Chapter 3

Research Designs and Methods

The research methodology started from studying of the preliminary study the case study, principles and theories that related with transportation management system, crossdocking, location selection, genetic algorithm and literature review of several methods that used to improve transportation management system, all of these was detailed in the chapter 2. The current state of daily production that started from supplier to customer was created and analyzed by using VSM and 9 logistics activities. The selection of feasible crossdock locations in this research were used simple additive weighting method (SAW) to make a decision by criterions such as customer location and demand. For the next step, GA was become important role, it used to solve VRP with single DC (without crossdocking system) and VRP with crossdocking system. Final approach was an evaluation all alternative solutions by efficiency and economic perspective by using cost-benefits analysis tools; BEP analysis, IRR, and PB. The flow chart of this research designs, tools and methods are shown in figure 3-1 and the details of every step will be described below.

3.1 Preliminary study of the case study and related literatures

The preliminary study of case study was started from the general data related to business operation and basic main problems of the case study. The preliminary study has been done by interviewing and observation then created simple work flows, data flow started from delivery of suppliers through production line to delivery finished goods to customers. After the simply flow roughly finished, a big picture will be analyzed in holistic view by using sense of engineering. For interesting departments that related to the suspected problems will be find out more details by interviewing company employees in related departments, and gathering more information from sales data, customer data, delivery points, current fleets and fuel consumption. From the analysis bring about the roughly ways to figure out the main problems and be able to plan and design research methodology. The results of case study analysis consisted of the primary problem or warning sign of the logistics problem, the necessary information for detail analysis the problem statement. The study and review of related principles, theories and literatures was shown in chapter 2 already.

