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Optimization of Transportation System by Tailored Logistics Network: A Case Study in Automotive Industry

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ABSTRACT

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This thesis aims to redesign the supply chain system in an automotive industry in order to obtain space reduction in the inventory by using tailored logistics network. The redesigning process by tailored supply chain will combine all possible shipment methods including direct shipment, milk-run, milk-run via distribution center and Kanban delivery. The current supply chain system in Nissan goes rather well when the production volume is in moderate level. However, when the production volume is high, there is a capacity problem in the warehouse to accommodate all delivered parts from suppliers. Hence, the optimization of supply chain system is needed in order to obtain efficient logistics process and effective inventory consumption.

The study will use primary data for both qualitative and quantitative approach as the research methods. Qualitative data will be collected by conducting interviews with people related to procurement and inventory control. Quantitative data consists of list of suppliers with their condition in several parameters which will be evaluated and analyzed by using scoring method to assign the most suitable transportation network to each suppliers for improvement of inventory reduction in a cost efficient manner.

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1. INTRODUCTION

1.1. Background

The role of supply chain management has been well known in modern business industries. Furthermore, it is obvious that transportation plays a significant role in the global supply chains. There are many cases where freight transportation contributes up to two-thirds of the total logistics cost in many cases (Ghiani, Laporte & Musmanno, 2004). Hence, transportation network becomes an important issue to be taken into account in managing supply chain system. It is crucial to apply suitable network of transportation to enhance the value of supply chain and achieve an effective and efficient supply distribution.

This thesis will take Nissan Motor Indonesia, a Japanese car manufacturing located in Indonesia, as a case company. The current supply chain in Nissan goes rather well by direct delivery from suppliers to manufacturing plant in any condition except when the production volume is high. At a certain level, when the production volume is high and causes high amount of parts to be delivered from suppliers, Nissan faces a problem of warehousing the delivered parts before they are taken to production line. The capability of current warehouse is not enough to accommodate all of those parts. However, due to unstable level of demand, Nissan does not will to invest for constructing a new warehouse. Hence, it is better to improve the supply chain system to get more efficient supply chain process and to save some area in the inventory.

Designing the structure of supply chain network in automotive industry could be a complex decision-making process as there are plenty of aspects needed to be considered. Given those information, the company has to decide how to allocate all of its resources to fulfill supply chain for production process. This thesis deals with figuring out how company takes collaborative supply chain methods in the way to obtain time and cost efficiency and warehouse space effectiveness.

In the real condition, suppliers are often located in random area and there are various delivery quantities depending on the fluctuation level of demands. Hence, in this situation, a combination of different transportation networks can be applied to have better supply chain system. (Liu, Li & Chan, 2003).

1.2. Research Problems and Objectives

The current condition of inventory in company's case is often overfilled by upcoming parts which are still awaits to be transferred to production line. However, due to inconsistency demands, the company does not intend to make investment in building a new warehouse. Therefore, it is very good to optimize the transportation network of parts delivery method from suppliers to the manufacturing plant in order to fulfill the warehouse capacity even in the condition when the production volume is high.

The main objective of the thesis is to optimize the supply chain operation in delivery activities in order to reduce inventory consumption while the parts are await to be taken into production line. The redesigning process will be conducted by assigning the most appropriate delivery method for each supplier among several options of transportation network: direct delivery, direct milk-run, milk-run with distribution center, and Kanban delivery.

The research questions for this thesis are:

i) What is the most suitable division of different delivery methods to reduce warehouse consumption in a cost-effective manner?

ii) What are the enablers and challenges in applying tailored network concept as the company's supply chain strategy?

1.3. Theoretical Framework

The focus of this thesis is to assign tailored network as the transportation method in the case company. Tailored network is one kind of transportation network which combines all possible delivery methods where in this thesis the methods taken are direct shipment, direct milk-run, milk-run with distribution center, and Kanban delivery. The theoretical framework for this study can be described by the following figure, in which the concept of literature for each type of transportation network will be discussed.

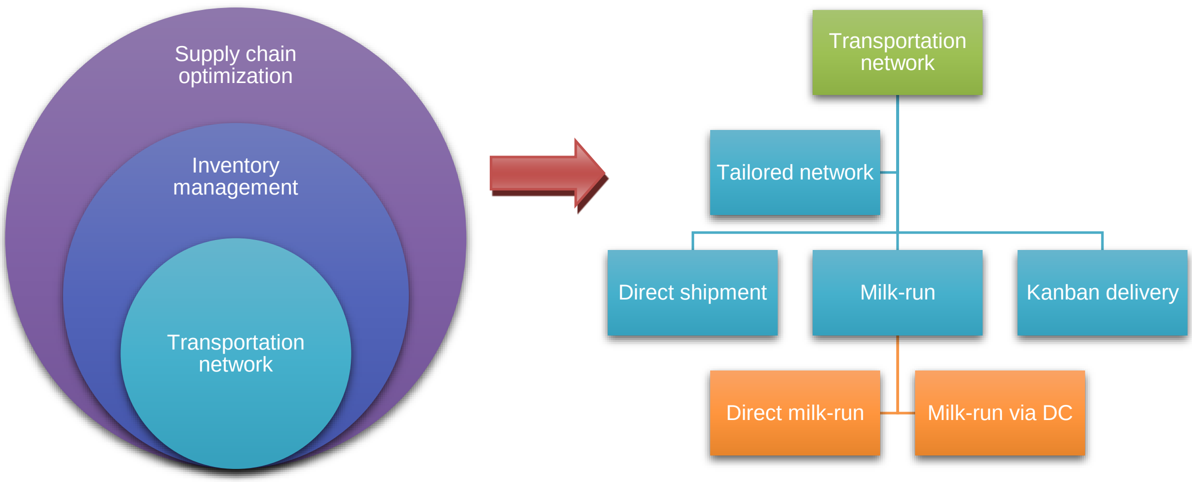

Figure 1. Theoretical framework

The topic of this thesis is related to supply chain optimization with inventory management as the main problem of the case company. One way to solve the warehouse problem of the case company is to optimize the transportation network for its supply chain system. This thesis attempts to apply tailored network as the proposed transportation framework for reducing warehouse consumption in order to help solving the inventory problem. Some of network options that will be used as alternative solution in this study are direct delivery, milk-run network in both direct way and via distribution center, and Kanban delivery.

The literature review in this thesis will consist of two parts based on theoretical framework in figure 1. The first part is about supply chain optimization, which is represented in the left figure, and consist of value chain and supply chain concept, inventory management including ABC analysis as its supporting tool and Just-in-Time as its supporting system, and transportation network for competitive advantage in supply chain. In the second part of literature review, transportation network will be described and discussed, as the right part of the figure. The contents of this section are types of transportation network. The first type is direct shipment. The second network is milk-run system including the explanation about direct milk-run, milk-run via distribution center, and the advantages of milk-run implementation. The third network is Kanban system which includes key success and some benefits of Kanban system application. The next one is cross-docking system which is briefly described since it does not match with the study requirement. Finally, tailored network will be described including its role in supply chain and its risk mitigation strategy. In tailored network review, the system's application will be also explained according to distance and density, size, and demand and value.

1.4. Definition of Key Terms

The key concepts of this research, which is transportation network and its different kinds of type, are defined in the following descriptions.

Supply Chains: An advanced logistics system where raw materials are processed to become finished products and finally distributed to the end users. The process includes vendors, manufacturing plants, warehouses, distribution centers and retail outlets. (Ghiani et al., 2004, p. 8)

Inventory Management: The management of store of goods waiting to be assembled, shipped, or sold. Recently inventory management is considered to be the key issue in supply chains system planning and control. (Ghiani et al., 2004, p. 6)

Transportation Network: A bundle of transportation modes, locations, and routes along where products can be delivered to the destination location. The performance of supply chain in obtaining desired degree of responsiveness at low cost is affected by the design of transportation network. (Chopra & Meindl, 2007, p. 54 & 395).

Tailored Network: The combination of all possible network options in order to obtain cost reduction, inventory consumption effectiveness, and responsiveness improvement in the supply chain operation by utilizing the most suitable option in each situation (Chopra et al., 2007, p. 398).

Direct Shipment: A transportation network where the products are directly shipped from the seller company to the end-user (i.e. from supplier to manufacturing company). In direct shipment, lead times are reduced and there is no need of distribution center facility. (Ghiani et al., 2004, p. 8)

Milk-run: A shipment method where a truck picks up goods from multiple supplier locations and delivers to one buyer location, or distributes products from one supplier to several buyer locations. Milk-run network can be applied directly or by using distribution center. (Chopra et al., 2007, p. 396)

Milk-run with Distribution Center: The application of milk-run system where goods from several suppliers are collected in DC before then distributed to the buyer location (Chopra et al., 2007, p. 398).

Kanban delivery: A transportation system where the delivery is made in a certain short time before the production schedule and the goods must be attached in a full container while no partially filled container is allowed. Hence, the goods do not take much time in the inventory since they are immediately transferred into the production line. (Graves, Rinnooy-Kan & Zipkin, 2003, p. 647-648).

1.5. Delimitations

i) The analysis is conducted only to suppliers that provide transportation cost data for their parts. All suppliers are required to submit breakdown quotation for each part which includes material and process cost, and logistics cost. Logistics cost can be break downed into packaging and transportation cost. However, not all suppliers provide the detail breakdown of logistics cost and therefore only suppliers which have transportation cost are taken as objects for the case study.

ii) Each car model is represented by the most production volume of the variety. For example, Nissan X-trail has three varieties (2.5 and 2.0 automatic transmission and 2.0 manual transmission) and the data will use 2.5 automatic transmission since it has most volume compared to other varieties.

iii) The assignment criteria are classified into general level (i.e. transportation cost as low, medium, high) to support the analysis process.

iv) The cost incurred by the final solution, i.e. distribution center cost, third party logistics cost, etc., will be calculated roughly to be compared with the transportation cost in current condition with direct delivery. Since the main purpose of this study is to optimize delivery in the supply chain to reduce warehouse consumption, not to get cost reduction, the cost calculation is made only to see whether the proposed solution will arise much additional cost.

1.6. Research GAP

According to Liu et al. (2003), the utilization of combined delivery methods has less attention compared to single delivery system. This statement is supported by Mokhtarinejad, Ahmadi, Karimi & Rahmati (2015), who claim that there are limited research and less attention of optimization by using a combination of delivery system. This thesis will try to analyze suppliers' condition of the case company and use different kinds of transportation methods by assigning the most suitable delivery network to each supplier. The proposed tailored network in this case study aims to optimize the supply chain system and to reduce the level of inventory consumption in the case company.

2. SUPPLY CHAIN OPTIMIZATION

2.1. Value Chain and Supply Chain Concept

Supply chain management is mainly representing the way that raw material flow through several conversion process and finally become finished goods for the costumers' use (Robeson & Copacino, 1994). According to Lai & Cheng (2009), supply chain activities include the process of movement from the source of raw material acquisition to the result of finished goods. There are four core elements in the logistics process: customers service, order processing, inventory management and transportation network. Customers' service represents the quality of managing the flow of products and services by utilization of time and place in the seven rights (7R) which is delivering the *right* products to the *right* customers at the *right* time and *right* place in the *right* quantity and *right* condition at the *right* costs. Order processing includes all activities related to the cycle of orders such as gathering, checking, entering and transmitting information about the orders. The collected information could be useful data for market and financial analysis, production planning and supply chain operations. Inventory management relates to manage inventory as effective as possible to support the demands in supply chain. Transportation network is about how to transfer physical items e.g. raw material, semi-assembled products and finished goods, between suppliers, manufacturing plants, distributors, retailers, and end customers in the supply chain. (Lai et al, 2009)

The concept of supply chain is commonly classified into two categories: push system and pull system. In push system, the amount of manufactured product is set based on the number of customers' demand. In other words, the production process is conducted only when there are requested products from customers. This type of system, which is also called make-to-order (MTO) system, does not require any inventories at the manufacturer plant. In pull system, which also refers to make-to-stock (MTS) system, the amount of production units is set based on forecasts and therefore cause inventories both in company's warehouses and at retailers' site. This system is more suitable for either long lead time production and distribution process, low cost products, or high and stable level of demand. Another alternative is to apply a mixed approach between both systems which is known as make-to-assemble (MTA) system. Here push system is used to manufacture components and semi-finished goods while pull system is applied in producing the final products. Inventories are needed to keep the components and semi-finished goods before they are used to assemble the final products. The final assembly stage is conducted immediately after customer's orders are received. (Ghiani et al., 2004)

The value chain principle should provide further thoughts on how supply chain can lead the firms to competitive advantage in terms of cost and service. Originally, there are two classifications of activities in the terms of value chain which are primary and support activities. Primary activities includes those actions that are involved in the production process, marketing and delivery service of the products or services. Support activities are other primary tasks such as purchase inputs, technology, human resources management and other necessary infrastructures to support the primary activities. Out of five primary activities, two are related to logistics activities. The first one is the action of supplying materials, parts or components, and other needed things for the production process which is called inbound logistics. The second one is the activity of managing the flow of finished products from the production line to customers which is called outbound logistics. However, nowadays there are researches that have pointed out that logistics also affect the customers' satisfaction and overall performance of the companies The impact of logistics performance to the firms' ability to satisfy their customers is also linked to customers loyalty and market share. Hence, developing supply chain capabilities is important for companies in order to achieve cost and service advantages. (Lai et al., 2009)

Recently, the value of supply chain management in terms of green logistics are also broadly discussed. According to Vijayuargy & Agarawal (2013), the practices of green supply chain management (GSCM) involves plenty of activities such as reducing and recycling the waste which are discharged by the company as well as the waste that are caused by other companies and taken by the companies with the intention of cost advantage, corporate image, social and environment responsibility assessment. Recently, the issues related to transportation industry over the impact of fuel usage in operational cost has been increased. This concerns arise mostly in urban freight transportation where most logistics and supply chain begins or ends and therefore also encounters related ineffectiveness. (Arvidsson, 2013). The environmental and sustainability issues in logistics activities has become a critical factor of business strategy and competitive advantage (Fichtinger, Ries, Grosse & Baker, 2015). In this case, managing efficient transportation networks in logistics activities could contribute some improvements in these environmental and sustainability issues.

2.2. Inventory Management

Inventory is the stockpiles of products which are waiting to be manufactured, distributed, shipped or sold. There are several typical examples of inventories: component or semi-finished goods that are waiting to be assembled in manufacturing plant (work-in-process), goods such as raw material, components and finished products that are distributed through the logistics process (in-transit inventory), finished products stored in distribution center waiting for being sold, or finished products stocked by final users or customers to meet needs in the future. (Ghiani et al., 2004)

Inventory management should be considered as one of the most important concerns regarding companies' objectives of cost reduction and waste abolition (Patel & Patel, 2013). The requirement of time and effort for picking up the goods in a warehouse, or in other words how the goods are retrieved from the shelves and delivered to a place where they will be loaded into the trucks, is a crucial issue for performance measurement (Kovacs, 2011). According to Fichtinger et al. (2015), the decision in warehouse and inventory management including the supply lead times, reorder quantities and storage equipment have significant impact to costs and emissions. An optimal inventory management would lead to cost minimization and profit maximization and a company's performance could be improved through inventory reduction activities (Koumanakos, 2008).

In inventory theory, the economic impact like a departure could be simulated by using penalty cost of stock out as the substitute. Each unit of stock out penalty cost is evaluated to the companies for every customer that the ready inventory cannot meet the customer's demand. There are plenty of interpretations on penalty cost such as accelerated delivery, extra things at substitute retailers, higher cost of alternative, and so on. Regularly, the penalty cost is meant to indicate the economic impacts about missing goodwill of customers. Penalty cost is usually hard to forecast, and moreover it is even more difficult to precisely simulate how the demand process can be affected by the level of which demands that are not exceeding the stock level. (Olsen & Parker, 2008)

Inventory management involves the coordination of several activities e.g. planning, organizing, controlling, directing, and with aims to obtain effective purchasing, transportation, stocking and usage of inbound goods in manufacturing companies centrally to production process activities. Hence, the inventory management in an organization should be put into attention for improvement that results less interruption in production operation and better performance in the process. The degree of available working capital can also be improved by managing the proper stock level that leads to more profitability in other sections. All of these goals are more likely possible to be obtained through suitable integrated approach to inventory management functions. (Akindipe, 2014)

2.2.1. ABC Analysis

ABC analysis is a common used method for optimizing inventory control by classifying inventory items into three categories (A, B, C) based on their values. A category contains items which are the most expensive ones and should be set as priority which should be handled tightly. B category is the medium ones which need standard effort of control. C category includes less expensive or the cheapest items that do not need much attention. The principle of Pareto rule is the basis of ABC analysis, which suggests that 20% of items need 80% of effort for inventory control while the remaining 80% only needs 20% of attention. (Waters, 2009)

The purpose of ABC analysis is to divide inventory items into different category and to apply different strategy of inventory control to each category. This classification is made because those items do not have equal value and importance. By listing the items into three categories based on its level of importance, it can help inventory manager to set different inventory control policy to each category and to pay more attention to the critical items rather than all items in the inventory (Ballou, 2004). The process of classification is based on calculation result of annual consumption value which is driven by multiplying unit cost with annual demand. The following table shows typical result of classification by percentage of number of items and items value in each category (Waters, 2009).

