

## Chapter 4

### Results and Discussion

#### 4.1 Case study

General data of the case study; Northern local company that manufactures, distributes and sells bakery products retail and wholesale such as bread, cake, pie, tart, roll, pizza, and more bakery products to 25 branches and 78 retail customers (October, 2011). The average sale per month was about 42 million baht. Current fleet, there was 3 types of vehicles, 7 pickup trucks, 8 medium trucks (6-wheel) and 2 large trucks (6-wheel). Their items are baking product so selling point not only delicious but also fresh that why they have to deliver their products daily. Accordingly, from study transportation cost (fuel cost) take up about 4% of product cost, see more detail in table 4-2. Furthermore, there are some hidden unaccounted costs such as maintenance cost, opportunity cost, and damages cost by accidents thus improving transportation system is the interesting issue to study. From observation found many concern of low delivery efficiency such as delivery schedule unsynchronized with the production line, fatigue of drivers from working overtime, vehicles breakdown, accident, late deliver and high fuel consumption and so on.

This research used VSM and 9 logistics activities to be the tools to analyze each activity in this chain. VSM will show flow of data, material and all process in big picture starting from supplier till the delivery finished goods to customers. VSM was shown in figure 4-1 and calculation details and raw data was in appendix C. This VSM information came from production data of “Shredded pork roll”, the vital product of case study. Starting the VSM with customer ordering, their requests will be sent to company. The company’s office will pass sale order to production team, they will transform customer request to work order and material request information. Material request information will be send to measurement team to convert to unit of each material. Next, store team will check their inventory if in stock ordered material will be sent to production line, on the other hand, send list of material needed by purchase order to suppliers. Generally, suppliers do a daily delivery so company no need to hold inventory excessively. However, the highest number of inventory is WIP, there are in every process.