The flow chart of research methodology

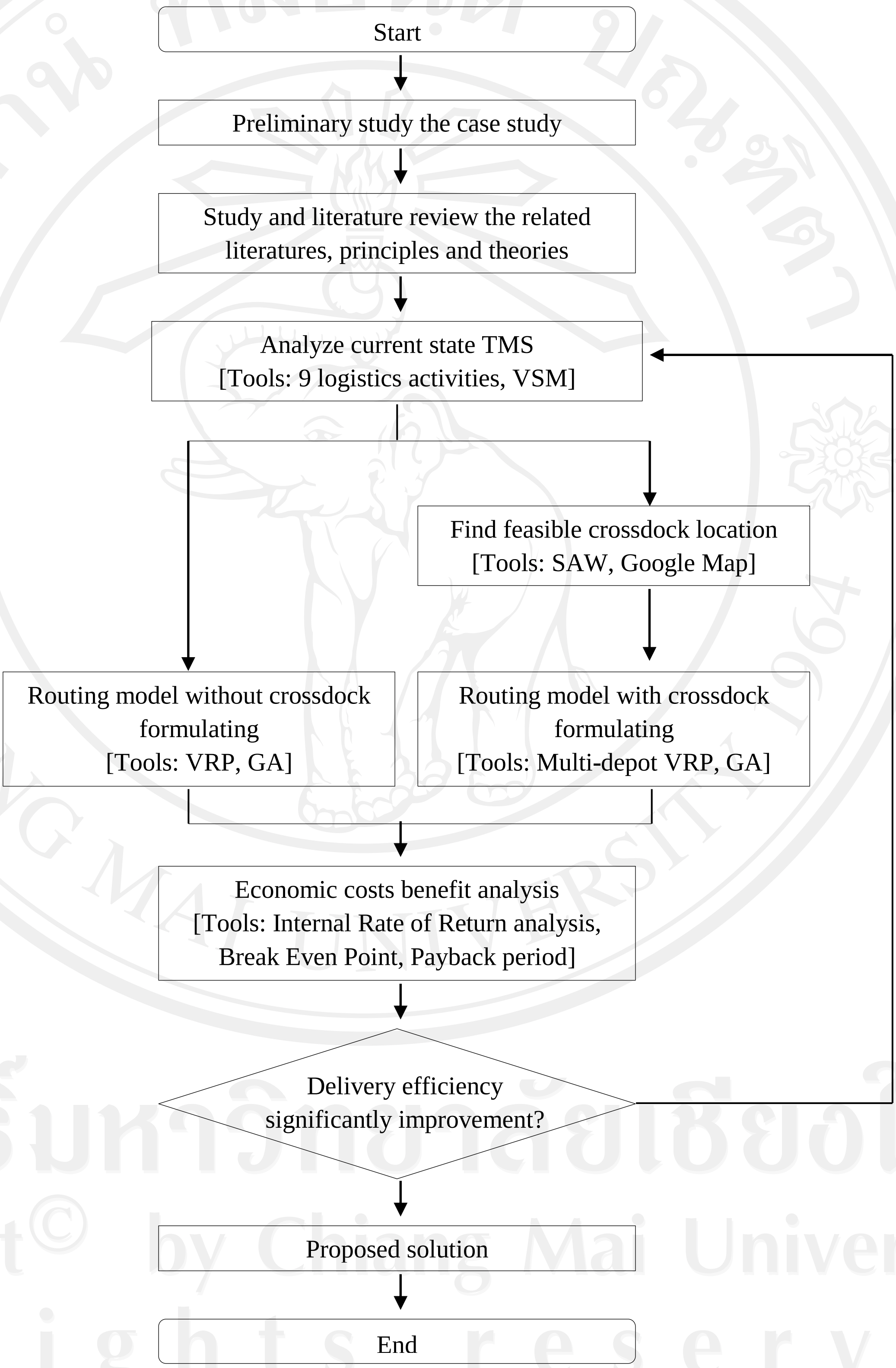

Figure 3-1: Flow Chart of Research Methodology

3.2 Analyze current state TMS

A current state of transportation management system was analyzed by using the collected data from title 3.1. This research used VSM to analyze the current state then defined problems. The VSM used data from vital-few products (Pareto's Theory) (Taylor, 2009) in this case the product was "Shredded pork roll" so VSM in this thesis was VSM of this product. After current state VSM finished next step was VSA (Value Stream Analysis). An additional analysis method was 9 logistics activities (Material Management, Order Processing, Packaging, Transportation, Inventory, Warehouse, Material Handling, Customer Service and Other Logistics Activities). This method will be the heading of studying logistics activities of case study. There was diagram of both method displayed in parallel line divided into 2 phases; collection phase and analysis phase (Figure 3-2). The results of this title were the analysis of VSM and 9 logistics activities and solutions of improving TMS. Please see more details in the next chapter.

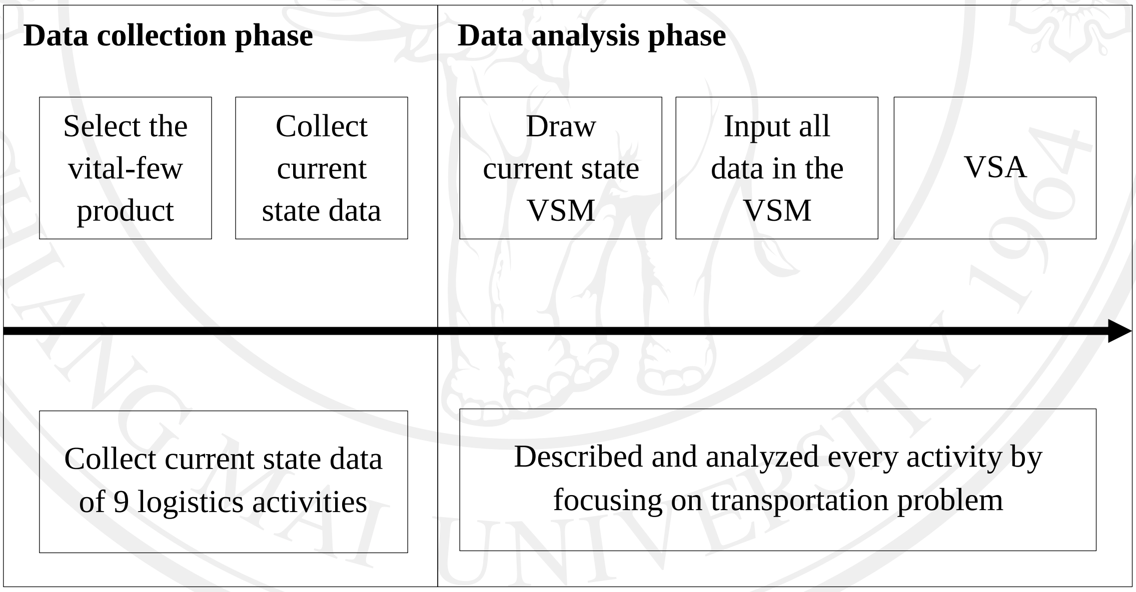

Figure 3-2: Analysis current state TMS diagram

The simulation of current state vehicle routing model of the case study was created and calculated in work sheet of software Microsoft Excel version 2010 by using collected data from recently title. The necessary data for creating the model were customer location, customer demand, properties of vehicles (truck type, truck capacity, fuel consumption) and distance between delivery points was calculated by Google map (http://map.google.com) (Tunjongsirigul & Pongchairerks, 2010), and then evaluated by the important factors of the current route; total distance, total fuel cost and number of vehicles used.