Category	Number of Items	Number of Values
A	10%	70%
B	30%	20%
C	60%	10%

Table 1. Classification in ABC analysis

According to the table above, ABC approach can be seen as a similar approach to Pareto's 80/20 rule principle. Category A has the most valuable items which worth around 70% of the total consumption value and typically includes only 10% of the total inventory items. Category B contains moderate valuable items which accounts for about 30% of total inventory items. Items in category C only worth 10% of annual consumption value but include around 60% of the total inventory items. On the whole, 10-20% of items, which is category A, approximately cover 70-80% of total value while the rest 20-30% of values come from 80-90% of the total items which cover category B and C. (Waters, 2009)

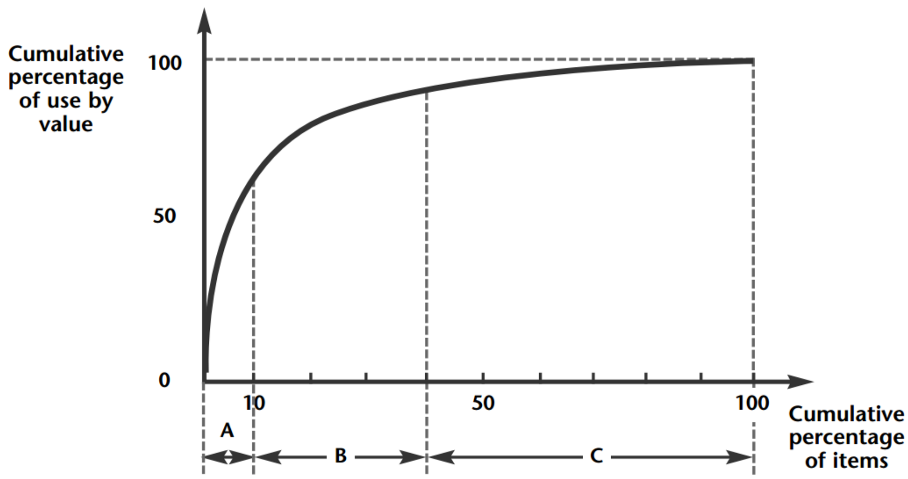

Figure 2. Typical result of an ABC analysis (Waters, 2009)

During the past decades, many researcher have been trying to develop the basic ABC analysis which considers only one criteria for classification which is annual consumption amount. The traditional ABC classification was considered less productive for nowadays complex inventory items, since there are many organizations such as P&G, Lenovo and ZTE which have thousands items in their inventories that are heterogeneous. To solve such complex inventory items, the traditional ABD analysis has been developed to be multiple criteria ABC inventory classification which considers multiple criteria in the classification process (Liu, Liao, Zhao and Yang, 2015).

2.2.2. Just-in-Time System

Japanese manufacturing industries has been drawn attention to competitive success by their principle of inventory reduction. One of their best known philosophy is just-in-time system, which has some close synonyms in the global repetitive manufacturing industrial all over the world such as zero inventory, stockless production, world class manufacturing, etc. (Graves et al., 1993). Just-in-time is a strategy approach of waste elimination throughout the whole supply chain and manufacturing process which is represented by low level of inventory and high level of quality and customers' satisfaction and its implementation could deliver highly significant impact on a company's performance and organizational culture (Cristopher, 1992). The principle of JIT has been proven as an effective way of managing supply chain system in terms of quality increment, productivity and efficiency improvement, better communication, waste and cost decrease, and enhanced chances of companies to obtain competitive advantage through their logistics system (Lai et al., 2009).

In terms of inventory management concerns, the philosophy of JIT can be applied for identifying waste and service improvement in process such as to assign manpower and required facilities to satisfy the needs of the distribution, to have less goods introduction time by improving responsive delivery methods, to enhance service quality by fulling buyer and seller relationship, etc. For example, bringing high volume of goods due to lower price offered by suppliers or to avoid stock-out possibilities can be considered as a waste in the inventory management which could cause additional expense by extra manpower and space area to accommodate the excess goods. By JIT principle, all kinds of raw material, semi-processed items or finished goods is only available in the exact amount of quantity as it is needed. Hence, the application of JIT can be achieved by eliminating unnecessary inventory and such thing as extra goods in inventory is not allowed. Another example is when there are delays of information flow among customers and suppliers which can cause excess stock. JIT system requires simple and responsive procedures in the ordering process and therefore includes continuous improvement and application of enabling information system such as Electronic Data Interchange (EDI) or Value Added Network (VAN) in the procedures of information flow to decrease the risk of delays which are caused by missing or mislead information. In this way the supply chain system can have access to the necessary information for decision making and as a result becomes enabled to responsively satisfy the market demand. Overall, there are many ways where JIT concept which emphases on waste elimination and service improvement can be implemented to improve the inventory management. (Lai et al., 2009)

2.3. Transportation Network for Competitive Advantage

Rahman, Sharif and Esa (2013) states that nowadays companies must find the way to improve their manufacturing operations in order to deal well with uncertain market change and to stay competitive in global business competition and lean manufacturing is one way of improving production performance. Supply chain management plays a critical role in modern business industries, while transportation management is an important driver of in supply chain since products are most likely not produced and consumed in the same location (Chopra et al., 2007).

Transportation network plays an important role in nowadays economies as it makes possibilities to have production process and consumption taking place in faraway location from each other which causes wider market. Due to this advancement, direct competitions between manufacturing companies from different countries become simulated and those companies to utilize economies of scale are driven. In addition, industries from developed countries might have benefits of less manufacturing operation salary in developing countries. As a result, perishable products are now available to be produced and consumed in a global worldwide market area. (Ghiani et al., 2004)

As transportation cost could contribute up to two of thirds of the total logistics costs, it becomes even more important in the global supply chains (Ghiani et al., 2004). There are plenty of big corporations that have optimized their transportation designs in order to achieve cost reduction and competitive advantage in the global business industries. For instance, Dell which currently has suppliers in global worldwide area has managed to sell its products to customers all over the world from few plants only by managing well the transportation in global network. Another example is Seven-Eleven Japan that has successfully managed the transportation network to obtain one of its business goals, which is availability to carry products from the stores to meet the customers demand while the customers are vary either by geographic location or time in a day. In this case, Seven-Eleven applies a transportation network which is very responsive and able to reload the stores several times in a day in order to satisfy customers' needs. (Chopra el al., 2007)

Transportation management in supply chain also functions to create effective inventory consumption and operate with less facilities which lead to cost efficiency (Chopra et al., 2007). There was a research conducted to General Motors assembly plant with the aim of reducing the supply chain costs by optimizing the transportation network managements from its warehouses (Cristopher, 1992). Dell manufacturing company also arranges its transportation network in order to be able to offer customers highly customized products with such affordable prices. Another case is a web based online shop Amazon that has successfully managed to improve its package carriers and transportation system to deliver the products to customers from a centralized warehouse. (Chopra et al., 2007)

3. TYPES OF TRANSPORTATION NETWORK

This chapter describes different kinds of transportation network that will be used as alternative solutions in this study. According to Du, Wang & Lu (2007), there are numbers of network solutions for a transportation method including direct shipment, cross-docking, milk-run and tailored network. The following subchapters provide the description and explanation about each type of transportation network.

3.1. Direct Shipment

Direct shipment is the most basic and pure transportation method for goods delivery. In direct shipment, suppliers are independently with their own fleet delivering ordered products to the manufacturing plant. (Liu et al., 2003) Direct shipment, where products are directly delivered from the suppliers to the manufacturing plant (Ghiani et al., 2004, 8), is a good option when the shipment satisfies a full truckload. On the other hand, when the shipments are less than a full truckload, the other types of transportation network should be taken into consideration (Du et al., 2007). The following figure illustrates the basic concept of direct shipment network, where each supplier utilizes their own truck or own service from third party logistics to load their products into the truck and deliver the goods to the manufacturing plant.

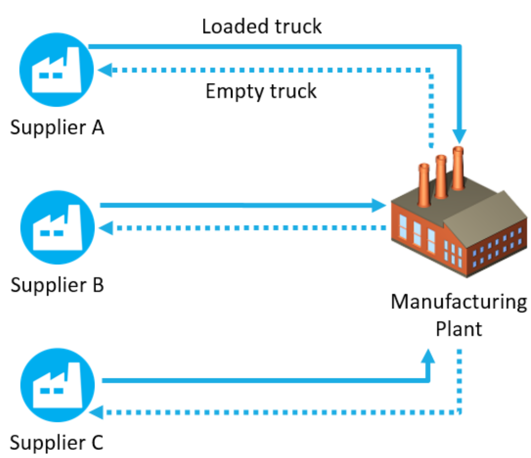

Figure 3. Direct shipment

The main benefit of using direct shipment is the simple coordination needed to operate this system and there is no necessity of transshipment facility or intermediate warehouse (Chopra et al., 2007). According to Liu et al. (2003), direct shipment can be an appropriate option if the quantity of order is high or the total lot size in one shipment is large enough to fulfill the full truck loads in each shipment of goods. This statement is supported by Mokhtarinejad et al. (2015) who states that in those conditions, the vehicle cost of transportation is higher than the shipment through cross docking system. However, when the lot size is small or the demand is not high enough to meet the full truck load requirement, the other types of delivery network can be utilized to reduce the transportation cost (Liu et al., 2003). Furthermore, the fully implementation of direct shipment is not flexible that it might cause delays and lead to penalty. Therefore, it is necessary to enlarge the design of transportation network by using mixed delivery methods in order to increase flexibility in the system. (Mokhtarinejad et al., 2015)

3.2. Milk Run System

Milk-run system, additionally known as cyclic product taking, originates from northern ancient system for mercantilism milk within the West, wherever the deliveryman accustomed walk to the customers' homes along with his horse-cart during a such that route, put the bottled milk in front of the consumers' doors, and take back the empty bottles (Sadjadi, Jafari & Amini, 2009). This system is economical once the loading volume of every provider is actually less than a truck load and infrequently enforced in internal plant offer chain system to move raw materials, finished merchandise, and waste between producing or assembly stations and therefore the warehouse of the assembly plant (Kovacs, 2011). Milk run supply has been enforced in many various industries and automotive companies is the main industry that there have been several automotive manufacturing companies implementing this distribution method (Du et al., 2007).

The pick-up and delivery of components in milk-run distribution network is operated through defined routes on set schedules, where every route consists of several points of assembly line stations that have been defined (Patel et al., 2013). The route, type, time schedule, and also the variety of components are determined where numerous trucks has to retrieve the goods from some different spots of suppliers and every trucks has to take the empty pallets back to the demand center (Sadjadi et al., 2009).

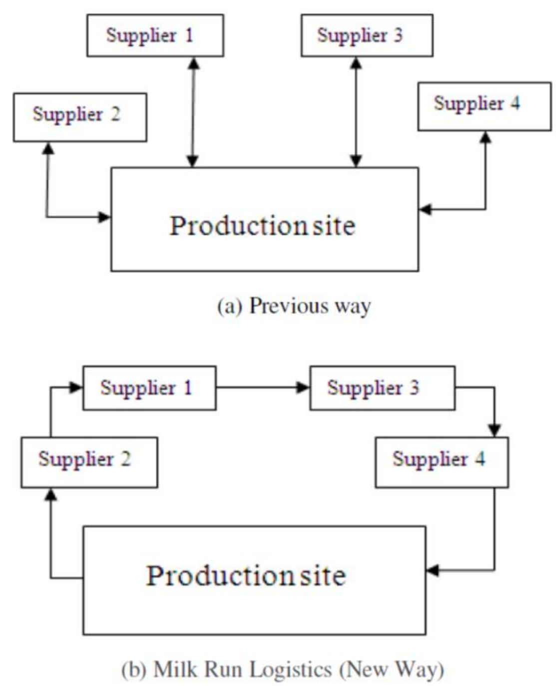

Figure 4. Implemented milk-run (Brar et al., 2011)

The first step of implementing milk-run system is to pick out the suppliers for routing integration. The suppliers' selection process is made according to supported location, material specification, and delivery performance. The most effective way to optimize the transport route potency is to choose a set of suppliers that are aggregately located near one another in one route, even when their location is not close to the manufactory. Once the chosen suppliers are obtained, it involves modeling and coming up with route for the milk-run system. After the route cycles are determined, the next step is to negotiate the pick-up and delivery service fee per route with the third party logistics. The third party logistics should provide the trucks to pick up the products from suppliers and take them to the assembly plant according to the schedule that has been set within the routes cycle. Another major factor is that suppliers should be well-informed in advance regarding the volumes of the goods and the pick-up schedules for daily milk-run route transportation system before the full implementation (Brar & Saini, 2011).

3.2.1. Direct Milk-run

According to Chopra et al. (2007), milk run system can be implemented in both direct and shipment with distribution center. Direct shipment with milk run is a route of goods delivery either from multiple suppliers to a single buyer or from a single supplier to multiple buyers. The following figure illustrates the milk-run with direct shipment distribution system routes in both ways.

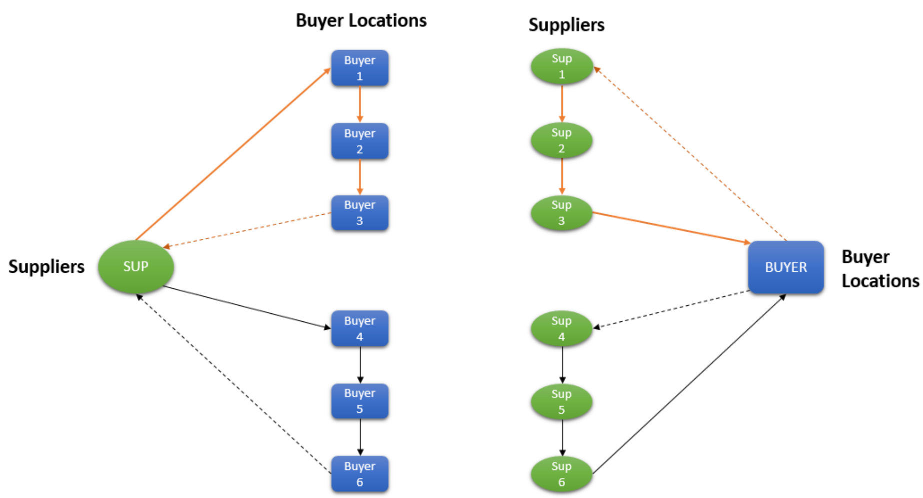

Figure 5. Milk-run with direct shipment

Direct milk-run network has an advantage that intermediate warehouse or temporary distribution center is not necessary so that the transportation cost would be more effective as milk-run with direct shipment consolidates directly deliveries from or to multiple suppliers or buyers location on a single vehicle. The lot size replenishment of each supplier or buyer location might be small and when the lot size is sent directly, LTL shipment is needed. Direct milk-run application sets the shipments from or to multiple locations by consolidated in a vehicle which makes improvement in trucks utilization and also cost reduction. The implementation of direct milk-run can significantly reduce the transportation cost when the small deliveries are frequent enough on a regular basis and the suppliers or buyers group location are aggregated in geographic proximity. For example, Japanese automobile industry Toyota applies milk-run distribution system for parts deliveries from suppliers to support the supply chain and Just-in-Time manufacturing operation system in Japan and United States. In Japan, where Toyota has many manufacturing plants, the milk-run deliveries are implemented from a single supplier to multiple manufacturing plants location. While in United States the milk-run deliveries are applied from multiple suppliers to the manufacturing plant. (Chopra et al., 2007)

3.2.2. Milk-run via Distribution Center

In milk-run shipment using distribution center, goods from several suppliers are collected in DC before then picked up to the manufacturing plant. Milk-run with DC is good to be applied if the lot sizes of the goods are small and the location of buyers or suppliers to the manufacturing plant is in long distance (Chopra et al., 2007). The following figures illustrates the milk-run delivery via distribution center.