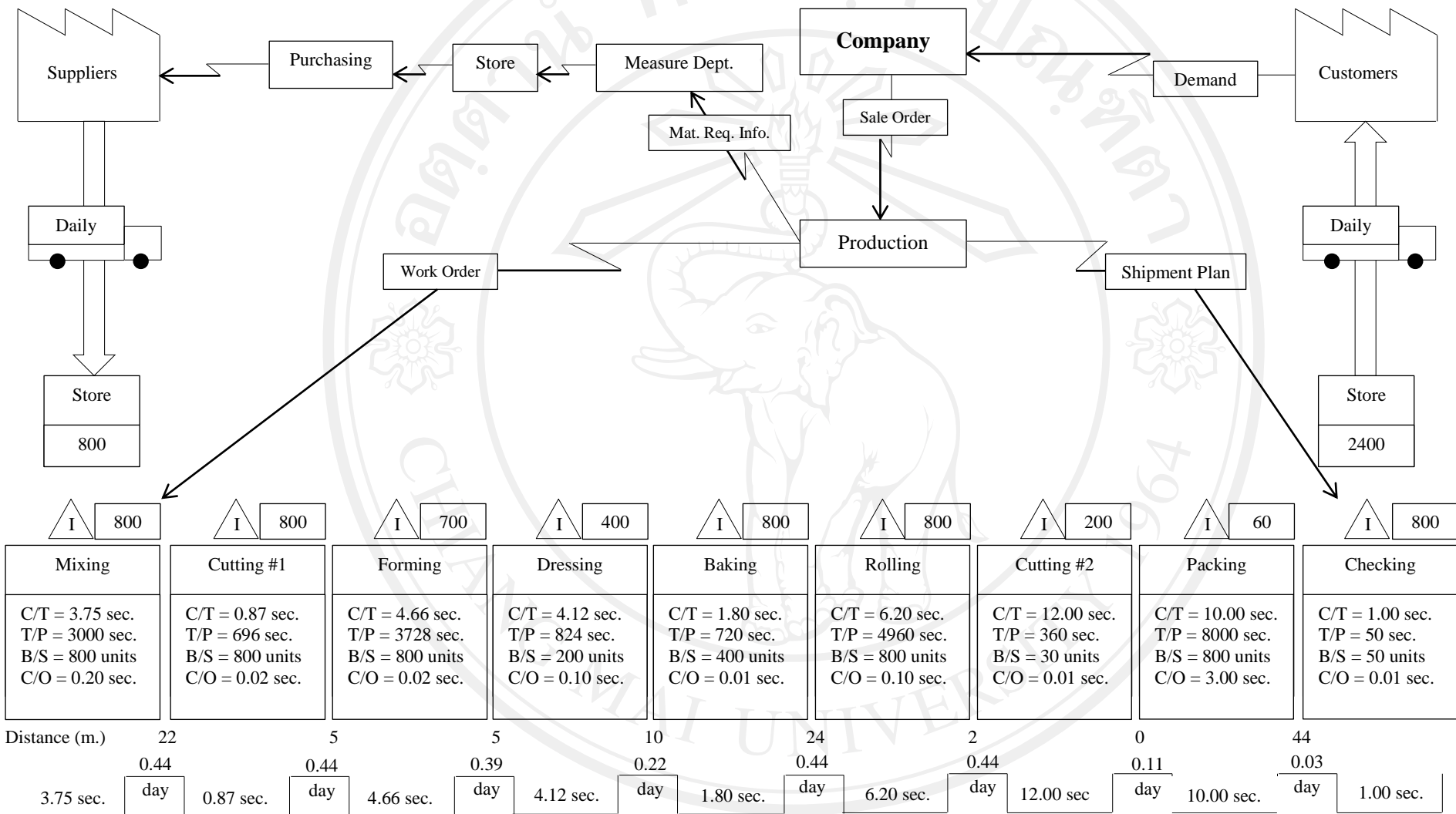


Figure 4-1: Current state VSM of Shredded pork roll

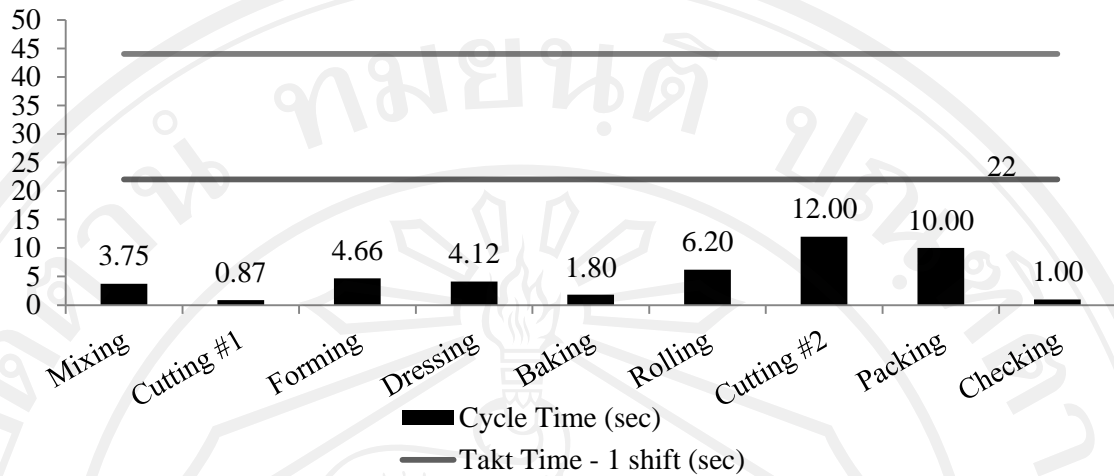


Figure 4-2: Current state cycle time

### Activities Analysis

Started from big picture, in figure 4-1, interesting point was at the delivery process from company to customer that happen on daily basis. Inventory at store area before deliver was finished goods which were waiting for loading into trucks. This waiting occurred because they did arrangement for each customer before loading when all products finished excepted one product they still cannot load. Nevertheless, if they wanted to load, they need to request for cut the normal production line by the rush product. This action led to unsteady production. Next part will analyze the production activities.

The activities to be considered are rolling, cutting#2, and packing because they waste a lot of cycle time (Figure 4-2). These 3 activities are also processed in sequence. First, baked bread will be delivered to the packing zone. Then, they will be taken out of the trays and put overlap for 3 layers (Figure 4-3) to save the trays that have to bring back to use in another production unit. This activity is NVA. Next is rolling; spreads mayonnaise onto bread, follows by shredded pork, then uses the roller to roll the bread together with paper and put it back into a basket for the next process. Cutting #2; brings the basket full with rolled bread and removes the wrapping papers out (NVA). Then, uses a knife to cut rolled bread, measures the width by using a plate, cut them piece by piece, and arranges the cut bread in a set of 9 pieces. The bread will be pasted mayonnaise for both sides, coated with shredded pork, and arranged in tray. They are prepared for packing by putting logo stickers on boxes which used as packaging. Finally, packs the bread by putting them into the box and seals. The boxes will be put back into the basket. These 3 sequentially activities are in the same area. The processes are done continuously but are slowed down because each work unit has to finish and wait to continue and that lead to too many of WIP and NVA. All important data of current state was shown in table 4-1.



