplier's factory by using six wheels truck with approximately four trips per day.

Step 6: After loading the batteries the transportation company will go back to its warehouse and consolidate all the required parts in due time.

Step 7: The transportation company consolidates all the parts to be delivered to Vehicle Manufacturer in due time using JIT delivery system. As agreed, the transportation company's truck will arrive at the Vehicle Manufacturer one hour in advance to prevent production shortage.

Step 8: The internal process of Vehicle Manufacturer is supplying batteries into production line, separate between domestic production line and export vehicle line.

The above steps show that the scope of this study is concentrated on transportation, from Step 1 to Step 6. These parts will be used in trying to improve the delivery system in terms of cost.

4.2 Data Analysis

Vehicle Manufacturer considers implementing GRASP concept to provide optimization for battery transportation. GRASP methodology consists of two phases to implement which are constructive phase and improvement phase as mentioned in Chapter 3. The constructive phase solution is by stacking pallet with additional tool along with data implementation from 4.1. Thus, improvement phase is consistent with constructive phase to add more technical detail. Hence, allocation of constructive phase applied in part 1 is to optimize batteries transported by balancing with truck load capacity. It is considered an improvement phase by selecting the right truck type and match it with loading capacity after implementing the constructive phase. The overall consequences will be shown by transportation cost in May 2016 as experimental period.

4.2.1 To Study How the Company can Utilize Container Space Utilization and Maximize on Truck Load Capacity

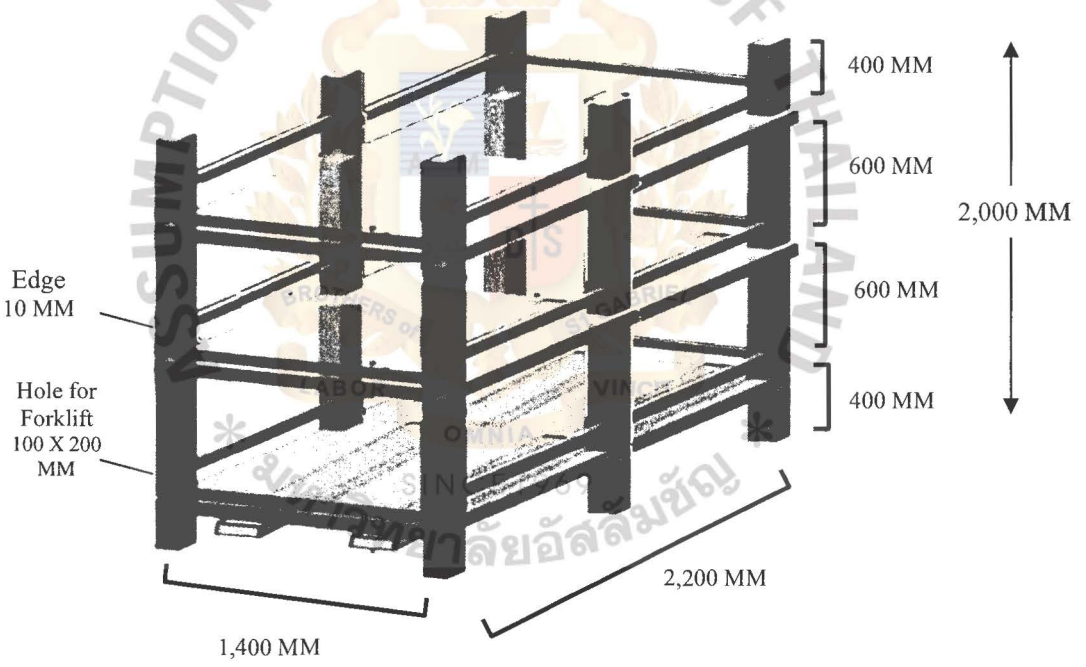
Vehicle Manufacturer's data is concentrated on battery transportation for export vehicle. To implement the methodology in this research the researcher has selected May 2016 as experimental period. The calculation was based on Excel spreadsheet to optimize transport utilization for Vehicle Manufacturer. GRASP phase 1 is explained below.