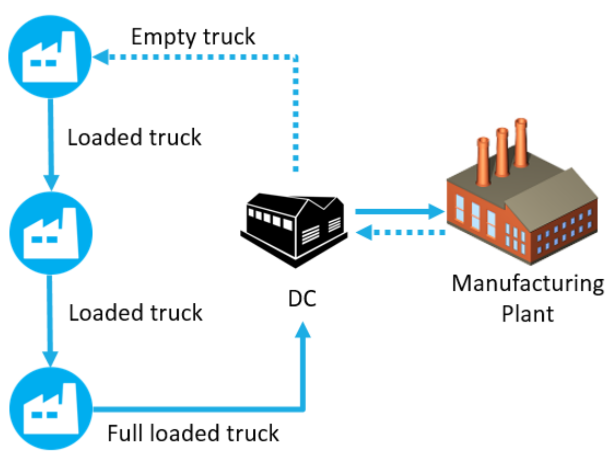

Figure 6. Milk-run with distribution center

This combination system has been implemented in different kinds of industries such as the convenience store 7-Eleven Japan, online grocer Peapod, and children's wear manufacturer OshKosh B'Gosh. 7-Eleven applies this concept in shipping small replenishment lots to each of its stores. The fresh food which are delivered from its suppliers are consolidated in a distribution center before being sent to the retail outlets by milk-run distribution system. These activities result in transportation cost reduction as the total shipment to a store from all the vendors cannot fill a full load truck. Peapod also implements this system for lowering the transportation expense of small shipments delivery to homes. Furthermore, OshKosh B'Gosh has managed to utilize this system for cutting LTL shipments from the distribution center to retail stores. (Chopra et al., 2007)

3.2.3. The Benefits of Milk-run Implementation

The advantages of milk-run application are transportation cost reduction, warehouse and inventory improvement, and optimization of trucks utilization that can also result to less CO2 emissions in terms of green supply chain management issue. Arvidsson (2013) states that recently there are concerns about transportation activities regarding the usage of fuel which impact to environments issue. Urban freight transportation is the most case in which this concern happens, where most supply chain transportation activities begins or ends. Moreover, this condition is also related with inefficiencies. The major purpose of operating milk-run is to decrease the amount of transportation cost either by reducing the total distance that have to be passed through the transporting process or optimizing the number of trucks used (Gyulai, Pfeiffer, Sobottka & Vancza, 2013). A milk-run system was also proposed for an automobile manufacturing industry in Indonesia by using Differential Evolution algorithm method to optimize the vehicles' travelled distance to obtain efficient routes and effective truck's utilization in the company. The study was applied to 30 suppliers and the proposed network was then compared to the current system that was applied. The analysis result indicated that the proposed system might decrease the total distance up to 1,230 km each day or around

15.23%, which leads transportation cost reduction up to IDR 10 million or around 25.21%. (Rachman, Dhini & Mustafa, 2009)

Volling, Grunewald & Spengler (2013) stated that milk-run network is one of the most expansive strategies that can be applied in centrally operating coordinated inbound logistics which facilitates the regular delivery of less than a full truckload volumes and therefore contributes towards lead time reduction. This network could bring consolidated collection of parts necessary to improve the logistics systems, which also comes up with improvement of the production line in the assembly or manufacturing process and better Just-in-Time (JIT) products delivery due to the synchronization (Brar et al., 2011). After observing the warehousing and inventory assignment problems with milk-run distribution system, Kovacs figured out that the proposed distribution network might result some advantages compared to the previous system which was operated based on classification for the solution in related warehouse and inventory problems (Kovacs, 2011).

Another research done by Kumar and Shilpa's (2014) showed that milk-run distribution system is an efficient transportation network for inventory optimization as it optimizes the loading rates in possible levels and decrease the amount of vehicles and travel distance. This delivery network can also improve the production line logistics system particularly in JIT distribution. Nemoto, Hayashi & Hashimoto (2010) stated that milk-run network has been considered as a standard method of an overseas system of JIT principle. The schedules and time table of parts pick-up and delivery activity are arranged and defined according to JIT production system, neither late nor early, where the full truckload of goods are picked up and delivered to the buffer stock inventory location in order to support the production process in the assembly line station (Patel et al., 2013).

Milk-run logistics network also plays a role in green supply chain management issue. The main problem in global level is the feedback on environmental issues. In this case, one of the major concerns in logistics field is how to reduce the amount of CO2 generated from the shipping activities. (Nemoto et al., 2010) Milk-run logistics system is aimed to optimize loading rates at possible levels that results to decreased trucks utilization and travel distance. Therefore, milk-run can be considered to be a good logistics network that can result less exhaust gas of vehicles. Hence, in terms of environmental policy, the promotion of milk-run system should be highly evaluated. (Brar et al., 2011)

A case of Webasto/Schenker's scheme of suppliers' delivery method was discussed by Nemoto (2013). In this case, the vehicles kilometers can be saved up to 30% by using milk-run network while the rest 70% was caused mostly by modern trucks fleet. Hence, it can be concluded that about one third of the total environment cost can be saved. (Nemoto, 2013) Another research was conducted in a Japanese automotive manufacturing company in Thailand where the logistics operation systems were compared. In this case, milk-run application can decrease up to 13.6 tons of CO2 gas emissions each day which is around 53% reduction compared to the distribution system without milk-run. On the whole, milk-run network can be considered as a big step towards the achievement of green supply chain management. (Nemoto, 2013)

3.3. Kanban System

Another delivery method is by using Kanban system. Kanban is one of the most supporting aspects of Just-in-Time system that can achieve inventory efficiency. In Kanban system, the in-process of inventories is effectively limited and the transportation of material to production stage is coordinated effectively. (Graves et al., 1993) This statement is supported by Naufal, Jaffar, Yusoff and Hayati's (2012) Kanban research at manufacturing company in Malaysia which concludes that developing Kanban system could result in reducing lead time and minimizing inventory as well as optimizing warehouse area. Their study states that Kanban system distributes part in right amount, right type, right place, and right time and therefore manages to control smooth material flow in supply chain with minimum level of inventory (Naufal et al., 2012).

Kanban system uses Kanban cards to authorize transportation of goods for production process which requires clear information of material type and amount, the authorized material transportation, and the location of material to be stored (Graves et al., 2012). There are two kinds of Kanban card systems: single-card and two-card Kanban system. Single-card Kanban system uses one card, which is called Production Instruction Kanban (PIK), to trigger the upstream productions that are necessary. Two-card Kanban system also uses PIK card and another card which is called Production Withdrawal Kanban (PWK). PIK in two-card Kanban system card is used for pulling what is needed for preceding process and PWK card is used for instructing previous process to produce necessary things for inventory replenishment. (Naufal et al., 2012) The following figure illustrates the flow process of information and material in two-card Kanban system.

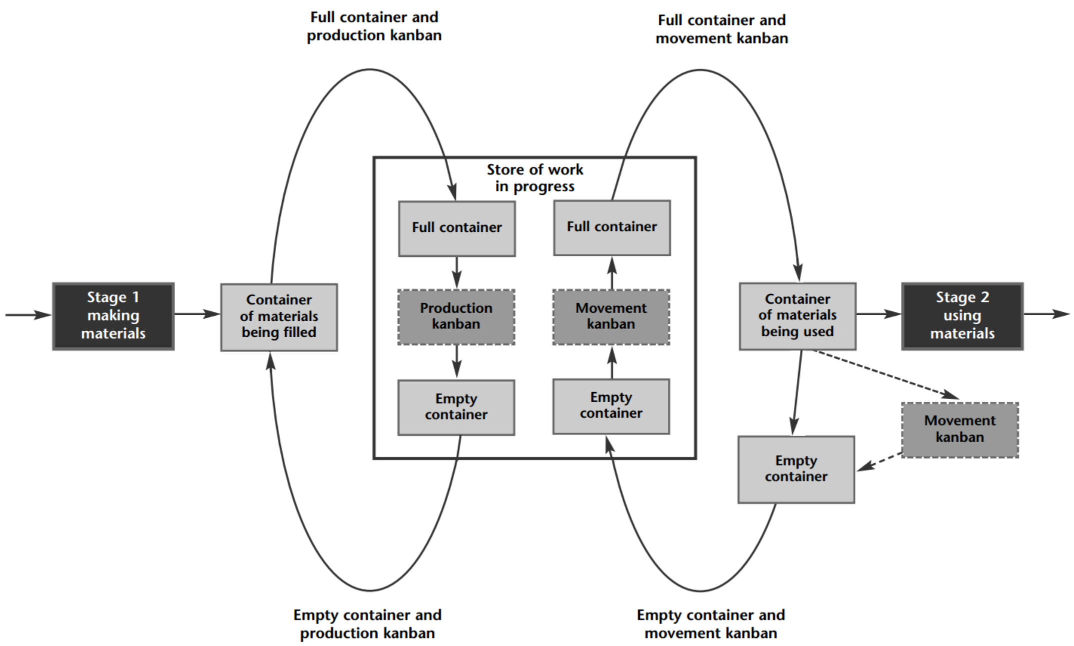

Figure 7. Flowchart in a two-card Kanban system (Waters, 2009)

3.3.1. Key success of Kanban system

According to Rahman et al., (2013), there are several factors needed in order to successfully operate Kanban system which are top management's support and commitment, suppliers' participation, good inventory management and quality improvement.

In nowadays organization situation, employees' commitment and nice rapport between staffs and managers are the most necessary in order to maintain good teamwork and cooperation among organization members to obtain their goals. Active participation of all workers are needed to the success of the new implemented Kanban network as well as the organizations succeed in the future. Therefore, it is important for top management level in supporting their employees by treating them well and fairly so that they can give total contribution in what they do for the company. (Rahman et al., 2013)

Supplier's participation are also needed in Kanban delivery provide quick services and efficient material supply. Since Kanban system should minimize the inventory consumption where the size of inventories needed should be equal with the size of goods for production line, supplier's commitment is very crucial to support the production process going smoothly and effectively. There are some parameters that should be considered in selecting suppliers for Kanban implementation: the quality of suppliers, suppliers' willingness to cooperate, technical competence, suppliers' geography location to the manufacturing plant, and products price. As the main objective of this system is to reduce the consumption in inventory, implementing this system needs excellent tuning suppliers and production scheduling system so that inventory level can be minimized by delivering the goods when they are needed to be immediately taken into the production line and work in progress should be maintained under monitoring. (Rahman et al., 2013)

In real condition, managing inventory is a complex problem as it deals with many factors and uncertainty. There are four classifications of inventory issues: raw material inventory, work in progress inventory, finished goods and maintenance, repairing and operating inventory. Inventory management becomes more complicated as there are many things involved including storage and holding cost and capacity issue in the factory. (Rahman et al., 2013) Applying Kanban system will help to reduce space in inventory and avoid any capacity problem.

Besides inventory reduction, Kanban system can also maintain and control quality improvement of the finished goods. In traditional time, companies believe that quality needs more cost, production defects can be occurred due to human error, and it is enough to have minimum level of quality as long as costumers are still satisfied. While in companies which have implemented Kanban, they believe that quality can result less cost, production defects are mostly caused by system, and quality should be continuously improved with the principle of Kaizen concept. When a company has successfully applied Kanban system, it will control all delivered goods and make sure that they meet certain level of quality standard before accepting those goods for the next operation process or distributed to the customers. Organizations with Kanban principle will believe that by improving the process they can produce things with guaranteed good quality and by producing good quality products they can achieve a competitive advantage. (Rahman et al., 2013)

3.3.2. The Advantage of Kanban System

There are plenty of benefits of Kanban application in operation management and business industry. Implementing Kanban system could help companies to acquire productivity improvement and waste reduction in their production process. (Rahman et al., 2013). Naufal et al. (2015) states that Kanban demonstration is necessary to ensure that the flow of material in the manufacturing process keeps going smoothly and applying Kanban with full commitment could also optimize and improve the industry's capability of satisfying customers' demands.

After developing Kanban system in a local manufacturing company, Naufal et al (2015) found that the company could successfully obtained significant improvement in some of its sectors. Some of the improved areas are lead time shortened by 40%, reduction in in-process and finished goods inventory consumption by 23-29%, and finished goods area optimization by 4%. The lead time can be reduced as the production is operated only according to Kanban card instruction. The principle of Kanban in terms of variety of product level and mixing could prevent proceeding production of products that are not demanded which therefore minimizes the consumption of finished goods inventory. Furthermore, Kanban has several tools that can be used to help decision makers to determine which types of products are needed to be produced. (Naufal et al., 2015)

3.4. Cross-docking

Cross docking, also known as just-in-time distribution, is a transferal facility where the goods from incoming shipments are sorted, consolidated with other goods, and then transferred directly to outgoing trailers without intermediate storage or order picking (Ghiani et al., 2004). In other words, it will just take a short period of time for the products to stay in the facility before they are taken into the users. If the products are placed in the transshipment facility for longer period of time, this can be called warehousing system. There are four major activities in the warehousing system according to Ghiani et al. (2004): receiving the incoming products, putting them in storage, and finally order picking and shipping the products to the next destination. Hence, the function of storage and order picking could be the most expensive operations due to the fee of the inventory holding and labor cost. Since cross-docking is mostly used for distributing products from retailer to customers, this system will not be considered as an alternative in this study.

3.5. Tailored Network

Tailored network is the combination of both full truckload and less truckload shipment by shipping high volume orders from suppliers directly to customers and distributing less truckload shipment orders by using the other distribution systems (Du et al., 2007). As tailored network utilizes several different kinds of shipment method, the implementation of this network requires high investment for information infrastructure for facilitating more advanced coordination. The main purpose of tailored network is to reduce the transportation and inventory cost. The following table shows the advantages and disadvantages of each transportation network model including tailored logistics network. (Chopra et al., 2007)

Transportation Network	Strength	Weakness
Direct shipment	No transshipment facility needed and simple coordination	High level of inventory High expense for receiving
Direct milk-run	Transportation cost reduction and lower inventory level	Increase in coordination complexity
Milk-run with DC	Lower outbound transport cost for small lots	Further increase in coordination complexity
Kanban	No additional cost required for operation process	Limited to close suppliers location and full TL condition
Tailored network	Most suitable transportation option based on needs of individual product and store	The highest level of coordination complexity

Table 2. Types of transportation network

There are number of researchers who have been studying the possibility of implementing different kind of transportation networks. Liu et al. (2003) design a transportation model with heuristic algorithm in combining direct shipment and hub-and-spoke with milk-run distribution system. Hosseini, Akbarpourshirazi & Karimi (2014) propose a transportation network approach with cross-docking system and milk-run distribution in a consolidation network by using a hybrid of harmony search and simulated annealing approach. They focus of tailored network simultaneously implementation in order to reduce the transportation cost in the distribution system (Hosseini et al., 2014).