Figure 4-3: Overlapping bread 3 layers, rolling, cutting and arranging step respectively

From table 4-1 the total distance was total distance of product movement in production line. Production lead time was 3 days, this took so long because it was calculated by WIP and inventory. Processing time was the time that spent for 1 unit production; from table 4-1 processing time was 44 seconds to produce 1 unit. From this table the big different between lead time and processing time bring about which issue was essential to focus. Thereafter, study and analysis of each logistics activities of the case study.

Table 4-1: Current state conclusion data

	<b>Current</b>	<b>Unit</b>
Total Distance	112	Meters
Production Lead Time	3	Days
Processing Time	44	Seconds

#### 4.2 9 logistics activities

Logistics activities used to divide or classify activities. After activities were divided, it will be more obvious to identify and analyze problem easier for each activity. Activity in logistics point of view can be divided to 9 activities and the details were shown below.

#### 4.2.1 Material Management

This case study used their own original suppliers for most of their materials. They dealt business with the suppliers since established the company. This kind of suppliers gave them some privilege such as credit term, stable quality of material and fast delivery and short lead time because they were located nearby the company. Short lead time helped them to simply manage their material and less inventory cost than using supplier that had longer lead time.

#### 4.2.2 Order Processing

There were 2 ways to order. First, directly ordered and took back by themselves from distribution center, Chiang Mai. Second, call in to order, cut off time is 4:00PM the day before delivery date. Then the request will be sent to production team. Production team will hand over material request information to measurement team. Then this team will break down product order into list of materials that they need and forward to warehouse team to check their inventory. If warehouse had sufficient material to provide they must delivered material to production team, in contrast, if not they have to send purchase order to purchasing team. Final process was at purchasing department, sending a purchasing order to supplier and signed for receiving product to confirm the delivery when received the packages.

#### 4.2.3 Packaging

All products was designed their package for fitted in the tray and basket for ease in transportation. Packaging of studied product (shredded pork roll) and every other plastic box package are still using manual packaging by clam shell hand sealer (Figure 4-4). For plastic bag was packed by automatic sealer machine but still need to use manpower to put product in plastic tray and feed into the machine (Figure 4-5).



Figure 4-4: Clam shell hand sealer



Figure 4-5: Automatic sealer machine

#### 4.2.4 Transportation

Idea improvement from observation, the company was not focus on transportation but sale. Currently, routing schedule was done by using experience of senior driver as well scheduling, without supporting data (numerical data) to make decision so this research will help to start gathering essential data about transportation. First data set was general current situation of transportation system was shown in table 4-2. Average sales were come from approximately of average between sales volume of August and September 2011. Also average product cost which was collected data from production and sale data. Source of average fuel consumption was from shell fleet card data. Fuel price was used data from diesel average price from [http://www.eppo.go.th/retail\\_prices.html](http://www.eppo.go.th/retail_prices.html), the price was THB 32 in April 2012. The last row was fuel cost and product cost ratio which displays fuel cost THB 4 of every THB 100 of product cost.

Table 4-2: Current transportation system information

List	Amount	Unit	Remark
Average sale	42	M. Baht/Month	Aug. – Sep.2011
Average product cost	13	M. Baht/Month	Aug. – Sep.2011
Average fuel consumption	19,148	Liters/Month	Dec.2010 – Dec.2011
Diesel price	32	Baht/Liter	April 2012
Average fuel cost	570,419	Baht/Month	
Fuel/Product cost	4	Percent of product cost	

### Fleet Information

As of October, 2011 current fleet consist of 7 of pick-up trucks, 8 medium trucks and large 2 trucks all detail was shown in table 4-3 underneath.