3.3 Routing model without crossdock formulating

This research was begun routing by creating VRP model in Mathematics model. The Mathematics model will be shown in the next chapter; chapter 4; results and discussion. The calculation of total distance was done by creating model in excel work sheet and recheck correctness, error of formula by using sample or initial solution set. If the model completed then set up GA value (select optimized cell, type of goal; min. or max., adjustable cell, solving method, mutation rate, crossover rate, population size and run time) set up value will be shown in each model. This thesis was applied an application from Palisade decision tools, Evolver version 6.0; the Genetic Algorithm (GA) optimization add-in for Microsoft Excel to be an optimizer of problem in distribution and more (Palisade Decision Tools, 2012). This model objective was minimization of total transportation cost of routing with constraints of vehicle type, number of truck, vehicle capacity, customers demand, and the results were appropriate routing sequence and correspondingly a number of vehicles of each type. In table 3-1 was information of each truck type as number of truck, fuel consumption, capacity and rental cost (included driver and truck).

Assumption

1. No truck ban.
2. There were 3 types of truck; pick-up truck, medium truck and large truck. Fleet detail and properties of each truck were identified in table 3-1 below.
3. 58 drop points with 1 distribution center.
4. Distance between point to point was based on calculation from Google map (http://map.google.com).
5. 1 truck for 1 route.
6. Fuel price was 29.99 Baht per liter.

Table 3-1: Fleet details and vehicles properties

Truck Type	Number of truck	Fuel consumption (Km/liter)	Capacity (Baht/truck)	Rental cost (Baht/month)
Pick-up	7	8	51,657	32,700
Medium	8	5	179,267	43,000
Large	2	4	360,533	88,000

The algorithm was used code of Evolver 6.0 (add-in for Microsoft Excel), Palisade decision tools and run in Microsoft Excel 2003 on Microsoft Windows XP Professional, version 2002 service pack 3 with an Intel(R) Core(TM) i5 CPU M520@2.4Ghz 1.99GHz, 1.85GB of RAM. GA parameters were set mutation rate at 0.05 and crossover rate at 0.6, 0.7 and 0.8. Population was used n, n + (n/2), 2n which was 180, 270 and 360. For each experiment was run 30 times with 100,000 trials each time. The experimental detail was already concluded in table 3-2.

Table 3-2: Experimental of GA parameter

Mutation rate	**Crossover rate**	**Population**
0.05	0.6	180 270 360
	0.7	180 270 360
	0.8	180 270 360

The VRP which discussed in this thesis could be described as following assumption below in the next title 3.3.1. In next sub-title; variables, there were N customers in the network to be serviced. Every customers $\{C_i\ ;\ i = 1,2,3,\ldots, N\}$ had demand $\{d_i\}$ that need to be delivered, all customer had N+1 customers including depot which was represented the number 0 $\{i = 0\}$customer by symbol C_0. Each customer was represented by node, every loop of delivery route starting with vehicle departed from depot with full capacity then delivered goods to each customer until it ran out of goods and finished each loop by returning to depot.

Accordingly, the number of every trip that occurred will be represented a number of needed vehicle for demand at that time (Jun L. , 2009). If this loop cannot served all customers requirement the next loops must came back to satisfy until all of demand of every customers could be completed.

3.3.1 Mathematics model for VRP without crossdocking system.

Notations

The list of notations were described what does they mean below

Z = Total transportation cost
N = A number of all customers
C_i = Customer i
C_0 = Depot
c_{ij} = Distance of between customer i and customer j
d_i = Demand of customer i
U = Number of pick-up truck
V = Number of medium truck
W = Number of large truck
q_α = Capacity of vehicle α

q_β = Capacity of vehicle β
q_γ = Capacity of vehicle γ
f_α = Fuel consumption of vehicle α
f_β = Fuel consumption of vehicle β
f_γ = Fuel consumption of vehicle γ
i = Customer number i $\{i = 0,1,2,3,\ldots,N\}$
j = Customer number j $\{j = 0,1,2,3,\ldots,N\}$

Decision Variable

Variable x was represented a binary variable of the every routing model in this thesis (equation 3.1 - 3.3). If α_{ij} or β_{ij}or γ_{ij}equaled to 1 it means vehicle α or β or γ has been choose to travel from node i to node j but in contrast if it equaled to 0 means route i, j has not been choose.