3.5.1. Tailored Network in Supply Chains

Tailored transportation network utilizes different types of networks based on the products and customers characteristics. There are plenty of companies that produce variety of goods and sell them to different segments of customers. The variety of the products can be in the size, value, and other factors while the variety of customers can be in their responsiveness, loyalty, amount of their purchase, uncertainty of their orders, and so on. Due to these differences, those companies should not use the same design of transportation network to serve all needs. On the contrary, customers need can be satisfied at a more cost efficiency by implementing tailored transportation network to use the most suitable network based on the products and customers characteristics. The design of the transportation for tailored network can be adjusted based on customers' density and distance, customers' size, and products' demand and value in order to obtain suitable responsiveness and cost effectiveness. (Chopra et al., 2007)

3.5.2. Tailored Transportation by Distance and Density

The density and distance of the customers should be taken into consideration in designing the logistics methods for tailored transportation network. The condition of customers' density and distance are significant factors to degree of provisional aggregation in delivery to customers. Locations with high customers' density are more likely to give adequate transportation's economies of scale and result provisional aggregation less valuable. Thus, companies should serve this type of area more frequently. For locations with low customers' density, companies should increase the degree of provisional aggregation in order to save transportation costs. The following table shows the ideal network for each condition of costumers' distance and density. An industrial distributor of office suppliers, Boise Cascade Office Products, has referred to suggestions based on below table in designing its transportation networks. (Chopra et al., 2007)

	Short distance	***Medium distance***	***Long distance***
Low density	Milk-run with 3PL service	LTL or package carrier	Package carrier
Medium density	Milk-run with 3PL service	LTL carrier	LTL or package carrier
High density	Milk-run with private fleet	Milk-run via DC	Milk-run via DC

Table 3. Tailored network based on customers' distance and density

When the customers' density is high and the distance is short, companies should use private fleet for milk-run supply system because this would make a very good use of the trucks. When the density is high and the distance is long, it is better to use service of third logistics party for the shipment to cross-dock or DC area where the products are then shipped into customers by using small trucks and milk-run delivery system. In this case, using private fleet of the company is not recommended since the truck would be empty in the return trip with long distance. Therefore, it is not an ideal option for the company to own a private fleet. When the density is medium, it is better to use an LTL carrier or 3PL service for milk-run operation since 3PL carriers can aggregate deliveries across many companies. Finally, when the companies serve locations with low customers' density and long distance, it might be the best solution to use a package carrier service since the use of LTL carriers may no longer be worthy. (Chopra et al., 2007)

3.5.3. Tailored Transportation by Size

Size of customers should be considered as well to achieve an effective mode of tailored transportation network. TL carrier can be utilized to supply large size of customers, while LTL carrier or milk-run can be applied to small size of customers. There are two types of expense which are occurred by milk-run implementation: pick-up and delivery service based on the route cycle and delivery cost based on total number of deliveries.

Transportation cost for pick-up and delivery service would be equal either for small or large customers. The transportation cost can be optimized by including some deliveries to small customers into a delivery to large customers depending on the vehicle capacity condition. However, as the delivery cost per unit for small customers is higher than for big customers, it is not efficient to make delivery to small and large customers in the same frequency with equal cost. There are some options in this situation that the companies can do. The first solution is to charge more delivery price to small customers. The other alternative is to arrange the milk-run route to go to large customers with high level of frequency than to small customers. The customers can be classified into small (S), medium (M) and large (L) size based on the demand of each customer. The milk-run route can be optimized by combining small, medium and large customers in each cycle. For example, delivery to large customers can be made every milk-run route, delivery to medium customers can be made in every other milk-run route and delivery to small customers can be made every three milk-run routes. This combination of tailored sequence gives a benefit that each vehicle would carry almost the same level of load and deliveries to large customers are made more often than small customers based on the relative delivery cost. (Chopra et al., 2007)

3.5.4. Tailored Transportation by Demand and Value

In many cases, there are varieties of demand and value in the products that companies should apply appropriate degree of inventory aggregation and method of transportation network used in the supply chain system. The following table shows the variety of suitable network and inventory setting based on products demand and value condition. (Chopra et al., 2007)

	High value	*Low value*
High demand	Disaggregate cycle inventory. Aggregate safety inventory. Inexpensive mode of transportation for replenishing cycle inventory and fast mode when using safety inventory.	Disaggregate all inventories and use inexpensive mode of transportation for replenishment.
Low demand	Aggregate all inventories. If needed, use fast mode of transportation for filling customer orders.	Aggregate only safety inventory. Use inexpensive mode of transportation for replenishing cycle inventory

Table 4. Tailored strategy based on product value and demand

For products with high value and demand, the inventory cycle should not be aggregated to optimize the transportation cost since it allows replenishment of orders to be delivered in lower cost. Fast mode of transportation is allowed to be applied when the safety inventory, which can be aggregated for inventory reduction, is required to meet customers demand. For products with high demand and low value, the inventories should be disaggregated and kept near the customers to lower the transportation costs. For high value and low demand products, the safety inventories should be aggregated to reduce the inventory costs. For products with low value and low demand, the safety inventories can also be aggregated to save the inventory costs and get some advantages from aggregations. In this kind of products, the cycle inventory should be held near the customers to reduce transportation costs and therefore can be replenished by utilizing inexpensive method of transportation network for cost saving. (Chopra et al., 2007)

3.5.5. Tailored Risk Mitigation Strategy

According to Chopra and Sodhi (2004), there are plenty of factors that drive the risks in supply chain which can be classified into several categories: delays, disruptions, forecast risks, procurement risk, systems risk, inventory risk, capacity risk, receivables risk and intellectual property risk,. Each of those risk category might have some driven factors. Delays might be caused by high capacity utilization at supply source, inflexibility of supply source, poor quality or yield at supply source. Disruptions can be driven by natural disaster, war, terrorism, labor disputes, and suppliers' bankruptcy. Forecast risks can be driven by inaccurate forecasts due to long lead times, seasonality, product variety, short life cycles or small customers' base. Bullwhip effect or information distortion can also emerge forecast risk. Procurement risk is driven by exchange-rate risk, fraction purchased from a single source and industry wide capacity utilization. Systems risk can be caused by information infrastructure breakdown or system integration or extent of systems being networked. Inventory risk might be driven by rate of product obsolescence, inventory holding cost, or product value. Capacity risk can be caused by cost of capacity or capacity flexibility. Receivables risk is caused by number of customers or customers' financial strength. The last category, intellectual property risk might be caused by vertical integration of supply chain or global outsourcing and markets. (Chopra et al., 2004)

Ghiani et al. (2004) states that tailored transportation network allows management improvement in the strategic, tactical and operational level. In the strategic level, the network requires the most suitable vehicle and optimizes number of operators needed. In the tactical level, it determines the cost for a full truckload shipment. In the operational level, the network defines crucial strategies related to the flexibility resources allocation such as trucks, containers, trailers and operators without knowing the future demands. (Ghiani et al., 2004) The following figure presents the outline of some the tailored mitigation strategies. (Chopra et al., 2007)

Increase capacity	Focus on low cost, decentralized capacity for predictable demand
	Build centralized capacity for unpredictable demand
	Increase decentralization as cost of capacity drops
Get redundant suppliers	More redundant supply for high volume products and less redundant for low volume products.
	Centralize redundancy for low voluma products in a few flexible suppliers
Increase responsiveness	Favor cost ober responsiveness for comodity products
	Favor responsiveness over cost for short life-cycle products
Increase inventory	Decentralize inventory of predictable and lower value products
	Centralize inventory of less predictable and higher value products
Increase flexibility	Favor cost over flexibility for predictable high volume products
	Favor flexibility for unpredictable low volume products
	Centralize flexibility in a few locations if it is expensive
Pool or aggregate demand	Increase aggregation as unpredictability grows
Increase source capability	Prefer capability over cost for high value and high risk products
	Favor cost over capability for low value comodity products
	Centralize high capability in flexible source if possible

Figure 8. Tailored risk mitigation strategies (Chopra et al., 2007)

Chopra et al. (2007) defines the choice of network design as an important role in supply chain risk mitigation strategy that a good design of mitigation strategies actually brings significant improvement for supply chain's ability to cope with risks. For example, using multiple suppliers could help to mitigate disruption risk rather than having only one supplier. In March 2000, a plant belonged to Royal Phillips Electronics, which supplies to Nokia and Ericsson, was catching fire. At that time, Nokia managed to quickly handle the disruption by utilizing some other supply plants in its network sources. On the contrary, Ericsson which did not have any backup supplier was not able to deal with it well and caused lost revenues at around $400 million. Some risks such as price, global demand, and foreign exchange rate fluctuation can also be mitigated by flexibility in capacity. Hino Trucks plant has a flexible capacity to adjust the level of production according to various models by shifting workforce between lines. Therefore, Hino Trucks is able manage to maintain stable workforce in its manufacturing plant although every production line is adjusted to the level of supply and demand. (Chopra et al., 2007)

However, each mitigation strategy in supply chain comes at a cost and might increase other risks as well. For instance, using multiple suppliers might mitigate the disruption risk but it could increase expenses since each supplier might have problems in obtaining scale economy. Another example is that inventory increment might mitigates the delay risk but it could cause obsolescence risk. Therefore, developing tailored mitigation strategies is very important during network design that it can obtain a good balance between the level of mitigated risks and the level of cost increment. (Chopra et al., 2007)

4. RESEARCH METHODOLOGY

4.1. Data Collection

The data are collected through direct observation in warehouse area and interview with members of purchasing and inventory department in the case company. Some numerical data are also gathered to do the analysis. The types of information gathered from the case company are listed in the following table.

Source of Information	***Information***
Purchasing Department	List of suppliers and car models
	Transport cost of each supplier for each car model
	Suppliers location
	Production schedules
Inventory Section	Warehouse condition
	Lot sizes of suppliers
	Goods delivery system from suppliers

Table 5. Data collection

The data were collected from two departments in the case company which are purchasing and logistics department particularly in inventory section. There are four types of data gathered from purchasing department. The first data is the list of suppliers and the car models which each vendor supplies. There are originally over one hundred suppliers available. The second data is about the transportation cost that suppliers charge in the price of each part to the case company. However, not all suppliers provide this information of transportation cost or logistics cost in their quotations. There are only 63 suppliers giving the information and therefore only those suppliers are taken into this study. The next data is the location of each supplier which is gathered based on city area. The last thing is the data of yearly production schedule of each car model which is taken from the last six months production plan. The rest of information which contains of warehouse and inventory condition, supplier's goods lot size and current parte delivery system from suppliers to manufacturing plant were acquired from logistics department.

4.2. Methodology

Both qualitative and quantitative methods will be used in this thesis. Firstly, a set of suppliers is selected based on those suppliers which provide delivery cost in their parts' prices, as has been explained in the limitation section. After selecting number of suppliers which are taken for being analyzed, each supplier is given category for some parameters that will influence the decision of which transportation network is the most suitable for the supplier. The conditions that will be taken into consideration in selecting proper delivery method are mentioned in the following table.

No.	Parameter	Involved Factor		Related Network			
		Supplier	Car model	Direct shipment	Direct milk-run	Milk-run via DC	Kanban
1	Transportation cost for parts delivery	✓	✓		✓	✓	
2	Supplier's distance from manufacturing plant	✓			✓	✓	✓
3	Suppliers group location	✓			✓	✓	
4	Size of goods	✓	✓		✓	✓	✓
5	Level of demands		✓	✓	✓	✓	
6	Frequency of changed production schedule		✓		✓	✓	

Table 6. Parameters for assigning delivery method

There are four alternatives of transportation network which will be assigned to each supplier: direct delivery, direct milk-run, milk-run with distribution center, and Kanban delivery. By applying other methods than direct delivery, the warehouse consumption is certainly reduced in quite significant area. After all suppliers are assigned with the most suitable network among those five options, the cost associated with the final solution will be calculated and compared with the current expense of transportation cost in direct delivery. Figure 2 illustrates each step of methodology in this study.

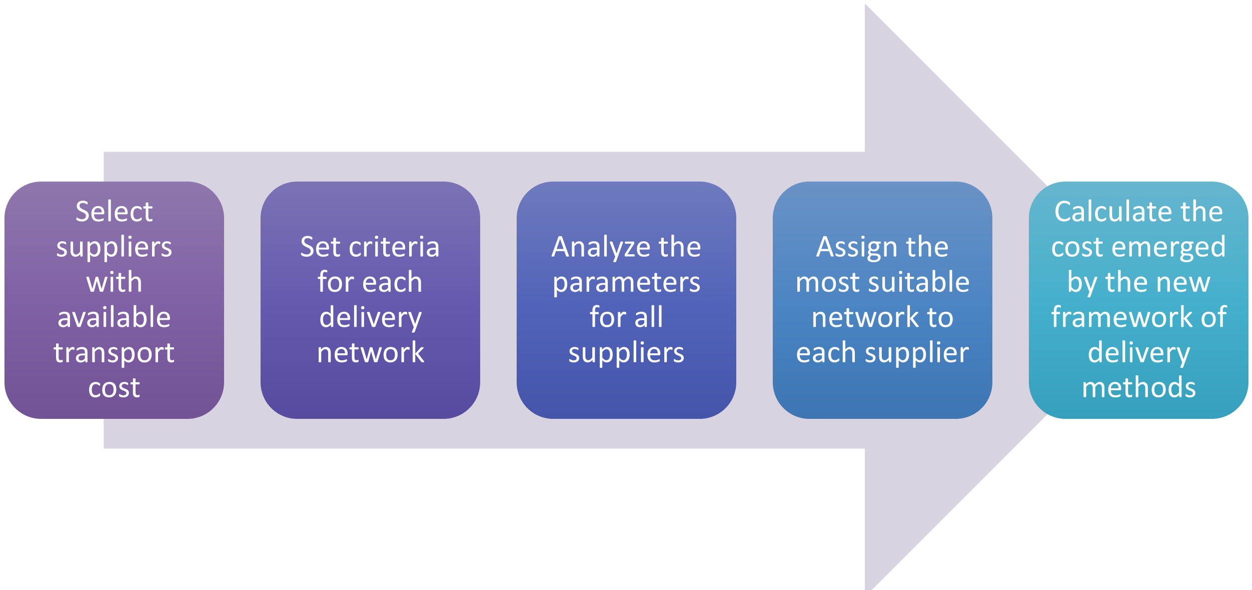

Figure 9. Framework of research methodology

As have been mentioned before, the first thing to do is to sort suppliers database based on the presence of transportation cost and filter only those which provide transportation cost in their quotations. The next step is to analyze the relationship between each network option with each parameter, for example how important the factor of supplier location for applying milk-run network. Furthermore, for each network must be set a certain criteria of each parameter (i.e. for milk-run network the suppliers should not be located in long distance from the manufacturing plant). The third step is to study the condition of each suppliers based on set of parameters (i.e. supplier location) which will be the factors of assigning the delivery method. All parameters will be classified into some categories in general way for each supplier (i.e. short, medium or long distance from manufacturing plant). As all suppliers have own values for each parameter and certain level of criteria has been set for each network, the matrix will be analyzed to decide which transportation mode is the most appropriate for each supplier. For instance, a suppliers for a car model with stable and high level of demand, with small size of goods, aggregated location with some other suppliers, short distance from the manufacturing plant, and medium transportation cost can be assigned to direct milk-run delivery network. This assignment process will be conducted by using scoring method, which will be explained in detail in the analysis part. After each supplier has its own suitable delivery method, the last step is to calculate the entire cost caused by the new framework design of transportation network. As an example, suppliers who are matched with direct milk run will cause cost reduction from cutting transportation cost in the products prices but arise additional expense to pay the third logistics party for the goods pick-up and delivery service. The calculation result will be taken into consideration in proposing the final network solution to be implemented in the case company.

5. PRESENTATION OF THE CASE COMPANY

5.1. Overview of the Company

PT. Nissan Motor Indonesia is one of the branch companies of Nissan Motors. The company was founded in 1986 with the headquarters located in Jakarta, Indonesia. PT. Nissan Motor Indonesia was officially operating since 2001 in the areas of sales, distribution, authorization of Nissan parts and after-sales service in Indonesia. As part of the Nissan Motor Corporation Ltd., PT. Nissan Motor Indonesia has an important role on the global business plan of Nissan Power 88, which is designed to continue enhancement of the brand and its' sales strength. One of the stated goals of Nissan is to gain 8 % of global automotive market share. The same plan is meant to continuously improve company's operating profit. By the end of fiscal year 2016 profit generation is aimed to be increase by 8 % on average.

PT. Nissan Motor Indonesia presents a series of products that are competitive in the most complete vehicle segments. Promoted campaign "Innovation that excites" underlines Nissan's commitment to innovative products with leading technology. There are two other brands that are associated and run by Nissan. Infiniti is upper segment or high class vehicle brand that produces performance and luxury oriented cars. Datsun on the other hand is producing budget or low cost vehicles that are mostly meant to compete in developing markets and oriented for people with limited income. Currently PT. Nissan Motor Indonesia has more than 98 dealers spread throughout Indonesia and an assembly plant located in Purwakarta. This particular plant in West Java, with targeted production of 100 000 units and actual output of around 96 000 units per year is one of the most important production plans for Nissan.