Table 4-3: Vehicle Information

No.	License Plate	Wheels	Baskets	Capacity (Baht)	Fuel Consumption (km/l)
1	4339	4	87	46,400	8.39
2	4846	4	87	46,400	8.39
3	6062	4	87	46,400	8.39
4	6945	4	87	46,400	8.39
5	6964	4	87	46,400	8.39
6	7726	4	87	46,400	8.39
7	9749	4	156	83,200	8.39
8	7904	6	273	145,600	5.30
9	3498	6	273	145,600	5.30
10	6428	6	280	149,333	5.30
11	4572	6	351	187,200	5.30
12	8331	6	378	201,600	5.30
13	8967	6	378	201,600	5.30
14	4956	6	378	201,600	5.30
15	6862	6	378	201,600	5.30
16	5643	6	600	320,000	4.75
17	9302	6	752	401,067	4.37

Regarding table 4-3, the second column was a license number of each vehicle. Next column was a type of vehicle; 4-wheel means pickup truck with the container on the bed, 6-wheel means medium truck and the last 2 rows are large truck. Column 4 was vehicle average capacity (average by triangular distribution) in basket from interviewing employees; driver, senior driver and transport planner for minimum capacity in basket unit, mode and maximum. Afterward, capacity in basket unit was converted to money unit by multiply basket with value per basket. This conversion was for ease of calculation with demand of customer which was in money unit as well. The last column was average fuel consumption of each vehicle type from shell fleet card also; distance in kilometer of vehicle to drive by 1 liter of fuel.

Next part below here was shown the map of all current customer location (Figure 4-6). In table 4-4 was a schedule of current routing, ordering by sequence. Figure 4-7 was an example of current route in Chiang Mai (**Bold**



Table 4-4: The sequence of current route

No.	Code	Location Name
1	CM PN	Distribution Center, Chiang Mai
2	CMB 5	Tesco Lotus, Kam Thieng
3	CMB 7	Som Petch Market, Chiang Mai
4	CMB 6	Central Kad Suan Kheaw
5	CM C 1	Behind CMU
6	CMB 1	Central Airport Plaza, Chiang Mai
7	CMB 2	Big-C Supercenter, Hang Dong
8	CM C 3	Big-C X-tra North Chiang Mai U.
9	CM B 4	Big-C X-tra, Chiang Mai
10	CM B 3	Big-C Supercenter, Chiang Mai
11	CM C 2	Boar Sang, Chiang Mai
12	CR C 4	Group of Mae Kha Chan's Customers
13	CR C 5	Kru Noom, Mae Kha Chan
14	CR C 3	K.Phung, Mae Kha Chan
15	CR C 2	Kru Tuu, Transportation Station Mae Kha Chan
16	CR C 6	K.Larh, Vieng Pa Pao Hospital
17	CR C 8	K.Ratchaneekorn, 108 shop Vieng Pa Pao
18	CR C 7	K.Sasitorn, Vieng Pa Pao
19	CR C 9	Moo Hao Chalearn
20	CR B 2	Central Plaza, Chiang Rai
21	CR B 1	Big-C Supercenter, Chiang Rai
22	CR C 10	K.Rung, Chiang Rai
23	CR C 11	K.Oa, Chiang Rai
24	CR C 12	K.Sripun, Chiang Rai
25	CR C 13	K.Oranuch , San Khong Chiang Rai
26	CR C 14	K.Srila Yanisa, Chiang Sand
27	CR C 1	Bangchak Gas Staion, Doi Sa Ked
28	CR B 3	Tesco Lotus, Mae Chan
29	CR B 4	Tesco Lotus, Mae Sai
30	CM C 4	Tesco Lotus, Fang
31	PY C 1	K.Nay, Wangnuea
32	PY C 2	K.Tadsanee, Wangnuea
33	PY C 3	K.Wilaiwan, Wangnuea
34	PY C 4	Mae Tum, Phayao
35	PY D 1	Distribution Center, Phayao
36	PY B 1	Charoen Pun Department Store, Phayao
37	PY B 2	Tesco Lotus, Phayao
38	PY C 5	K.Noi, Phayao University
39	PY C 6	Tom mart, Phayao University
40	LA B 3	Big-C Supercenter, Lamphun

Table 4-4: The sequence of current route (Continued)