$$\alpha_{ij} \in \{0,1\}\,;\ i,j \in [1,N] \tag{3.1}$$

$$\beta_{ij} \in \{0,1\}\,;\ i,j \in [1,N] \tag{3.2}$$

$$\gamma_{ij} \in \{0,1\}\,;\ i,j \in [1,N] \tag{3.3}$$

The objective function

The objective function of this problem was a minimization of total transportation cost (Z) including rental cost (table 3-1) and fuel cost (fuel price at 29.99 Baht per liter).

$$minZ = \sum_{i=0}^{N}\sum_{j=0}^{N}\frac{c_{ij}\alpha_{ij}*29.99}{f_\alpha} + \sum_{i=0}^{N}\sum_{j=0}^{N}\frac{c_{ij}\beta_{ij}*29.99}{f_\beta} + \sum_{i=0}^{N}\sum_{j=0}^{N}\frac{c_{ij}\gamma_{ij}*29.99}{f_\gamma} + \sum_{j=1}^{N}\alpha_{0j} * 32{,}700 + \sum_{j=1}^{N}\beta_{0j}\, 43{,}000 + \sum_{j=1}^{N}\gamma_{0j}\, 88{,}000 \tag{3.4}$$

Subject to

$$\sum_{j=1}^{N}(\alpha_{ij} + \beta_{ij} + \gamma_{ij}) \le U + V + W\,;\ i = 0 \tag{3.5}$$

$$\alpha_{ij} + \beta_{ij} + \gamma_{ij} = 1\,;\ i = 0,\ \forall j = [1,N] \tag{3.6}$$

$$\sum_{j=1}^{N}\alpha_{ij} \le U\,; i = 0 \tag{3.7}$$

$$\sum_{j=1}^{N}\beta_{ij} \le V\,; i = 0 \tag{3.8}$$

$$\sum_{j=1}^{N}\gamma_{ij} \le W; i = 0 \tag{3.9}$$

$$\sum_{j=1}^{N}\alpha_{0j} - \sum_{i=1}^{N}\alpha_{i0} = 0 \tag{3.10}$$

$$\sum_{j=1}^{N}\beta_{0j} - \sum_{i=1}^{N}\beta_{i0} = 0 \tag{3.11}$$

$$\sum_{j=1}^{N} \gamma_{0j} - \sum_{i=1}^{N} \gamma_{i0} = 0 \quad (3.12)$$

$$\sum_{i=1}^{N} (\alpha_{ip} + \beta_{ip} + \gamma_{ip}) - \sum_{j=1}^{N} (\alpha_{pj} + \beta_{pj} + \gamma_{pj}) = 0 \; ; \; \forall p = [1, N] \quad (3.13)$$

$$\sum_{j=1}^{N} \alpha_{ij} d_j \leq q_\alpha \, ; \forall i \in [1, N] \quad (3.14)$$

$$\sum_{j=1}^{N} \beta_{ij} d_j \leq q_\beta \, ; \forall i \in [1, N] \quad (3.15)$$

$$\sum_{j=1}^{N} \gamma_{ij} d_j \leq q_\gamma \, ; \forall i \in [1, N] \quad (3.16)$$

$$\sum_{j=1}^{N} (\alpha_{ij} + \beta_{ij} + \gamma_{ij}) = 1 \; ; \; \forall i \in [1, N] \quad (3.17)$$

$$\sum_{i=1}^{N} (\alpha_{ij} + \beta_{ij} + \gamma_{ij}) = 1 \; ; \; \forall j \in [1, N] \quad (3.18)$$

$$\sum_{i \in 1}^{N} \sum_{j \in 1}^{N} (\alpha_{ij} + \beta_{ij} + \gamma_{ij}) \leq |S| - 1 \; ; \; \forall S \subset [1, N] \quad (3.19)$$

$$U = 7, V = 8, W = 2 \quad (3.20)$$

3.5	Number of truck out of depot must not exceed number of truck in current fleet.
3.6	Each truck of each type can delivered from depot to only one customer.
3.7 – 3.9	Number of trip out of depot of each type less than or equal to *U* or *V* or *W* trucks.
3.10 – 3.12	Number of outbound from depot truck equal to number of inbound truck.
3.13	Once vehicle arrived at a node, it must also leave that node.
3.14 – 3.16	These constraint guaranteed that each vehicle would never be delivered goods exceed its capacity.
3.17 – 3.18	Every customer is delivered exactly once by one vehicle.
3.19	The constraint is sub-tour elimination inequality.
3.20	Number of vehicle by truck type.