5.2. Current Supply Chain System

According to one classification, there are two kinds of supplied parts for production process: import parts and local parts. Import parts are the original parts that are used for assembling car models that have been existing in other country. However, in terms of cost efficiency and savings, it is much more beneficial to find local companies that will produce components although this is not always possible. At the moment there are over 100 local suppliers that support the company in providing parts for production process. Most of those suppliers deliver parts to the manufacturing plant in the daily basis. The current supply chain system at the company goes rather well to support production process. However, problems arise when there are increasing demands which requires higher volume of production. This condition will cause higher amount of order to suppliers and therefore when the parts are delivered, number of stocks in the inventory is increased. Some parts have to be placed outside while waiting for being taken to the production line. This is not a good condition since the weather in Indonesia is mostly filled by blazing sun or heavy rain. The following pictures show the actual condition when parts were placed outside due to less capacity in the warehouse.

Figure 10. Actual condition where parts are placed outside

The increasing amount of demands does not always happen and therefore it is hard for Nissan to make investment of adding a new warehouse to fit all goods because in low amount of production volume, the current warehouse is enough to fit all necessary parts for production. In this situation, it is better to improve the supply chain system to get more efficient supply chain process and to save some area in the inventory.

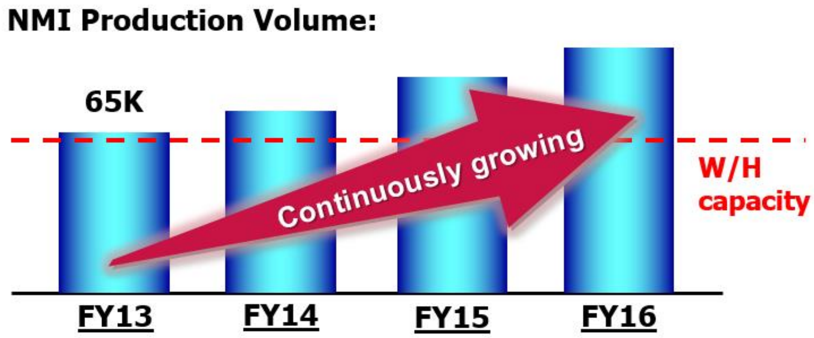

Figure 11. NMI's warehouse capacity

The figure above is made by people from the inventory department that they have considered about warehouse capacity concern in future condition. As the volume of production plan keeps increasing year by year, it will lead to high level of inventory that the existing warehouse might not be able to accommodate all of the stocks. Besides the capacity issue, they also concern about the traffic load when trucks come to unload the goods. Therefore, they also believe that a breakthrough for logistics process improvement is required. By implementing tailored network in suppliers' parts delivery process, the amount of inventory consumption must be reduced and the traffic level of incoming trucks would be less.

6. ANALYSIS FOR TAILORED NETWORK

The study will be based on supplier instead of part, since it is less likely possible to apply different methods for different parts from same supplier. As the first step is conducted, there are 63 suppliers available which provide transportation cost for their products. There are four alternatives of delivery methods: direct shipment, direct milk-run, milk-run with distribution center, and Kanban delivery. There are six parameters that will be considered in determining the most appropriate delivery method for each supplier: transportation cost, level of demand, stability, suppliers' distance from manufacturing plant, suppliers' group location and size of the goods ordered from each supplier. The following subchapters will describe the process of setting criteria for each alternative solution and the analysis of suppliers' condition in each parameter.

6.1. Criteria for Network Options

In this section, the parameters will be analyzed for each delivery method options to set the proper condition of each parameter for each network. The following figure shows the relationship between each delivery method and parameter.

Relationship Key:

	Strong	Medium	Weak
Weight	9	3	1

	X's (parameters)					
Y's (Delivery Methods)	Transportation cost	Level of demands	Stability of production schedule	Size of the goods	Supplier group location	Distance from supplier to manufacturing plant
Direct shipment		3		3		
Direct milk-run	3	3	3	9	9	9
Milk-run with DC	3	9	3	9	9	3
Kanban delivery		3	1	9		9

Table 7. Relationship between parameters and network options

In the table above, the level of relationship is classified into three numbers based on the weight of the relationship between each transportation network and parameter. Number of nine is given to strong relationship, three is given to medium relationship, one is given to weak relationship, and blank space or zero is given to those parameters which do not have any relationship with the transportation networks. The explanation about reasons behind all given weights of relationships for each delivery network is described in the following subchapters.

6.1.1. Direct Shipment

There are not many requirements in applying direct shipment since this is the simplest method of parts delivery. As mentioned in the theoretical part, direct shipment is suitable if the demand is high or the lot size is large enough to make a full truckload for shipment. Another theory states that the distance between suppliers and manufacturing plant for direct shipment should not be too far. However, when the condition of suppliers do not satisfy the requirement of other networks, direct shipment will be the only option left for those suppliers to be assigned to. Therefore, the weights of direct shipment's parameters are not classified as strong relationships.

6.1.2. Milk-run

The most important factors in applying milk-run distribution system are size of the goods and suppliers' geographic location. In milk-run network, parts delivery for one day's production is divided into several cycles e.g. four to six delivery in a day. The lot size must not be too large or otherwise there will not be enough space in the truck capacity to accommodate the goods from other suppliers. The allowance for size of the goods in milk-run alternative is ranged between small and medium parts. Since size of goods has a strong relationship with the milk-run system, this network cannot be applied to suppliers which do not satisfy the range of this criteria which means there will not be any possibility to implement milk-run to suppliers that have large size of the goods.

Suppliers' geographic location consists of two parameters: distance from manufacturing plant and aggregation location among some other suppliers. To implement milk-run system, suppliers should not be located too far from the manufacturing plant. In its implementation, the truck for example can have four to six route each day to pick up the goods from one suppliers location and deliver them to manufacturing plant. To meet the timetable of production schedule and taken into account the severe traffic jam in Indonesian road condition, the allowed distance for milk-run network is between short and medium range. Another crucial thing is the condition whether there are several numbers of supplier located in same area. For instance, if there is only one supplier located in a city which is isolated far away from other cities, milk-run cannot be implemented to that supplier. When there are at least three suppliers located in same area, milk-run might be applied depends on the quantity of orders and the lot size if they can fit towards a full truckload. Another possibility also implies to a supplier which is located in a different area with a condition that the area is located in somehow the same direction with other area where milk-run is applied, so that the truck can also come to pick up goods from that supplier without going out of the route too much.

The other parameters criteria are also required for milk-run implementation in medium scale of relationship: transportation cost, level of demand and stability. The parameter of transportation cost is the main reason that the availability of suppliers' transportation cost is necessary for this study. In current condition where direct shipment is applied, suppliers include transportation cost in their products prices. When milk-run is applied to suppliers, goods are picked up by third party logistics service so that suppliers do not spend resources for delivery process. Therefore, once milk-run is operated, the transportation cost in each product's price should be eliminated. The total amount of cost reduction from the products' price does not necessarily have to cover the amount of additional expense for the third logistics party service, as the main benefit gained from this change system is the reduction of warehouse consumption. However, the gap between eliminated transportation cost and additional service cost should not be too high so that it will be more worthy to apply milk-run to suppliers with available transportation costs which are not too low. For direct milk-run network application in this study, suppliers should have moderate to high transportation cost to be suitable being assigned to this system.

The level of demand in milk run concept aims to increase the cycle of pickup and delivery service in each day. The more cycle that the third party logistics service have, the lower price of service they can offer. It is not worthy to implement milk-run when the order is not much enough for making the delivery process separated in some cycles. Moreover, the inventory consumption will not be reduced that much either. The criteria set for demand level in milk-run network option is from medium to high. Stability also has a significant role that has to be taken into consideration to avoid future problem with the 3PL party. If the production schedule keeps changing overtime, it will be difficult to manage the route cycle to be in the schedule plan. The allowance for stability condition in milk-run network is also ranged between high and moderate level.

6.1.3. Milk-run via DC

All parameters are also significant in milk-run via distribution center system. However, the importance level and category range of each parameter is a bit different with direct milk-run. Since there will be more additional expense for distribution center rent, transportation cost is more prioritized to those suppliers with high transportation cost although the level of importance remains the same with direct milk-run: between high and medium transportation cost. In addition, there will be extra cost for hiring third party logistics service that there will be one additional truck needed for the operation. The normal trucks aim to pick up goods from suppliers and deliver to distribution center, while the extra truck is needed to carry the goods from distribution center to manufacturing plant. Hence, it is much more worthy to implement milk-run with DC to suppliers which provide high transportation cost to help to mitigate the additional cost for both DC rent and third party logistics service.

Suppliers' geographic location still play a fundamental role in this system. There has to be some numbers of supplier which are located in same area. The different criteria for suppliers' location between direct milk-run and milk-run via DC is the distance between suppliers and manufacturing plant. In milk-run through DC, suppliers' distance has moderate level of importance. While in direct milk-run suppliers should be located close to manufacturing plant, in milk-run via DC system suppliers should be located far away from manufacturing plant to make it worthy utilizing the distribution center. The range of distance allowance for this system is long to medium category.

Demand plays more important role in milk-run with DC system rather than direct milk-run network. The high importance category for demand level is due to achieve effectiveness of implementing this system by having high level of demand to make it worth. In addition, milk-run via DC network is worthy to be applied if only there are at least two groups of suppliers where the milk-run system can be applied. The level of stability for milk-run via DC system are also limited to high category and the importance of both parameters remain the same. The stability level becomes higher to maintain the smoothness of supply process to support production line, since suppliers which will be assigned to this network are not located in short distance to be able to give a quick countermeasure if something goes wrong.

6.1.4. Kanban System

Some factors related to Kanban delivery implementation are size of the goods, suppliers' geographic location in term of distance from manufacturing plant, level of demands and stability of production schedule. There are two possible ways of implementing Kanban system: suppliers still do the delivery on their own resources or goods are picked up from suppliers' site by using third logistics party service. In this study, the first scenario is used so there will not be any additional cost for 3PL and there will not be any reduction transportation cost from the parts prices and therefore transportation cost does not play any role in this network's criteria.

Size of the goods and suppliers' distance to manufacturing plant are the most important roles to apply Kanban delivery system. In this system, goods are supposed to be delivered just in a certain amount of time before they are needed in the production line.

For example, there can be up to eight times delivery in a day if the parts are large enough to fit a full truckload for one or two lots. Therefore, the criteria set for size of the goods in Kanban system must be ranged between large and medium size. In terms of suppliers' geographic location, suppliers must be located close to the manufacturing plant to be able to catch the time for continuous delivery activity to maintain the production supply going smoothly.

The parameter of demand has a moderate level of importance in Kanban delivery network. This criteria is basically supporting the criteria of lots size in aims of making the delivery in full truck load. When the lots size are large, the level of demand does not really matter even if the parts have low demand. When the lots size are medium, it will be helpful if the level of demand is high to fulfill one full truck load. The factor of stability does not play an important role in Kanban system although the preferred range for it is still in high and moderate level. This is due to the suppliers' location that must be located close to manufacturing plant so they are able to give quick countermeasure when there are sudden changes in the production plan schedule.

6.1.5. Overall Criteria for Each Network

The following table summarizes all the criteria needed for each transportation network. Green symbol indicates the suitable condition that should be satisfied for assigning suppliers to delivery network alternatives. Red symbol indicates the condition that must not be existed in selecting delivery method for suppliers because the importance issue of the parameter to the network option is in strong level. Cells contain parameters that do now affect the network solution are left blank. Blank cells can also represent the conditions for network option which are not preferable but still tolerable.

Parameters	Criteria	Direct shipment	Direct milk-run	Milk-run with DC	Kanban
Transport cost	High		✓	✓	
	Moderate		✓		
	Low				
Stability	High		✓	✓	✓
	Moderate		✓		✓
	Low				
Demand	High	✓	✓	✓	
	Moderate		✓	✓	
	Low			✗	
Size	Large	✓	✗	✗	✓
	Medium	✓	✓	✓	✓
	Small		✓	✓	✗
Location	Aggregated		✓	✓	
	Non-aggregated		✗	✗	
Distance	Long		✗	✓	✗
	Medium		✓	✓	✗
	Short		✓		✓

Table 8. Criteria for each network

Parameter of transportation cost has effects on direct milk-run and milk-run via distribution center. High transportation cost is more preferable for both milk-run networks particularly for milk-run via DC. However, when suppliers have low transportation cost, it is still possible to apply milk-run networks to those suppliers if the other parameters condition are satisfied. Parameter of stability has impact on milk-run networks and Kanban delivery. Again, there is no strict requirement of stability condition that suppliers must meet. High stability is preferable for milk-run networks and Kanban delivery, but all of the networks can still be applied to suppliers with low stability level. In parameter of demand, which has relationship with direct shipment and milk-run networks, there is one strict condition for milk-run via distribution center as can be seen there is a red mark in the table. High level of demand is preferable for all related networks, and suppliers with low level of demand can be assigned to any network except milk-run via distribution center. Due to a strong relationship key between milk-run via DC network with level of demand, non-preferred category of the criteria, which is low level of demand, is not tolerable for the suppliers to be assigned to the network. The next parameter, size of the goods, is related to all networks and has strict condition to milk-run network and Kanban delivery. Large size of goods is not allowed for direct milk-run and milk-run via DC network. On the contrary, small size of goods is not allowed for Kanban delivery. The location of suppliers affects strongly to direct milk-run and milk-run via DC network. Both milk-run networks require aggregated location of suppliers to be able to apply the networks. The distance between suppliers and manufacturing plant has moderate effect on milk-run via DC network and strong effect on direct milk-run and Kanban delivery. Long distance is not allowed for direct milk-run, while Kanban delivery only tolerates short distance which means there is no chance to assign Kanban delivery to suppliers which are located in medium and long distance from the manufacturing plant.

6.2. Parameters Analysis

This subchapter describes the third step of the study which is the analysis of suppliers' condition based on given parameters and criteria. For each parameter, all suppliers will be classified into different criteria based on table 6. The suppliers' classification into categories for each parameter are taken based into suppliers' database from the case company. In the end of each section, there will be results provided about the outline of suppliers' condition for each parameter. The summaries are presented in tables showing number of suppliers in each category of each parameter along with some hypothesis about the possibilities to assign those suppliers into each related networks.

6.2.1. Transportation Cost

The transportation cost for each supplier is calculated in one year turn over by using the latest data taken of production plan in FY 2015. The calculation is made by multiplying the total transport cost for one unit car model with the total amount of production volume in one year. After the calculation is done for each supplier, the percentage of each supplier's cost portion compared to the total cost of all suppliers is calculated. The principle of ABC analysis is used to categorize each supplier into A category (high cost), B category (moderate cost) and C category (low cost). The following table shows the final result of transportation cost classification process for all suppliers.

Category	**Number of Suppliers**	**Percentage of cost**
A (high)	9	79.8%
B (moderate)	23	18.4%
C (low)	31	1.8%
Total	63	100%

Table 9. Suppliers' classification of transportation cost

According to the table above, there are more suppliers with low transportation cost and only few suppliers with high transportation cost. This condition is unlikely to support implementation in direct milk-run and milk-run via DC network, however there is no strict condition about this parameter to the networks. Both networks can still be applied to suppliers with low and moderate transportation costs whose categories in other parameters meet the ideal condition of milk-run networks.

6.2.2. Level of Demand and Stability

In this section, the variety of changed demands for each car model will be analyzed. The data is taken from the last six months production schedule. The following table shows the number of units that are planned to be produced in one year, including the difference number of units between previous and next month.

CAR MODEL	Month I	GAP 1	Month II	GAP 2	Month III	GAP 3	Month IV	GAP 4	Month V	GAP 5	Month VI
Grand Livina	11,223	-122	11,101	19	11,120	-109	11,011	72	11,083	182	11,265
Serena	2,652	0	2,652	0	2,652	0	2,652	-96	2,556	24	2,580
Juke	8,920	200	9,120	1	9,121	1,314	10,435	-372	10,063	-11	10,052
X-trail	10,825	-85	10,740	0	10,740	84	10,824	0	10,824	-84	10,740
Datsun	40,051	-367	39,684	168	39,852	36	39,888	0	39,888	9	39,897

Table 10. Data of production schedule

The GAP numbers from table 8 are taken in absolute value to see and calculate the total fluctuation number for each model, as well as the percentage to the amount of unit production. The total units of fluctuation for each car model in the last six months is presented in below table.