Phase 1: Constructive phase. This phase is done by building iterative process that is separated in two steps. The first step is building an additional tool called "tower rack"

to enhance the battery pallet stackability. The second step is to allocate the tower rack and battery into the truck container.

Step 1: The initiative is finding additional tool to stack the batteries in the container to become efficient in each transport trip. It is called "Tower rack" and it is designed to fit with the batteries and truck dimension. Moreover, the constraints must be considered and these constraints include stability, orientation, stackability, and weight during transportation.

Figure 4.7: Battery Tower Rack Picture



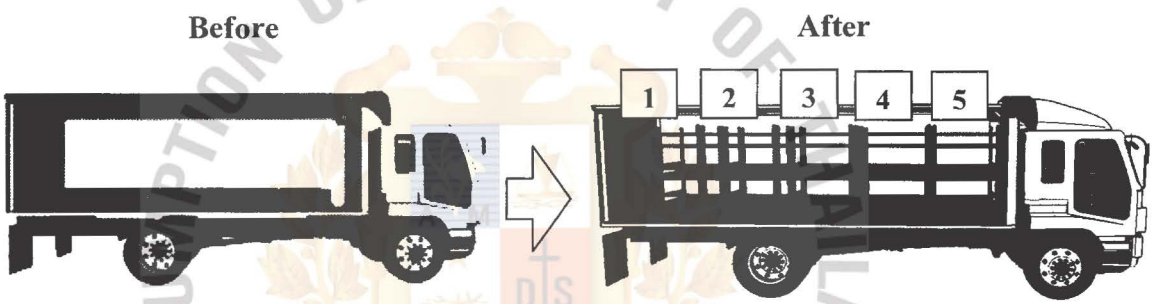
Source: Vehicle Manufacturer

Figure 4.7 shows a tower rack picture. Tower rack is an additional tool to enhance the loading capacity for battery transportation. The tower rack is designed for stacking batteries up to three levels. The height dimension of the tower rack base is 400 millimeters, gap level one is 600 millimeters, gap level two is 600 millimeters, and gap level three is 400 millimeters. The length is 2,200 millimeters and the width is 1,400 millimeters. Moreover, it has an additional edge protection of 10 millimeters in

each level and the hole for the forklift is 100 x 200 millimeters. The total height of the tower rack is 2,000 millimeters with a weight of 1,900 kilograms. The material used in the tower rack is metal for durability reason and to protect the batteries during transportation. This added tower rack in transportation is beneficial for Vehicle Manufacturer. Its normal battery packaging consists of only one level and the tower rack allows it to have three levels. The packaging was mutually developed by the local company in Thailand and the head company in Japan because the Japanese company has a team of specialists in their research and development. The two companies met together to check the trial packaging in Thailand. They inspected the packaging material, considered possible accidents and constraints in loading process. Since product quality is important for both companies, packaging is a priority that must be improved and solved to avoid scraping and distorting the battery products. After the development, the final prototype will receive approval and the local company can begin using the new tower rack in the loading process.

Step 2: This is using the developed battery tower rack and loading the batteries into the truck container. This process is to try the designed tower rack on calculated space and observe the maximum number of batteries that can be loaded per trip. It is a technical loading so the process requires calculation in every dimension such as maximum forklift capacity and match with the container roof. The gaps between battery pallets and tower rack are eliminated in order to limit the battery pallet's movement during transportation.

Figure 4.8: Loading Tower Rack into Truck Container



Source: Vehicle Manufacturer

Figure 4.8 shows a trial process of loading battery into the tower rack and into the truck container. The process of loading the tower rack requires the use of the forklift truck. The maximum number of tower racks in the truck is five units. Furthermore, the concept of utilizing the tower rack requires it to be permanently placed in the truck. Then, the loading staff will only load the batteries in and out of the tower rack. This method saves time from loading the whole tower rack. However this method only allows the truck to be used for loading batteries.