3.4 Feasible crossdock location

Begin this step with generating criteria of feasible solutions (possible crossdock locations). The important criteria for consideration in location selection problem were accessibility, safety, customer demand, proximity to customers, possibility of expansion and costs (detail and definition were in table 3-3). A method of decision making in this step is Delphi method based on information of each location to screen possible locations where were easy to set up the crossdock. A consideration of location was used by the online application “Google Map” that provide sufficient information to decide such as customer location and distance, land size and road. After possible location screening, all candidate would be selected by scoring method, Simple Additive Weighting known as SAW was handled with scoring and ranking the alternatives by using criteria in table 3-3. When SAW method was finished, all candidate location would be ranked. Top 1 candidate for each province would be used for sensitivity analysis of VRP with crossdocking system then result will show the trend between the increasing of number of crossdock and transportation cost of each solution. The VRP with crossdocking system will be calculated in the step.

Table 3-3: Criteria for crossdock location selection

Criteria	Definition	Criteria type
Accessibility (C1)	Access by public and private transport modes to the location.	Benefit
Safety (C2)	Safe and secured from accidents, theft and harm.	Benefit
Customer demand (C3)	Customer demand nearby 20 kilometers radius.	Benefit
Proximity to customers (C4)	Distance of location to customer locations.	Benefit
Possibility of expansion (C5)	Ability to increase size to adjust for growing demands.	Benefit
Costs (C6)	Costs in obtaining land; rental cost.	Cost

3.5 Routing model with crossdock formulating

After suitable crossdocks were selected then VRP with crossdocking system model will be created. There were 2 main VRPs, firstly, the VRP of crossdock to crossdock. The second VRP was routing of crossdocks to customers in their service area. The objective of this optimization problem was still minimization of total transportation cost. Nevertheless, objectives of setting new crossdocks were archiving better service level, 5Rs, increasing TMS efficiency and reducing transportation cost that are the reasons why we considered about creating new crossdock. If the creating of crossdocks was not improved these objectives, there had no need to generate any crossdock. Finally, selected the best one of the solutions of this method (VRP with crossdocking system) to compare with the best answer of VRP with crossdocking system by economics cost-benefit analysis.

3.5.1 Mathematics model for VRP with crossdocking system.

Notations

The list of notations were described what does they mean below

Z = Total transportation cost

N = A number of all crossdock or customer
C_i = Crossdock *i* or Customer *i*
C_0 = Depot or Crossdock
c_{ij} = Distance of between customer *i* and customer *j*
d_i = Demand of crossdock *i* or customer *i*
U = Number of pick-up truck
V = Number of medium truck
W = Number of large truck
q_α = Capacity of vehicle α
q_β = Capacity of vehicle β
q_γ = Capacity of vehicle γ
f_α = Fuel consumption of vehicle α
f_β = Fuel consumption of vehicle β
f_γ = Fuel consumption of vehicle γ
i = Crossdock or Customer number *i* $\{i = 0,1,2,3,\ldots,N\}$
j = Crossdock or Customer number *j* $\{j = 0,1,2,3,\ldots,N\}$

Decision Variables, Objective function, Constraints

Using the same variable *x* as the previous model the equation 3.1 - 3.3 but the subscript parameter at variable α_{ij} or β_{ij}or γ_{ij} was mean crossdock number or customer. For example, if α_{ij} in the equation 3.1 equaled to 1, it mean vehicle α_{ij} has been chosen to deliver from crossdock or customer *i* to crossdock or customer *j*. Objective function was the same as VRP without crossdock, to minimize total transportation cost of the system, likewise, the equation (equation 3.4). Correspondingly, the constraints were not different with the aforementioned model.

3.6 Economics cost-benefit analysis

This analysis was used to evaluate how worth of each solution. The methods of this analysis were engineering economics tools consist of Internal Rate of Return analysis (IRR), break-even point (BEP) and payback period (PB). Every method has different benefits, limitations and also strength. For example, the strengths of IRR were in comparing project cost streams directly and it was a good method of capital planning, on the other hand, the weaknesses are it does not good for comparing two projects and difficult to calculate. Break-even point strengths' were very easy to calculate and understand, and signified the shortest time period of project or the lowest quantity of product/service that necessary to prevent losses, in contrast, it was only a supply side analysis. The PB was period of time required for the return on an investment to "repay" the sum of the original investment. The strengths of PB were ease of use and PB used for evaluate time of investment. In this research will be used all 3 methods to compare all project. BEP for finding first point of project break-even in cost unit. PB was for finding when or how fast investment project will return the profit. IRR was for evaluating each project. Then used all information from economics cost-benefits analysis to support decision-making which solution gave the best result will be the chosen model.

This chapter was about how to complete the research or research methods but in the next chapter will be shown results of this research such as VSM, 9 logistics activities, the new route of VRP with and without crossdocking system and economics and cost analysis. Subsequently, in conclusion chapter will be revealed and concluded about results of this research.