CAR MODEL	UNIT						PERCENTAGE					
	1	**2**	**3**	**4**	**5**	**TOTAL**	**1**	**2**	**3**	**4**	**5**	**TOTAL**
Grand Livina	122	19	109	72	182	**504**	1%	0%	1%	1%	2%	**5%**
Serena	0	0	0	96	24	**120**	0%	0%	0%	4%	1%	**5%**
Juke	200	1	1,314	372	11	**1,898**	2%	0%	14%	4%	0%	**20%**
X-trail	85	0	84	0	84	**253**	1%	0%	1%	0%	1%	**2%**
Datsun	367	168	36	0	9	**580**	1%	0%	0%	0%	0%	**1%**

Table 11. Calculation of fluctuation

The fluctuation level in both measurement of units, which is the real value, and the total percentage compared to the total number of production volume from table 9 are taken and summarized as in below figure.

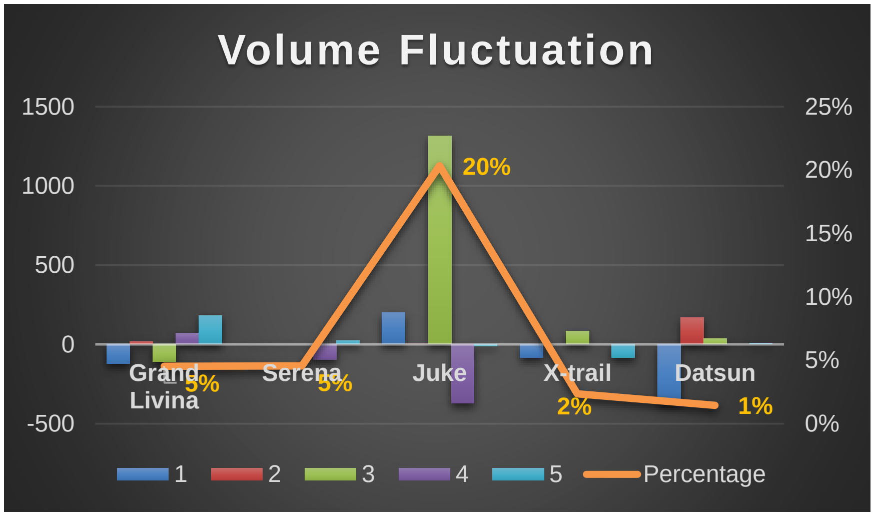

Figure 12. Fluctuation of each car model

From the graph above, Juke is clearly seen as the most fluctuated model in both units and percentage measurement (20%). Followed by Grand Livina and Serena model with 5% fluctuation to the amount of volume. The most stable car models according to the graph percentage are X-trail with only 2% and low units of fluctuation and Datsun with 1% volatility although the units of fluctuation seems higher. The summary of demand and stability level for each car model is listed in below table.

CAR MODEL	**DEMAND**	**STABILITY**
Grand Livina	Moderate	Moderate
Serena	Low	Moderate
Juke	Moderate	Low
X-trail	Moderate	High
Datsun	High	High

Table 12. Level of demand and stability for each model

The information about demand and stability level of each car model are then used to analyze suppliers’ demand and stability level based on the car models that they supply. When the suppliers supply for car models with high and moderate demand or stability, they are classified as high. Suppliers that supply for moderate demand or stability car models are classified as moderate, as well as if they also supply to low demand or stability car model. Suppliers that only supply for car model with low demand or stability are classified as low. The following table shows number of suppliers in each parameter’s classification.

	Demand	**Stability**
High	49	23
Moderate	12	27
Low	2	13

Table 13. Number of suppliers in demand and stability parameters

In parameter of demand, 49 out of 63 suppliers are in high demand level which is likely to support direct shipment, direct milk-run, and milk-run via DC network implementation. In parameter of stability, 50 out of 63 suppliers are in high and moderate stability level which is also likely to support implementation of direct milk-run, milk-run via DC network, and Kanban delivery. Overall, the condition of suppliers’ demand and stability level is good to support the application of tailored transportation network.

6.2.3. Size of the Goods

There are over 1,000 kinds of part in total to be order for producing all types of car. The size of the goods will be determined based on supplier’s standard number of packing (SNP) for one lot, since the orders are made in lot amount, and then multiplier by the total amount of lots for the whole year, based on the latest production plan. The category for the lots size is originally classified into five levels. Those categories are extra-large, large, medium, small, and extra-small. However, since there is no differentiation between extra-large and large and between extra-small and small in criteria setting of network options, the category for size of goods was narrowed into three classifications: large, medium, and small size in order to simplify the analysis process. Yet the original categories will be presented in the final framework analysis as consideration to estimate the suppliers grouping for milk-run network and milk-run via DC system. The following table shows the number of suppliers which are classified into each category based on their lots size.

Original Category	Amount of Suppliers	Simplified Category	Amount of Suppliers
XL	11	Large	24
L	13		
M	20	Medium	20
S	8	Small	19
XS	11		

Table 14. Suppliers' classification based on size of goods

From the table above, the category in size of the goods parameter seem to be almost equally distributed. There are 44 suppliers in the range of large and medium size which are likely to be assigned to either direct shipment or Kanban delivery. There are 39 suppliers in the range of medium and small size which are likely to be assigned to direct milk-run or milk-run via DC network. However, there is no possibility to assign both milk-run networks to 24 suppliers with large size and 19 suppliers with small size cannot be assigned into Kanban delivery.

6.2.4. Suppliers' Geographic Location

There are two parameters which are related to geographic location. The first one is suppliers' distance from manufacturing plant. The classification of this parameter is based on the city that suppliers are located. Those 63 suppliers are located in 10 different cities. Two cities are classified as short distance, three are medium, and 5 cities are categorized as long distance. The other parameter is suppliers' location in aggregated area near other suppliers. The classification is made based on suppliers' location in same city. If there are more than two suppliers in a city, then they are categorized as aggregated location. Otherwise, when there are less than three suppliers in a city, they are classified as non-aggregated. The following table shows the number of suppliers with each category in both parameters.

Parameter	***Distance***			***Location***	
Category	Short	Medium	Long	Aggregated	Non-aggregated
Number of Suppliers	23	23	17	58	5

Table 15. Suppliers' geographic location parameters

The parameter of suppliers' distance has impact on direct milk-run, milk-run via distribution center, and Kanban delivery while the parameter of location is only related to both milk-run networks. From the table above, there are 23 suppliers which are located in short distance can be assigned to Kanban delivery, 46 suppliers in the range of short and medium distance can be assigned to direct milk-run, and 40 suppliers in the range of medium and long distance can be assigned to milk-run via DC network. On the other hand, there are 17 suppliers which are located in long distance cannot be assigned to direct milk-run and 40 suppliers with medium and long distance cannot be assigned to Kanban delivery. In the parameter of location, there are only five suppliers which are not located in aggregated area so that they cannot be assigned to neither direct milk-run nor milk-run via DC center. On the whole, the condition of both suppliers' distance and location are likely to support the application of tailored network.

6.2.5. Overall Condition of Suppliers

The complete table of suppliers with all parameters is presented in Appendix 1. The following table shows accumulation of number of suppliers on each parameter's classification.

Parameters	Criteria	Number of Suppliers
Transport cost	High	9
	Moderate	23
	Low	31
Stability	High	23
	Moderate	27
	Low	13
Demand	High	49
	Moderate	12
	Low	2
Size	Large	24
	Medium	20
	Small	19
Location	Aggregated	58
	Non-aggregated	5
Distance	Long	17
	Medium	23
	Short	23

Table 16. Suppliers' classification of each parameter's category

From the parameter of transportation cost, the possibilities to apply milk-run networks seem to be moderate as there are only nine suppliers with high transportation cost and more than a half with low transportation cost. According to numbers of stability level, there are more than 50% chance to apply direct milk-run, milk-run via DC, and Kanban delivery. Size of the goods and distance classification show almost similar possibilities of both milk-run networks and Kanban delivery. Demand condition indicates high possibilities for assigning suppliers to direct milk-run, milk-run via DC, and Kanban delivery system. 92% of suppliers are located in aggregated location which indicates that there are many suppliers are likely assigned to direct milk-run and milk-run via DC network. There are 23 suppliers located close to the manufacturing plant which can be candidates for being assigned to Kanban delivery, 46 suppliers located in the range of medium and short distance are candidates for milk-run network, and 40 suppliers located in long and medium distance are candidates for milk-run via distribution center network. Therefore, in parameter of distance, the possibilities for assigning suppliers to different networks seem to be evenly distributed.

6.3. Network Selection

The selection process for the most suitable network for each supplier is conducted with scoring method. The scoring will be given to each parameter for each delivery network. The first step is to determine the range of scoring value with the remark of each value. Criteria of each score will depend on network's parameter's weight and condition. The following table lists the score values and explanation related to each score.

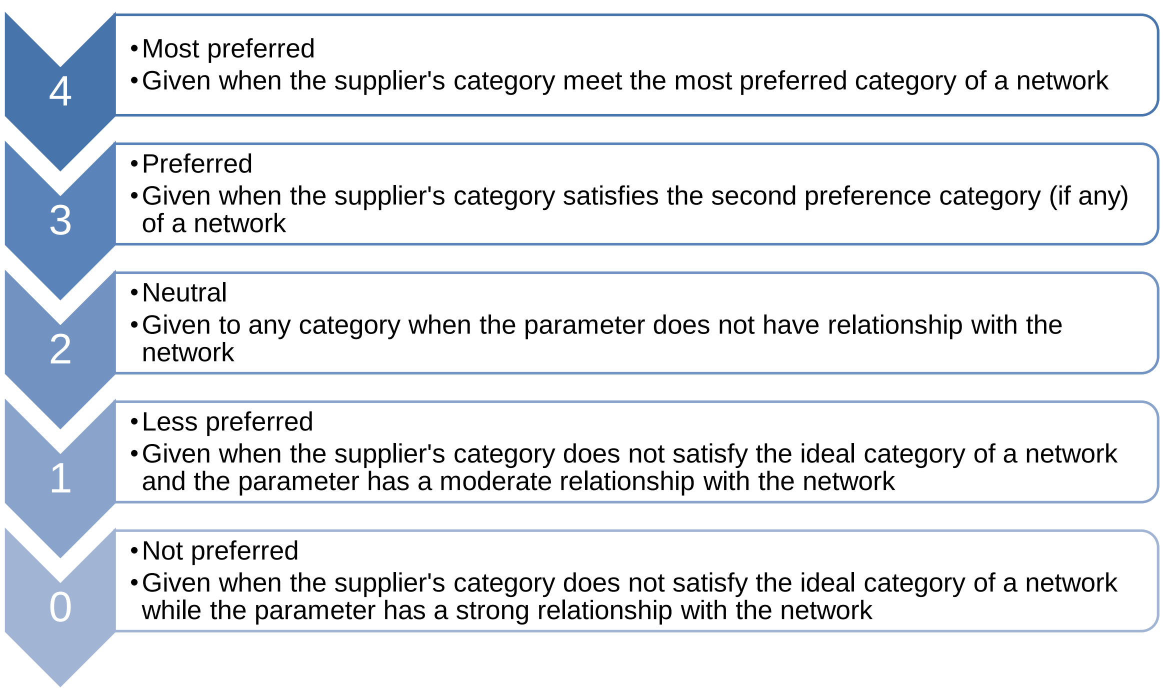

Figure 13. Scoring category

The figure above shows the range of scoring number between zero to four based on the supplier's condition compared with the ideal condition of each network. The scoring also takes into account the weight of parameters in the relationship with network options. For example, milk-run network has a strong relationship with the parameter of size and moderate relationship with the parameter of demand. In term of size, the most preferred category for milk-run network is medium size and the second preference is small size. In term of demand, the most ideal category is high demand and the second one is moderate level of demand. In the scoring process of size, four will be given when a supplier has medium size of parts which is the most preference category and three will be given if the supplier's parts size is categorized as small which is the second preference condition of size parameter in milk-run network. The same rule applies to scoring process of demand. However, when the supplier's size is large, which does not satisfy the required condition for milk-run, zero will be the score since size is weighted as an extremely important for milk-run implementation. Therefore, there is no toleration if the condition cannot meet the ideal requirement of milk-run network. While in term of demand, if a supplier has low category, one will be given because the relationship between milk-run network and parameter of demand is moderate which means that even if the supplier's demand category cannot meet the preference condition, milk-run can still be applied as long as supplier's condition in other parameters could satisfy the ideal criteria of milk-run network. The score of two is given when the network is not significantly correlated to the parameters. For example, direct shipment has almost nothing to do with the parameter of location. Hence, two will be set as the score for any condition of supplier's location in the analysis of direct shipment.

As have been mentioned above, in the data scoring process, the score will be given based on the suppliers' condition of each criteria compared to the ideal condition for the network options. The following table provides the first and second preference for ideal condition of each parameter in each network solution.

Network	Preference	Stability	Demand	Size	Location	Distance	Transport Cost
Direct shipment	**1st preference**	Neutral	High	Large	Neutral		
	2nd preference		-	Medium			
Milk-run	**1st preference**	High	High	Medium	Aggregated	Short	High
	2nd preference	Moderate	Moderate	Small	-	Medium	Moderate
Milk-run via DC	**1st preference**	High	High	Medium	Aggregated	Long	High
	2nd preference	-	Moderate	Small	-	Medium	-
Kanban delivery	**1st preference**	Neutral	High	Large	Neutral	Short	Neutral
	2nd preference		Moderate	Medium		-	

Table 17. Network selection preference condition

Each network can have one or two preferences of its ideal condition of each parameter. For example, in parameter of size, direct milk-run mostly prefers to have goods with medium size and second preference with small size goods. However, in parameter of location, direct milk-run has to have aggregated location of suppliers and in this case there is no second preference. There are some parameters which are not related to the networks or have weak relationships with the networks. Here, there is no preference for the network's ideal condition which is expressed as neutral. This table will be used as guidance for scoring process of each supplier to each network. The matrix of scored parameters for all suppliers and network options is presented in appendix 2.

After scoring networks' parameters of all suppliers, the next step is calculating final score for each network option. The first part of calculation is done by summing the product of parameters' scores with parameter's weights. The numbers of parameters weight in this calculation are nine, three and zero. Nine is for strong related parameters to the networks, three is for moderate parameters' impact to the networks, and one is for both weak correlation and no correlation of parameters to the networks. This formula aims to emphasize the scores of strong parameters that meet the ideal criteria of the network by multiplying the scores with the weights. The next calculation is to multiply the result of the first calculation with the product of the scores in each supplier. This formula is intended for eliminating the network, which has any strong parameter that does not satisfy its ideal criteria, as a solution. Since in that case the given score is zero, the final calculation result will be zero after being multiplied by each parameter's score. The final score is then used to determine the most appropriate network option for each supplier.

7. RESULT

7.1. Framework of Tailored Network

According to the network selection result, all of the four networks options are applied to different numbers of suppliers. The result of network selection which contains final score and chosen network for each supplier can be seen in appendix 3, while the number of suppliers that are assigned to each delivery network is presented in below table.

Transportation network	**Amount of suppliers**
Direct shipment	17
Milk-run	21
Milk-run with DC	17
Kanban delivery	13

Table 18. Number of suppliers in each network

There are 17 suppliers which are assigned to keep applying the current delivery method by direct shipment. Hence there will not be anything changed to those suppliers and there is no further analysis needed. 13 suppliers are assigned to Kanban delivery and this matter is also independent from other suppliers' condition. On the other hand, suppliers that are assigned to milk-run in both direct way and via distribution center are still needed to be analyzed to check if there are still located in aggregated location. The following subchapter will analyze the outline possibilities of applying direct milk-run to 21 suppliers and milk-run with DC to 12 suppliers.

7.1.1. Scenario for Milk-run Networks

The purpose of this section is to recheck the feasibility of milk-run networks application to the chosen suppliers, as well as to set the suppliers grouping for milk-run route cycles. The following table presents the list of suppliers which are assigned to direct milk-run and milk-run with distribution center, along with their city area and the size of their parts.