Figure 4.9: Loading Battery Pallets into Tower Rack

Source: Vehicle Manufacturer

Figure 4.9 shows a trial process of loading battery pallets into the tower rack in the truck. In the process the forklift is used to move the batteries from the cross dock into the container truck. The forklift loads two battery pallets each time in order to save time. This process allows an increased loading capacity from the current 13 pallets to

30 pallets per trip. This process enables a savings in transportation cost for Vehicle Manufacturer.

After the trial loading, there was no problem in the process and it did not create and damage anything while stacking the batteries. As for the loading staff, it is important to provide them a new working instruction in implementing the stacking concept. Basically they have to take and pass forklift driving training for specific technical operation. They must know that each level of the tower rack has different gaps and designed to fit with battery pallets. This operation requires working experience for the lifting part and any problem during actual operation must be solved. However, the loading process requires an officer from the quality control department to monitor the loading operation as well as specify the action for damage in terms of cost and the responsible department.

In the implementation of the tower rack and enhancing the truck space utilization, the trial operation showed that Vehicle Manufacturer faced with weight limit by adding the tower rack into the truck. The particular tower rack is made of metal so its weight is also reducing the weight capacity of the truck. This leads to a continuation in phase two. Most importantly this improvement solution requires the company to match the tower rack with the truck.

Figure 4.10: Trucks in Battery Transportation

Period	Battery Pick Up Time		Truck Type	Number of Trips
	07.30 – 12.00 AM	13.00-16.30 PM		
Before			6 Wheels	4 Trips per Day
After			10 Wheels	2 Trips per Day

Source: Vehicle Manufacturer

Figure 4.10 shows the truck usage in battery transportation of Vehicle Manufacturer. Currently, battery pick up time is two times daily which are 7:30-12:00 AM and 13:00-16:30 PM. The transport company is responsible in picking the batteries from the supplier factory following their due dates and time. The number of truck in transport is two trucks because the battery is loaded only at one level of the truck with no stack. This is obviously an opportunity loss from the container's empty space. Then the number of daily trips is usually four round trips from the battery supplier to the transport company's warehouse. As a result, it is causing problem as it cannot pick up all the batteries ordered with only one truck. The solution is to change the truck from six wheels to ten wheels. The main purpose of the improvement can be explained in three areas. First is to balance the weight after adding the tower rack into the container truck. Second is the weight increase due to the increase in number of battery pallets in the truck. Third is the reduction of number of truck from two trucks to one truck as well as the number of trips, reduced from four trips to two trips.

4.2.2 To Examine How the Company can Reduce Battery Transportation Cost

In designing the new tower rack, more loading capacity was made available. This new loading capacity provides a great impact on the battery transportation cost of the transport company. Vehicle Manufacturer can take advantage from this cost reduction. The calculation of the cost of battery using price per piece (PPP) allows Vehicle Manufacturer to negotiate for a new transportation price. The major factors influencing the price are cubic meter, weight, quantity, fuel cost, and others. The result from the negotiation between Vehicle Manufacturer and the transport company showed that the price per piece can be reduced from 24.6967 baht to 21.2214 baht. The difference is 3.4653 baht. The transport cost reduction also gives impact to the transport company. It has additional loading time by the increased battery pallets per truck, the trucking cost from changing truck type, and others.

4.3 Data Evaluation

This section presents a result after implementing the research methodology with traditional operation. It is mainly calculated by Excel spreadsheet. The key evaluation of the experimental validity is volume utilization, truck loading capacity, and transportation.

4.3.1 Volume Utilization

The experiment in Figure 4.10 illustrates a trial process of loading the battery pallets into the tower rack on the truck. In the loading process the manual loading of each pallet was done by the loading staff with experience in using forklift. Stacking battery pallets is explained below.

Table 4.4: Volume Utilization in Battery Transportation

Period	Condition	Number of Battery Per Trip			% Volume Utilization Per Trip
		Battery Pallets	Tower Racks	Battery Pieces	
Before	Loading 1 Level (Floor only)	13	0	195	↑ 130%
After	Loading 3 Levels (Add Tower rack)	30	5	450	

Source: Vehicle Manufacturer

Table 4.4 shows the comparison of loading the batteries into the truck by using the current method and the new method with tower rack. By the traditional battery loading, 13 pallets or 195 units of batteries were loaded into the truck. It only used one level and it has a lot of empty spaces in each transport trip. By the new method, 30 pallets or 450 units of batteries were loaded into the truck. This method allowed the use of three levels and five tower racks. This resulted in an increased of batteries loaded in each transport trip by 130%.