No.	Code	Location Name
41	LA B 1	Wholesale, Lamphun
42	LA B 2	Jam Fah Plaza, Lamphun
43	LA C 1	Suan Bunyo Phatum School
44	LP C 4	K.Sunan, Nam Tong Market, Lampang
45	LP C 2	K.Nittaya, Lampang
46	LP C 1	K.Berm, Lampang
47	LP B 1	Big-C Supercenter, Lampang
48	LP B 2	Tesco Lotus, Lampang
49	LP C 3	K.Narong, Pang Ma-O Lampang
50	PH C 3	K.Kanlaya, Phrae
51	PH C 4	K.Suweena,, Phrae Hospital
52	PH C 1	Mark Four Plaza, Phrae
53	PH B 1	Big-C Supercenter, Phrae
54	PH C 2	K.Ja-ded, Phrae
55	UD B 1	Friday Department Store, Uttaradit
56	PL B 2	Topland Plaza, Phitsanulok
57	PL B 3	Train Station, Phitsanulok
58	PL D 1	Distribution Center, Phitsanulok
59	PL B 1	Big-C Supercenter, Phitsanulok

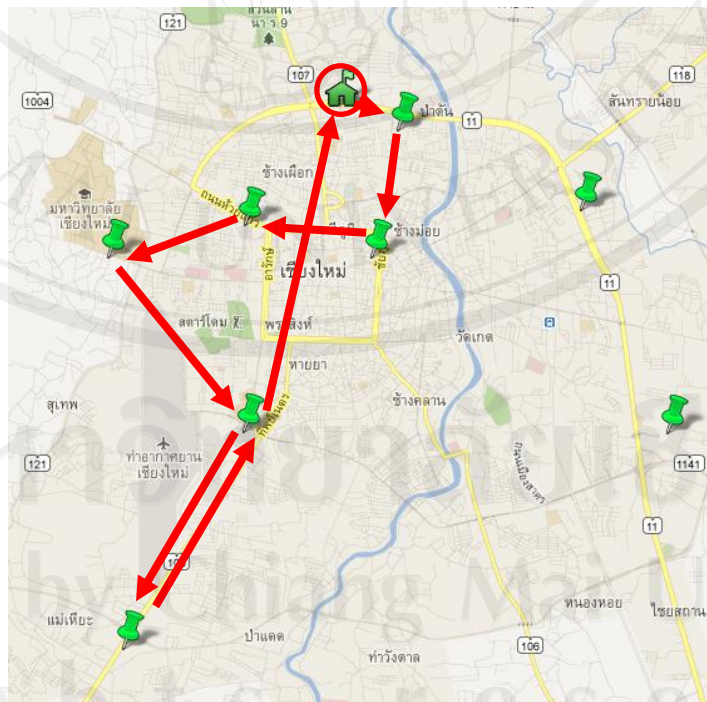


Figure 4-7: Illustration of 1 current route in Chiang Mai

#### 4.2.5 Inventory

Mainly of inventory was packaging material and for baking material that was typically stocked in warehouse is a bag of flour. The others baking material, fresh material are stock on site known as work in process (WIP) for example eggs, sausages, hams, and etc. The important inventory was created in arrangement process before delivery (identified in figure 4-1 at store area before delivery) that has to wait for the last product finished this is a non-productive activity and affected to the production process also late delivery.

#### 4.2.6 Warehouse

They own 2 warehouses located nearby production site. One was nearby bakery production site, in Chiang Mai, for stock raw materials and packages. Another one was close to beverage production plant in Lumphun stored raw material and finished goods.

#### 4.2.7 Material Handling

Conveyor was applied in only few production lines. Generally, several products used multi-layer tray cart (Figure 4-8) for moving WIP or finished product from machine to machine or process to next process. Regular cart used to move raw material or heavy stuff and also a basket of finished goods that can be overlapped (Figure 4-9).

Limitation of moving between sector causes by layout of the building. The production building is 5 floors building which was augmented from 4 floors. When some product that has to go through many processes that work station was in different floor, it must use elevator. For example, plastic box packing is on the 4<sup>th</sup> floor the only way to move is elevator. Additionally, they have just 2 small elevators; one can move between 1<sup>st</sup> – 4<sup>th</sup> floors, the second one can move to every floor.