Network	Suppli	Area	Size
Direct milk-run	S28	A	M
Direct milk-run	S39	A	M
Direct milk-run	S37	A	S
Direct milk-run	S1	A	XS
Direct milk-run	S2	B	M
Direct milk-run	S27	B	M
Direct milk-run	S45	B	M
Direct milk-run	S48	B	M
Direct milk-run	S53	B	M
Direct milk-run	S56	B	M
Direct milk-run	S41	B	XS
Direct milk-run	S38	C	M
Direct milk-run	S47	C	M
Direct milk-run	S31	C	S
Direct milk-run	S61	C	S
Direct milk-run	S16	C	XS
Direct milk-run	S36	C	XS
Direct milk-run	S43	C	XS
Direct milk-run	S49	C	XS
Direct milk-run	S23	D	M
Direct milk-run	S60	D	M
Milk-run via DC	S12	B	M
Milk-run via DC	S10	B	S
Milk-run via DC	S33	B	S
Milk-run via DC	S40	B	XS
Milk-run via DC	S4	E	M
Milk-run via DC	S8	E	M
Milk-run via DC	S21	E	M
Milk-run via DC	S22	E	M
Milk-run via DC	S30	E	S
Milk-run via DC	S44	E	S
Milk-run via DC	S35	E	XS
Milk-run via DC	S17	F	XS

Table 19. Suppliers mapping in direct milk-run and milk-run via DC

In the table above, data has been sorted in the order of assigned network, area which represents city location, and size of supplied goods. From the list of area, it can be seen that most of suppliers are still being in aggregated location as there are more than three suppliers located in same area. There are two suppliers (S23 and S60) which stand only in pair in area D and one supplier (S17) which stands alone in area F. Therefore, these suppliers can be dropped from the milk-run list and moved to other possible network solutions. From the table of final score, the next suitable solution for S23 and S60 is Kanban delivery while S17 has only one option left which is direct shipment.

Suppliers that are located in area B are assigned to different method, direct milk-run (S27, S45, S48, S53, S56, and S41) and milk-run with DC (S12, S10, S33, S40). Out of four suppliers which are assigned to milk-run with DC network, two have small size and one has extra small size. Given these conditions, it will be more effective to move them to direct milk-run network and join with other seven suppliers.

As some little change are made, the next step is to determine how many trucks or groups needed to facilitate those suppliers with milk-run networks. The division of groups will be estimated based on the size of goods without detail calculation. Implementing milk-run will be assumed to pick up and delivery goods for three lots of production in each route. According to the interview with people from inventory department, one truck is estimated to fit approximately three lots medium size parts from four to five suppliers. This information is used as the basis of assigning the suppliers into groups for the milk-run route cycle. The number of groups needed in each city area for milk-run implementation is presented in below table. The analysis result will then be used for calculating the additional cost emerged by the application of milk-run distribution

Network	Suppli	Area	Size	Group
Direct milk-run	S28	A	M	1 group
Direct milk-run	S39	A	M	
Direct milk-run	S37	A	S	
Direct milk-run	S1	A	XS	
Direct milk-run	S2	B	M	2 groups
Direct milk-run	S27	B	M	
Direct milk-run	S45	B	M	
Direct milk-run	S48	B	M	
Direct milk-run	S53	B	M	
Direct milk-run	S56	B	M	
Direct milk-run	S12	B	M	
Direct milk-run	S10	B	S	
Direct milk-run	S33	B	S	
Direct milk-run	S40	B	XS	
Direct milk-run	S41	B	XS	
Direct milk-run	S38	C	M	1 group
Direct milk-run	S47	C	M	
Direct milk-run	S31	C	S	
Direct milk-run	S61	C	S	
Direct milk-run	S16	C	XS	
Direct milk-run	S36	C	XS	
Direct milk-run	S43	C	XS	
Direct milk-run	S49	C	XS	
Milk-run via DC	S4	E	M	1 group
Milk-run via DC	S8	E	M	
Milk-run via DC	S21	E	M	
Milk-run via DC	S22	E	M	
Milk-run via DC	S30	E	S	
Milk-run via DC	S44	E	S	
Milk-run via DC	S35	E	XS	

Table 20. Fixed suppliers mapping in direct milk-run and milk-run via DC

From the table above, there is only one group of suppliers that is assigned to milk-run via distribution center system, which is not the best condition in this system application. As has been mentioned in the network criteria analysis part, it is more worthy to implement milk-run via DC system if there are more than one group of milk-run cycles that will deliver parts to the DC. The final cost calculation will still be made based on this scenario by taking into consideration that there is only one milk-run group using distribution center facility so that it does not require a big distribution center area to accommodate the parts from those suppliers before taken to the manufacturing plant. The final conclusion and recommendation for the company will be made based on the cost calculation result.

7.1.2. Final Framework of Tailored Network

As there are some modifications in milk-run area which also impact to the number of suppliers in direct shipment and Kanban delivery, hence the final result of network assignment for each supplier is presented in this section. The following table shows the list of all 63 suppliers with the selected network option for each of them.

Supplier	Network	Supplier	Network	Supplier	Network
S1	Milk-run	S22	Milk-run via DC	S43	Milk-run
S2	Milk-run	S23	Kanban	S44	Milk-run via DC
S3	Kanban	S24	Direct shipment	S45	Milk-run
S4	Milk-run via DC	S25	Kanban	S46	Kanban
S5	Kanban	S26	Kanban	S47	Milk-run
S6	Kanban	S27	Milk-run	S48	Milk-run
S7	Direct shipment	S28	Milk-run	S49	Milk-run
S8	Milk-run via DC	S29	Kanban	S50	Direct shipment
S9	Kanban	S30	Milk-run via DC	S51	Direct shipment
S10	Milk-run via DC	S31	Milk-run	S52	Kanban
S11	Direct shipment	S32	Direct shipment	S53	Milk-run
S12	Milk-run via DC	S33	Milk-run via DC	S54	Kanban
S13	Direct shipment	S34	Direct shipment	S55	Direct shipment
S14	Direct shipment	S35	Milk-run via DC	S56	Milk-run
S15	Direct shipment	S36	Milk-run	S57	Direct shipment
S16	Milk-run	S37	Milk-run	S58	Direct shipment
S17	Direct shipment	S38	Milk-run	S59	Kanban
S18	Kanban	S39	Milk-run	S60	Kanban
S19	Direct shipment	S40	Milk-run via DC	S61	Milk-run
S20	Direct shipment	S41	Milk-run	S62	Direct shipment
S21	Milk-run via DC	S42	Direct shipment	S63	Kanban

Table 21. Final framework of tailored network

The amount of suppliers that are assigned to each transportation method based on the final version of tailored network framework are presented in the following table.

Transportation network	**Amount of suppliers**	**Percentage**
Direct shipment	18	29%
Milk-run	23	36%
Milk-run with DC	7	11%
Kanban delivery	15	24%
Total	**63**	**100%**

Table 22. Fixed number of suppliers of each network

There are 18 suppliers which cover around 29% of the total number of suppliers that are not supposed to change their current delivery system by direct shipment network. 23 suppliers are assigned to direct milk-run distribution system while milk-run via DC network is applied to seven suppliers. Both networks with the basis of milk-run concept can be implemented to 47% of suppliers which is almost a half of the total suppliers. In these two networks, some additional costs will be emerged and some transportation cost will be reduced which will be calculated in the next section. The rest 24% which consists of 15 suppliers are assigned to Kanban delivery network which does not make any change in cost.

7.2. Cost Calculation

The last step in this study is to calculate how much the costs will be emerged by implementing the proposed framework as well as how much the transport cost can be eliminated from the purchased parts. As have been mentioned in methodology part, the cost calculation will be measured roughly based on assumptions. Some assumptions of the calculation are number of lots carried in each cycle (three lots per cycle), number of cycles in one day (five cycles per day), and a fixed milk-run transportation fee without considering possibilities of increased fee due to inflation or other economic matters.

The aim of calculation is to compare the emerged cost from milk-run networks and reduced transportation cost from the parts price. The following table shows the data of all necessary numbers for the calculation. All price have been converted to Euro currency with the rate of 15,000 IDR for one EUR.

No.	Element	Original version	Roundup version	Remarks
1	3PL service fee each cycle	€ 55.00		On the basis of supplier's quotation
2	Total volume in one year	39,897.00		Taken from the highest volume of car model (Datsun)
3	Total lots in one year	3,324.75	3,325	Total volume in one year divided by 12 (roundup)
4	Working days in a year	245.00		22 days in a month reduced by public holidays
5	Total lots in one day	13.57	14	Total lots in one year divided by working days in a year (roundup)
6	Cycle per day	4.52	5	Total lots in one day divided by three (roundup)
7	Cycle per year	1,108.25	1,225	Cycle per day multiplied by working days in a year
8	Yearly expense for one group	€ 60,954	**€ 67,375**	Cycle per year multiplied by 3PL service fee each cycle

Table 23. Calculation of 3PL service fee

The cost for goods pick-up and delivery service from suppliers is taken from 3PL supplier’s quotation which is € 55 for each trip. It means if for example there are three routes for two groups in one day, then the price will be multiplied by three and two. The total volume of production units in one year is taken from the highest volume of car model based on the latest production forecast by the time the observation was conducted, which is Datsun with 39,897 units, because the milk-run system will combine all parts from all model so that the total trips are based on the highest production volume car model. Since the production process is set based on lot size, which means when producing one car model it has to be minimum one lot or 12 units of car, the parts order to supplier is also made based on lot quantity. Therefore, the total lots of the highest car model unite production in one year is the total volume divided by 12 and results 3,325 lots in roundup version. There are 245 working days in one year and the amount of lots for one day is the total lots in one year divided by working days which results around 14 lots per day. The milk-run system is assumed to have three lots in one cycle so that there are five lots per day and multiplied by working days per year, there will be 1,225 cycles in one year. Therefore, the total expense for milk-run pick-up and delivery service is € 55 multiplied by 1,225 cycles and results € 67,375 per year for one group of suppliers location.

Based on the table 20, there are four groups will be set for direct milk-run. Therefore, the total expense will be the yearly expense for one group multiplied by four which results € 269,500. After getting the additional expense for direct milk-run system, it will be compared to the total amount of transportation cost which ideally should be cut from the products prices. The table of transportation cost of each suppliers which are assigned to milk-run distribution system can be seen in appendix 4. The total transportation cost in one year is around € 248,298. Hence, for implementing direct milk-run system, the company has to spend additional expense around € 21,202 in one year.

The next calculation if for calculating the additional expense for milk-run via distribution center system. The calculation for milk-run with DC network is presented in below table.

Element	Basic fee	Yearly expense	Total cost
Milk-run cost	€ 67,375 / year / group	€ 67,375	€ 154,363
DC rental cost	€ 2,400 / month	€ 28,800	
Cycle cost	€ 47.5 / cycle	€ 58,188	

Table 24. Cost calculation for milk-run via DC network

Since there is only one group needed for the milk-run distribution process from suppliers to the DC, the yearly expense for milk-run service is taken as € 67,375. Another additional costs are emerged from the DC rental fee and distribution service from the DC to manufacturing plant. The rental cost for the distribution center is around € 2,400 per month which results € 28,800 for one year. The service fee for carrying goods from DC to manufacturing plant is € 47.5 per cycle. Using the calculation from table 20, there are approximately 1,225 cycles in one year for the milk-run routing activities which results 58,188 for parts distribution from the DC to manufacturing plant. Hence, the total additional expense for implementing milk-run via DC system is € 154,363. From appendix 4, the total transportation cost from suppliers with milk-run via DC network could be reduced to € 158,233. Therefore, there is surprisingly a decreasing cost at amount of € 3,871 in milk-run via DC implementation. The final cost calculation from both networks are then combined as the following table.

	Direct milk-run	**Milk-run via DC**
Additional expense	+ € 269,500	+ € 154,363
Eliminated transport cost	- € 248,298	- € 158,233
Total	+ € 21,202	- € 3,871
Combined cost	**+ € 17,331**	

Table 25. Summary of cost calculation

The table above shows the accumulation of additional and reduced cost in both direct milk-run and milk-run via DC system. As a result, the total cost that has to be spent by the company for implementing the proposed framework is around € 17,331 per year or € 1,444 per month.

8. CONCLUSION

Tailored network is an excellent shipment method to optimize the supply chain system both from suppliers to manufacturing plant or from distributors to consumers. The concept of tailored network contains flexibility to assign different shipment method to suppliers based on some conditions. In this case study, f our different methods are proposed to be applied to different number of suppliers in order to optimize the logistics system and reduce the warehouse consumption in the case company. Out of 63 suppliers with direct shipment as their current delivery system, 18 suppliers are suggested to keep using direct delivery method. 25 suppliers are assigned into milk-run distribution systems, 18 of them by using direct milk-run network and seven with milk-run via DC system. Finally, the rest 15 suppliers are assigned to Kanban delivery system.

One challenge in applying tailored network to the supply chain system is there would be higher coordination required in the operation, particularly at the beginning of implementation. Changing current transportation system would involve number of parties including people from logistics and inventory section, receiving and loading process, purchasing department and suppliers. However, this system should be simpler than it sounds at the beginning by the time people are getting used to run it this way. According to cost calculation result, the company has to spend around € 17,331 in one year as additional cost for implementing the proposed transportation framework which is another challenge to adopt this concept of tailored logistics network. However, this amount of expense is still less than the cost for renting or building another warehouse and there are some points of beneficial in implementing this framework. The company should consider about the saving consumption in the current inventory area which is the main purpose of this study. By applying tailored logistics network, the consumption of warehouse would be much less and all parts should be accommodated well in the inventory even when the production volume is high. Another thing that can be taken into account are the concern about green logistics issues. By implementing tailored logistics network, particularly direct milk-run system and milk-run via distribution center, the logistics activities could support the concerns of green supply chain management. The milk run distribution network is designed to improve loading rates at possible levels which leads to the number of trucks and distance reduction. As a result, it is a very good transportation system which can reduce the exhaust gas of trucks. Therefore, the application of milk run logistics can be highly evaluated from the viewpoint of environmental policy.

One of limitations on this study is the incomplete number of suppliers which are taken into analysis. When the transportation costs from all suppliers have been completed, the framework of tailored network would be better with more than one group assigned to milk-run with distribution center system. And theoretically, implementation of tailored logistic network should reduce transportation cost if all ideal conditions are satisfied including support from suppliers, which in this case to provide transportation cost data in their products prices to be eliminated as they do not conduct the delivery process anymore in milk-run systems. Another limitation is there is no calculation of reduced consumption in the warehouse after implementing the proposed framework. Further study can attempt to complete suppliers' data for more optimum results and use appropriate method for measuring the reduction of inventory area to be compared with the emerged cost from other ways of delivery methods to obtain better evaluation of the proposed transportation network.