4.3.2 Truck Load Capacity

The truck load capacity is related to the increased space utilization by adding battery pallet and tower rack into the truck. This improvement is to balance the actual loaded weight on the container truck with the actual truck capacity. This is in line with the regulation from the Inland Transportation Department, to follow on weight limitation. Moreover the investment of tower rack is added in this process to develop simultaneously. Particularly, Vehicle Manufacturer is concerned on the cost trade-off from changing truck type to match with their production volume.

Table 4.5: Balancing on Truck Load Capacity

Cost of Truck			Cost Saving (Baht)
Detail	**Current**	**New**	↑ 639,110
Truck Type	6 Wheels	10 Wheels	
Number of Truck Usage	2	1	
Number of Round Trip (Trip)	4	2	
Total Trucking Cost	1,789,230	1,150,120	
Truck Load Capacity			**Truck Capacity (%)**
Detail	**Current**	**New**	↑ 42%
Actual Truck Capacity (Kg.)	6,200	15,000	
Actual Tower Rack Weight (Kg.)	-	1,900	
Actual Truck Load with Battery (Kg.)	4,250	12,500	
Total Truck Load by Weight (Kg.)	4,250	14,400	
Total Truck Load by Percentage (%)	68%	96%	

Source: Vehicle Manufacturer

Table 4.5 shows the different truck load capacity after changing from six wheels to ten wheels. It is explained by the two data which are trucking cost and trucking capacity. First is trucking cost. It describes a reduction in the number of truck usage and the number of round trips before and after changing the truck. The result shows that changing from six wheels to ten wheels truck, Vehicle Manufacturer can achieve a cost saving of 639,000 baht per month. Second is trucking capacity. It shows the detail on each truck weight limit and the weight balance after placing the tower rack in the transportation. The result shows Vehicle Manufacturer can fully utilize the ten wheels truck capacity by 96%. Therefore, Vehicle Manufacturer can gain benefit from this additional capacity by 42%. The number of batteries transported can be definitely increased following the new truck size.

Table 4.6: Battery Tower Rack Investment

Detail	Tower Rack Investment in 2016
Tower Rack Cost per Unit (Baht)	35,000
Total Number of Tower Racks (Unit)	5
Total Tower Rack Investment (Baht)	175,000
Total Cost Saving from Transportation (From Table 4.5)	639,110
Total Cost Saving (Baht)	**464,110**

Source: Vehicle Manufacturer

Table 4.6 shows the investment data of battery tower rack by its deposit payment in 2016 (May to December). Tower rack is only a one time investment. The tower rack cost is 35,000 baht per unit and the requirement per truck is five units. The budget allocation is a cost saving from changing truck type (Table 4.5). The initial cost saving contribution is 639,110 baht. After the deduction from the tower rack investment of 175,000 baht, Vehicle Manufacturer will achieve a profit of 464,110 baht in 2016.

4.3.3 Transportation Cost

This research is to implement a research methodology with actual battery transportation of Vehicle Manufacturer in May 2016. Implementing the new battery tower rack is a response to enhance the battery volume loaded. This solution requires Vehicle Manufacturer to change its truck from six wheels to ten wheels. All these implementations are favorable in regards to transportation cost. The increase in battery volume transported can significantly reduce the transportation cost per piece.