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Appendix 1. Data of suppliers' category in each parameter

SUPPLIER	CAR MODEL					PARAMETER					
	Datsun	X-Trail	Grand Livina	Juke	Serena	Stability	Demand	Size	Location	Distance	Cost
S1	✓		✓			Moderate	High	Small	Aggregated	Medium	Low
S2	✓					High	High	Medium	Aggregated	Medium	Moderate
S3	✓					High	High	Large	Aggregated	Short	Moderate
S4	✓		✓			Moderate	High	Medium	Aggregated	Long	Moderate
S5			✓	✓		Low	Moderate	Large	Aggregated	Short	Low
S6	✓	✓	✓	✓	✓	Low	High	Large	Aggregated	Short	Moderate
S7	✓					High	High	Large	Aggregated	Medium	Moderate
S8	✓			✓		Low	High	Medium	Aggregated	Long	Low
S9			✓	✓		Low	Moderate	Large	Aggregated	Short	Low
S10	✓					High	High	Small	Aggregated	Medium	Low
S11	✓		✓	✓		Low	High	Large	Aggregated	Long	Low
S12	✓					High	High	Medium	Aggregated	Medium	Low
S13					✓	Moderate	Low	Small	Aggregated	Long	Low
S14	✓					High	High	Medium	Aggregated	Long	Moderate
S15	✓		✓			Moderate	High	Small	Non-aggregated	Long	Low
S16	✓					High	High	Small	Aggregated	Short	Moderate
S17	✓					High	High	Small	Aggregated	Long	Moderate
S18			✓			Moderate	Moderate	Large	Aggregated	Short	Moderate
S19			✓			Moderate	Moderate	Large	Aggregated	Long	Low
S20	✓					High	High	Medium	Non-aggregated	Long	Moderate
S21	✓					High	High	Medium	Aggregated	Long	Moderate
S22	✓		✓			Moderate	High	Medium	Aggregated	Long	Low
S23	✓		✓			Moderate	High	Medium	Aggregated	Short	Moderate
S24			✓			Moderate	Moderate	Small	Non-aggregated	Medium	Low
S25	✓	✓	✓			Moderate	High	Large	Aggregated	Short	High
S26	✓		✓			Moderate	High	Large	Aggregated	Short	Moderate
S27	✓		✓			Moderate	High	Medium	Aggregated	Medium	High
S28	✓					High	High	Medium	Aggregated	Medium	Moderate
S29	✓	✓	✓	✓		Low	High	Large	Aggregated	Short	High
S30	✓		✓			Moderate	High	Small	Aggregated	Long	High
S31	✓		✓			Moderate	High	Small	Aggregated	Short	Low
S32	✓					High	High	Large	Aggregated	Medium	Low
S33	✓					High	High	Small	Aggregated	Medium	Low
S34	✓		✓			Moderate	High	Large	Non-aggregated	Long	Low
S35	✓	✓	✓			Moderate	High	Small	Aggregated	Long	Low
S36	✓					High	High	Small	Aggregated	Short	Moderate
S37	✓		✓	✓		Low	High	Small	Aggregated	Medium	Moderate
S38				✓		Low	Low	Medium	Aggregated	Short	Low
S39			✓			Moderate	Moderate	Medium	Aggregated	Medium	Low
S40	✓					High	High	Small	Aggregated	Medium	Low
S41	✓		✓			Moderate	High	Small	Aggregated	Medium	Low
S42	✓					High	High	Medium	Non-aggregated	Long	High
S43	✓		✓		✓	Moderate	High	Small	Aggregated	Short	Low
S44	✓					High	High	Small	Aggregated	Long	Low
S45		✓				Moderate	Moderate	Medium	Aggregated	Medium	Low
S46	✓		✓			Moderate	High	Large	Aggregated	Short	Low
S47	✓					High	High	Medium	Aggregated	Short	Moderate
S48	✓		✓	✓	✓	Low	High	Medium	Aggregated	Medium	Moderate
S49		✓	✓	✓		Low	Moderate	Small	Aggregated	Short	Moderate
S50	✓		✓			Moderate	High	Large	Aggregated	Medium	High
S51	✓					High	High	Large	Aggregated	Medium	Low
S52			✓	✓		Low	Moderate	Large	Aggregated	Short	Moderate
S53		✓				Moderate	Moderate	Medium	Aggregated	Medium	Low
S54			✓	✓		Low	Moderate	Large	Aggregated	Short	Low
S55	✓					High	High	Large	Aggregated	Medium	Moderate
S56	✓		✓			Moderate	High	Medium	Aggregated	Medium	Low
S57	✓					High	High	Large	Aggregated	Medium	Low
S58	✓					High	High	Large	Aggregated	Long	Moderate
S59	✓					High	High	Large	Aggregated	Short	High
S60	✓		✓			Moderate	High	Medium	Aggregated	Short	Moderate
S61			✓	✓		Low	Moderate	Small	Aggregated	Short	Low
S62	✓		✓			Moderate	High	Large	Aggregated	Medium	High
S63	✓		✓			Moderate	High	Large	Aggregated	Short	High

Appendix 2. Suppliers scoring process

SUPPLIER	Direct Shipment						Milk-run						Milk-run via DC						Kanban					
	1	3	3	1	1	1	3	3	9	9	9	3	3	9	9	9	3	3	1	3	9	1	9	1
	Stabil ity	Dema nc	Size	Locati on	Dista nc	Cost	Stabil ity	Dema nc	Size	Locati on	Dista nc	Cost	Stabil ity	Dema nc	Size	Locati on	Dista nc	Cost	Stabil ity	Dema nc	Size	Locati on	Dista nc	Cost
S1	2	4	1	2	2	2	3	4	3	4	3	1	1	4	3	4	3	1	2	4	0	2	0	2
S2	2	4	3	2	2	2	4	4	4	4	3	3	4	4	4	4	3	1	2	4	3	2	0	2
S3	2	4	4	2	2	2	4	4	0	4	4	3	4	4	0	4	1	1	2	4	4	2	4	2
S4	2	4	3	2	2	2	3	4	4	4	0	3	1	4	4	4	4	1	2	4	3	2	0	2
S5	2	1	4	2	2	2	1	3	0	4	4	1	1	3	0	4	1	1	2	3	4	2	4	2
S6	2	4	4	2	2	2	1	4	0	4	4	3	1	4	0	4	1	1	2	4	4	2	4	2
S7	2	4	4	2	2	2	4	4	0	4	3	3	4	4	0	4	3	1	2	4	4	2	0	2
S8	2	4	3	2	2	2	1	4	4	4	0	1	1	4	4	4	4	1	2	4	3	2	0	2
S9	2	1	4	2	2	2	1	3	0	4	4	1	1	3	0	4	1	1	2	3	4	2	4	2
S10	2	4	1	2	2	2	4	4	3	4	3	1	4	4	3	4	3	1	2	4	0	2	0	2
S11	2	4	4	2	2	2	1	4	0	4	0	1	1	4	0	4	4	1	2	4	4	2	0	2
S12	2	4	3	2	2	2	4	4	4	4	3	1	4	4	4	4	3	1	2	4	3	2	0	2
S13	2	1	1	2	2	2	3	1	3	4	0	1	1	0	3	4	4	1	2	1	0	2	0	2
S14	2	4	3	2	2	2	4	4	4	0	0	3	4	4	4	0	4	1	2	4	3	2	0	2
S15	2	4	1	2	2	2	3	4	3	0	0	1	1	4	3	0	4	1	2	4	0	2	0	2
S16	2	4	1	2	2	2	4	4	3	4	4	3	4	4	3	4	1	1	2	4	0	2	4	2
S17	2	4	1	2	2	2	4	4	3	4	0	3	4	4	3	4	4	1	2	4	0	2	0	2
S18	2	1	4	2	2	2	3	3	0	4	4	3	1	3	0	4	1	1	2	3	4	2	4	2
S19	2	1	4	2	2	2	3	3	0	4	0	1	1	3	0	4	4	1	2	3	4	2	0	2
S20	2	4	3	2	2	2	4	4	4	0	0	3	4	4	4	0	4	1	2	4	3	2	0	2
S21	2	4	3	2	2	2	4	4	4	4	0	3	4	4	4	4	4	1	2	4	3	2	0	2
S22	2	4	3	2	2	2	3	4	4	4	0	1	1	4	4	4	4	1	2	4	3	2	0	2
S23	2	4	3	2	2	2	3	4	4	4	4	3	1	4	4	4	1	1	2	4	3	2	4	2
S24	2	1	1	2	2	2	3	3	3	0	3	1	1	3	3	0	3	1	2	3	0	2	0	2
S25	2	4	4	2	2	2	3	4	0	4	4	4	1	4	0	4	1	4	2	4	4	2	4	2
S26	2	4	4	2	2	2	3	4	0	4	4	3	1	4	0	4	1	1	2	4	4	2	4	2
S27	2	4	3	2	2	2	3	4	4	4	3	4	1	4	4	4	3	4	2	4	3	2	0	2
S28	2	4	3	2	2	2	4	4	4	4	3	3	4	4	4	4	3	1	2	4	3	2	0	2
S29	2	4	4	2	2	2	1	4	0	4	4	4	1	4	0	4	1	4	2	4	4	2	4	2
S30	2	4	1	2	2	2	3	4	3	4	0	4	1	4	3	4	4	4	2	4	0	2	0	2
S31	2	4	1	2	2	2	3	4	3	4	4	1	1	4	3	4	1	1	2	4	0	2	4	2
S32	2	4	4	2	2	2	4	4	0	4	3	1	4	4	0	4	3	1	2	4	4	2	0	2
S33	2	4	1	2	2	2	4	4	3	4	3	1	4	4	3	4	3	1	2	4	0	2	0	2
S34	2	4	4	2	2	2	3	4	0	0	0	1	1	4	0	0	4	1	2	4	4	2	0	2
S35	2	4	1	2	2	2	3	4	3	4	0	1	1	4	3	4	4	1	2	4	0	2	0	2
S36	2	4	1	2	2	2	4	4	3	4	4	3	4	4	3	4	1	1	2	4	0	2	4	2
S37	2	4	1	2	2	2	1	4	3	4	3	3	1	4	3	4	3	1	2	4	0	2	0	2
S38	2	1	3	2	2	2	1	1	4	4	4	1	1	0	4	4	1	1	2	1	3	2	4	2
S39	2	1	3	2	2	2	3	3	4	4	3	1	1	3	4	4	3	1	2	3	3	2	0	2
S40	2	4	1	2	2	2	4	4	3	4	3	1	4	4	3	4	3	1	2	4	0	2	0	2
S41	2	4	1	2	2	2	3	4	3	4	3	1	1	4	3	4	3	1	2	4	0	2	0	2
S42	2	4	3	2	2	2	4	4	4	0	0	4	4	4	4	0	4	4	2	4	3	2	0	2
S43	2	4	1	2	2	2	3	4	3	4	4	1	1	4	3	4	1	1	2	4	0	2	4	2
S44	2	4	1	2	2	2	4	4	3	4	0	1	4	4	3	4	4	1	2	4	0	2	0	2
S45	2	1	3	2	2	2	3	3	4	4	3	1	1	3	4	4	3	1	2	3	3	2	0	2
S46	2	4	4	2	2	2	3	4	0	4	4	1	1	4	0	4	1	1	2	4	4	2	4	2
S47	2	4	3	2	2	2	4	4	4	4	4	3	4	4	4	4	1	1	2	4	3	2	4	2
S48	2	4	3	2	2	2	1	4	4	4	3	3	1	4	4	4	3	1	2	4	3	2	0	2
S49	2	1	1	2	2	2	1	3	3	4	4	3	1	3	3	4	1	1	2	3	0	2	4	2
S50	2	4	4	2	2	2	3	4	0	4	3	4	1	4	0	4	3	4	2	4	4	2	0	2
S51	2	4	4	2	2	2	4	4	0	4	3	1	4	4	0	4	3	1	2	4	4	2	0	2
S52	2	1	4	2	2	2	1	3	0	4	4	3	1	3	0	4	1	1	2	3	4	2	4	2
S53	2	1	3	2	2	2	3	3	4	4	3	1	1	3	4	4	3	1	2	3	3	2	0	2
S54	2	1	4	2	2	2	1	3	0	4	4	1	1	3	0	4	1	1	2	3	4	2	4	2
S55	2	4	4	2	2	2	4	4	0	4	3	3	4	4	0	4	3	1	2	4	4	2	0	2
S56	2	4	3	2	2	2	3	4	4	4	3	1	1	4	4	4	3	1	2	4	3	2	0	2
S57	2	4	4	2	2	2	4	4	0	4	3	1	4	4	0	4	3	1	2	4	4	2	0	2
S58	2	4	4	2	2	2	4	4	0	4	0	3	4	4	0	4	4	1	2	4	4	2	0	2
S59	2	4	4	2	2	2	4	4	0	4	4	4	4	4	0	4	1	4	2	4	4	2	4	2
S60	2	4	3	2	2	2	3	4	4	4	4	3	1	4	4	4	1	1	2	4	3	2	4	2
S61	2	1	1	2	2	2	1	3	3	4	4	1	1	3	3	4	1	1	2	3	0	2	4	2
S62	2	4	4	2	2	2	3	4	0	4	3	4	1	4	0	4	3	4	2	4	4	2	0	2
S63	2	4	4	2	2	2	3	4	0	4	4	4	1	4	0	4	1	4	2	4	4	2	4	2

Appendix 3. Suppliers' final score and solution

SUPPLIER	FINAL SCORE				MAX SCORE	SOLUTION
	Direct Shipment	Milk-run	Milk-run via DC	Kanban		
S1	1472	49248	16416	0	49248	Milk-run
S2	5568	304128	101376	0	304128	Milk-run
S3	8192	0	0	46080	46080	Kanban
S4	5568	0	32256	0	32256	Milk-run via DC
S5	1472	0	0	33408	33408	Kanban
S6	8192	0	0	46080	46080	Kanban
S7	8192	0	0	0	8192	Direct Shipment
S8	5568	0	32256	0	32256	Milk-run via DC
S9	1472	0	0	33408	33408	Kanban
S10	1472	67392	70848	0	70848	Milk-run via DC
S11	8192	0	0	0	8192	Direct Shipment
S12	5568	96768	101376	0	101376	Milk-run via DC
S13	224	0	0	0	224	Direct Shipment
S14	5568	0	0	0	5568	Direct Shipment
S15	1472	0	0	0	1472	Direct Shipment
S16	1472	304128	22464	0	304128	Milk-run
S17	1472	0	96768	0	96768	Milk-run via DC
S18	1472	0	0	33408	33408	Kanban
S19	1472	0	0	0	1472	Direct Shipment
S20	5568	0	0	0	5568	Direct Shipment
S21	5568	0	138240	0	138240	Milk-run via DC
S22	5568	0	32256	0	32256	Milk-run via DC
S23	5568	317952	7488	31104	317952	Milk-run
S24	224	0	0	0	224	Direct Shipment
S25	8192	0	0	46080	46080	Kanban
S26	8192	0	0	46080	46080	Kanban
S27	5568	304128	101376	0	304128	Milk-run
S28	5568	304128	101376	0	304128	Milk-run
S29	8192	0	0	46080	46080	Kanban
S30	1472	0	96768	0	96768	Milk-run via DC
S31	1472	70848	5184	0	70848	Milk-run
S32	8192	0	0	0	8192	Direct Shipment
S33	1472	67392	70848	0	70848	Milk-run via DC
S34	8192	0	0	0	8192	Direct Shipment
S35	1472	0	22464	0	22464	Milk-run via DC
S36	1472	304128	22464	0	304128	Milk-run
S37	1472	49248	16416	0	49248	Milk-run
S38	960	7488	0	6912	7488	Milk-run
S39	960	51840	16416	0	51840	Milk-run
S40	1472	67392	70848	0	70848	Milk-run via DC
S41	1472	49248	16416	0	49248	Milk-run
S42	5568	0	0	0	5568	Direct Shipment
S43	1472	70848	5184	0	70848	Milk-run
S44	1472	0	96768	0	96768	Milk-run via DC
S45	960	51840	16416	0	51840	Milk-run
S46	8192	0	0	46080	46080	Kanban
S47	5568	433152	32256	31104	433152	Milk-run
S48	5568	70848	23616	0	70848	Milk-run
S49	224	51840	3564	0	51840	Milk-run
S50	8192	0	0	0	8192	Direct Shipment
S51	8192	0	0	0	8192	Direct Shipment
S52	1472	0	0	33408	33408	Kanban
S53	960	51840	16416	0	51840	Milk-run
S54	1472	0	0	33408	33408	Kanban
S55	8192	0	0	0	8192	Direct Shipment
S56	5568	70848	23616	0	70848	Milk-run
S57	8192	0	0	0	8192	Direct Shipment
S58	8192	0	0	0	8192	Direct Shipment
S59	8192	0	0	46080	46080	Kanban
S60	5568	317952	7488	31104	317952	Milk-run
S61	224	16416	3564	0	16416	Milk-run
S62	8192	0	0	0	8192	Direct Shipment
S63	8192	0	0	46080	46080	Kanban

Appendix 4. Transport cost data

Network	Supplier	Transport cost (EUR)
Direct milk-run	S28	53,196
Direct milk-run	S39	4,459
Direct milk-run	S37	7,492
Direct milk-run	S1	714
Direct milk-run	S2	16,110
Direct milk-run	S27	73,268
Direct milk-run	S45	2,304
Direct milk-run	S48	12,923
Direct milk-run	S53	430
Direct milk-run	S56	3,213
Direct milk-run	S12	1,330
Direct milk-run	S10	1,013
Direct milk-run	S33	209
Direct milk-run	S40	27
Direct milk-run	S41	19
Direct milk-run	S38	541
Direct milk-run	S47	8,977
Direct milk-run	S31	1,182
Direct milk-run	S61	1,140
Direct milk-run	S16	5,320
Direct milk-run	S36	8,767
Direct milk-run	S43	121
Direct milk-run	S49	45,545
Total transport cost for direct milk-run suppliers		**248,298**
Milk-run via DC	S4	14,640
Milk-run via DC	S8	3,400
Milk-run via DC	S21	53,196
Milk-run via DC	S22	744
Milk-run via DC	S30	83,784
Milk-run via DC	S44	1,912
Milk-run via DC	S35	558
Total transport cost for milk-run via DC suppliers		**158,233**