Table 4.7: Reduction in Battery Transportation Cost

Month	Battery Transport Cost Reduction in 2016					Estimated Cost Reduction per Month (Baht)
	Estimated Battery Volume in 2016 (Pieces)	Price per Piece Before (Baht)	Transportation Cost before Implementation (Baht)	Price per Piece After (Baht)	Transportation Cost after Implementation (Baht)	
May	21,090	24.6967	520,853.40	21.2214	447,559.33	73,294.08
June	18,540	24.6967	457,876.82	21.2214	393,444.76	64,432.06
July	16,910	24.6967	417,621.20	21.2214	358,853.87	58,767.32
August	17,010	24.6967	420,090.87	21.2214	360,976.01	59,114.85
September	12,931	24.6967	319,353.03	21.2214	274,413.92	44,939.10
October	13,718	24.6967	338,789.33	21.2214	291,115.17	47,674.17
November	17,085	24.6967	421,943.12	21.2214	362,567.62	59,375.50
December	12,947	24.6967	319,748.17	21.2214	274,753.47	44,994.71
Total	**130,231**		**3,216,275.94**		**2,763,684.14**	**452,591.79**

Source: Vehicle Manufacturer

Table 4.7 shows the cost reduction in battery transportation before and after implementing the battery tower rack along with changing the truck from six wheels to ten wheels. The result is a concentrated reduction on price per piece (PPP). The period of implementation is May 2016 by a trial in loading the new battery tower rack and changing truck size. The volume in calculation is actually transported in May 2016. Then the researcher used the battery orders plan in June until December to estimate yearly cost saving. After implementation, the result shows that Vehicle Manufacturer can reduce its price per piece cost by 14.10%. It shows that the total battery transportation cost before implementation is 3,216,275.94 baht and the total battery transportation cost is reduced to 2,763,684.14 baht. Vehicle Manufacturer can achieve an estimated cost reduction of 452,591.79 baht from May until December 2016. Therefore the solution provides cost benefit and volume utilization.

4.4 Chapter Summary

This chapter demonstrates an experiment of GRASP, a research methodology. The implementation is designed by two main phases which are constructive phase and improvement phase. Constructive phase is to build or find new solution for the company problem. The solution provided is a battery tower rack designed to increase space utilization in battery loading. The improvement phase is concentrated in improving the current truck capacity by changing the truck from six wheels to ten wheels. The purpose is to increase the loading capacity to balance it with the weight limitation. The implementation affected the battery loading operation and provided the loading staff with new knowledge and experience. Vehicle Manufacturer can achieve cost benefit measured by reduction in price per piece. It contributes competitiveness for Vehicle Manufacturer by eliminating opportunity loss. Most importantly it provides initiative for continuous improvement and value added for the company.

CHAPTER V

SUMMARY FINDINGS, CONCLUSION AND RECOMMENDATIONS

In this chapter, the researcher aims to provide the summary of findings, followed by conclusions of research result, theoretical implications, and managerial implications. Moreover the researcher also aims to further discuss the research limitations and significant recommendations.

5.1 Summary of the Findings

The research question defined from the first chapter "How can Vehicle Manufacturer optimize battery transportation?" is explained in the findings that this research question is significant. Vehicle Manufacturer is a major automotive company who sources vehicle components from local suppliers. The major product is a commercial vehicle for domestic and export customers. This research purpose is to find out the inefficient areas and provide an improvement solution. The problem, focused in transporting batteries for export vehicle, is obviously losing at present. Because the battery for export vehicle is solely purchased from FB supplier, it creates risk in terms of substitutes for unexpected situation and transport cost balancing. The finding shows Vehicle Manufacturer reviewed two outstanding problem areas in battery transportation. The first problem is in container space utilization where the number of batteries transported is low. The batteries are loaded in only one level on the container floor and delivered only 13 pallets or 195 units per trip. The second problem is the truck loading capacity related to the inefficient space utilization where the truck capacity is not fully utilized. The truck capacity's usage is only 68% per trip, resulting in a high number of transportation trips. These problems are directly impacting the transportation cost that Vehicle Manufacturer has to bear.

After identifying the outstanding areas for improvement, the researcher searched for an appropriate methodology for a solution. Battery transportation is a technical

operation in the industry so the researcher studied similar researches and literature for a possible parallel implementation. The methodology found is based on Greedy Randomized Adaptive Search Procedure (GRASP) to optimize the battery transportation of Vehicle Manufacturer. The key benefits in conducting this research are below.

The first objective is to study how the company can utilize container space utilization and maximize on its truck load capacity. After implementing the battery tower rack on the truck to support an increased load weight, the outcome is positive. This is shown by the 130% increase number of batteries loaded and the truck capacity increase of 42%.

The second objective is to examine how the company can reduce its battery transportation cost. The solution provided is the full utilization of the container space and the truck capacity. This is shown by the efficient 14.10% cost reduction of battery price per piece.

5.2 Conclusion

In this business, competitive advantage is significant to create cost benefits for the company. The initiative on continuous improvement is empowered internally to solve future problems. This research is aimed at providing solution in order to optimize the battery transportation area of the company. The researcher analyzed the problems based on interview, observation, and historical data. The research data and related information required the application of GRASP in the experiment. In the research, GRASP provided direction in the experiment. The implemented solution is building a new battery tower rack because the traditional loading cannot stack on battery pallet which provides a lot of dead space. Also considered is a change of truck size to contribute in cost saving. These implementations allowed the researcher to understand the advantages of space utilization after reviewing the case. Furthermore, the researcher had a chance to improve on her analytical skills, initiating

implementation, evaluating possible solutions, and analyzing cost before making her final decision.

5.3 Theoretical Implications

This case study used Greedy Randomized Adaptive Search Procedure, also called as GRASP. In utilizing GRASP, the methodology is separated by two practical phases, constructive phase and improvement phase. Constructive phase is establishing tools to enhance the volume of the existing operation in practice. The improvement phase is improving or changing the current operation in practice to be more effective. The purpose of applying GRASP is to find the highest volume or allocate the best fit in the space (Tamarit & Olivia, 2008). This method is used in allocating space in vessel containers and in similar areas of truck containers. The result is a positive improvement with the enhancement of volume utilized into the truck container, aside from the obvious cost benefit for Vehicle Manufacturer.

5.4 Managerial Implications

This research can be provided as a guideline for Vehicle Manufacturer to implement GRASP methodology in battery transportation. According to the implementation, Vehicle Manufacturer can gain in three major areas which are process, personnel, and cost. Process can create value added in loading batteries into the container truck by fully utilizing the container space and truck capacity. Personnel can gain opportunities to learn new experiences in loading process and forklift driving skill. Cost is the ultimate purpose to be achieved. Following the improvement of the battery transportation, the problem was overcome and the cost was reduced. In summary, Vehicle Manufacturer can improve its operation and at the same time create more profit.

5.5 Limitations and Recommendations for Future Research

5.5.1 Limitations

This research is conducted to improve the battery transportation for export commercial vehicle. The methodology provided is called GRASP with the concept of stacking products in the container by fully using the space available. The concept framework may not be suitable for other business problems due to the differences in environment and time frames.

i. Battery Sample Size

The implementation is the trial period. Therefore, the number of batteries is based on the sample size by three battery pallets loaded into one tower rack only. The researcher did not see a fully loaded tower rack and battery pallets in the container truck.

ii. Battery Loading Time

The loading staff has to take longer lead time in the loading process, both at the supplier factory and Vehicle Manufacturer due to the increased loading capacity. In the picking process, the staff can pick the finished battery products by two pallets per round. Then a number of picking rounds are added up and the stacking of batteries in each tower rack level takes time.

5.5.2 Recommendations for Future Research

This research focus is to improve on maximizing space utilization in a container truck. It started by investigating the losing area of Vehicle Manufacturer. The battery transportation is the first priority that needs analysis. The battery transportation observed is not a common practice in the industry because the product characteristics are different from each manufacturer. The researcher considered implementing GRASP methodology after reviewing many academic literatures. The methodology is commonly applied in vessel container problems but after the experiment, it showed that GRASP can be applicable in similar area and it provided positive results for

Vehicle Manufacturer, explained by the volume and cost achievement. It is an opportunity for other research to apply GRASP in related problem areas, especially space utilization and value added. However, there are some areas that are not covered in this research which are operating time and manpower. So it is significant to have continuous improvement for future research.

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