Figure 4-8: Multi-layer tray cart



Figure 4-9: Overlapable basket for finished goods

#### 4.2.8 Customer Service

As above, they have 3 types of customer. Branch, franchise and regular customer will get credit term (post-pay) half month, monthly or some customer twice a month. This method makes customers satisfy because they can get money first then pay later. Disadvantages, some customer did not pay on time or worse; disappeared.

No charge for delivery no matter how far customers located. Good for customer but company laded with transportation cost. Subsequently, this is another motive to improve transportation system to serve better service to customer with lower cost.

Some customer asked for keeping the baskets (material handling) to use so they just solved the problem by gave it to customers and marked name of customer at each basket. This issue led to next problem. Every customer had different order and company complied with separating products of each customer into each customer's basket. These issues conduced directly to delivery because truck cannot deliver before every product of every customer in the route finished. Moreover, loading time took very long time because of product arrangement for each customer. The problem of loading by routing sequence; if the first drop point customer ordered product that finished the last they still cannot load baskets of the last drop point customer. Nevertheless, these issues can be solved by crossdocking system, it can hold products of each service area so they do not need to arrange for each customer before delivery to crossdock but after products arrived at crossdock then can start arrangement. Alternative way to deliver product to customer is asking customer for picking up goods at crossdock by themselves exchange with discount.

#### 4.2.9 Other Logistics Activities

Current fleet of case study is all own vehicles. That caused a lot of cost such as maintenance cost, management cost. Nowadays, there are a lot of outsource transport business that has vary choice for deliver as rent both truck and driver with or without fuel cost, just only truck or driver and pay by trip.

An unsynchronized scheduling of transportation department and production department can be solved by using crossdocking system as above in 4.2.8. Without crossdock dispatcher cannot let trucks left early even they were ready because customer was not ready to receive such as not yet open. With crossdock, transportation department can immediately deliver after product finished, therefore, production team is able to adjust production schedule earlier and set the production time by popular products come first.

The conclusion of 9 logistics activities, main problem is transportation system as described above. Solution may possibly be crossdocking system that could be solved many problems in many logistics activities. However, any crossdock need to invest hence economic costs benefit analysis should be applied. Next step will show results of shorten the route, minimize total distance; Vehicle Routing Problem (VRP) and VRP with crossdocks. After the solutions will be the last title of this chapter; the analysis of economic costs benefit.

#### 4.3 Routing model without crossdock formulating

From study of current method, table 4-4 shown above was a current vehicle routing ranking by sequence of delivery stop point (for calculation detail, please find in table B-2, appendix B). Total distance of this routing method was 6,353 km. with 17 trucks (pick-up = 7, Medium = 8, Large = 2). After applied GA to optimize VRP without crossdocking system by using the GA parameter experimental 30 runs for each 1 of experiment with parameter values in table 4-5. For example, at mutation rate = 0.05, crossover rate = 0.6, population = 180, it was generated 30 answers which the best answer was 479,749 Baht. Afterward, when all experiment was finished, the 270 solutions were produced and the best answer (the lowest cost) was at 433,290 Baht. In addition, it was at mutation rate = 0.05, crossover rate = 0.7 and population = 360. The solution used 2 of pick-up trucks, 6 medium trucks and 1 large truck with total distance = 3,944 kilometers and total cost = 433,290 Baht. The example of the new route was displayed in table 4-6 as a 2 first routes. The first route was a medium truck route from depot to 5, 8, 2, 11, 9, 7, 18 and back to the depot respectively. Under the thick line was a pick-up truck route from depot 41, 36, 25, 26, 24, 23, 29, 27, 28, 6, 4, 10, 21, 3 and back to depot. These routes were also illustrated in figure

4-10, the normal arrow was represented the first route, medium truck and the direction of each trip was followed by the arrow head direction but first 6 stops were in Chiang mai the scale was too small to display. Displayed arrows were delivery route from Central Kad Suan Khaew, Chiang mai to Central Plaza, Chiang rai and return to depot. For more calculation details of the new route please see in appendix B, table B-3.

Table 4-5: Conclusion of the results of the GA parameter experimental

Mutation rate	Crossover rate	Population	Best Answer
0.05	0.6	180	479,749
		270	497,601
		360	433,974
	0.7	180	468368
		270	435,326
		360	<b>433,290</b>
	0.8	180	465,670
		270	435,067
		360	465,795

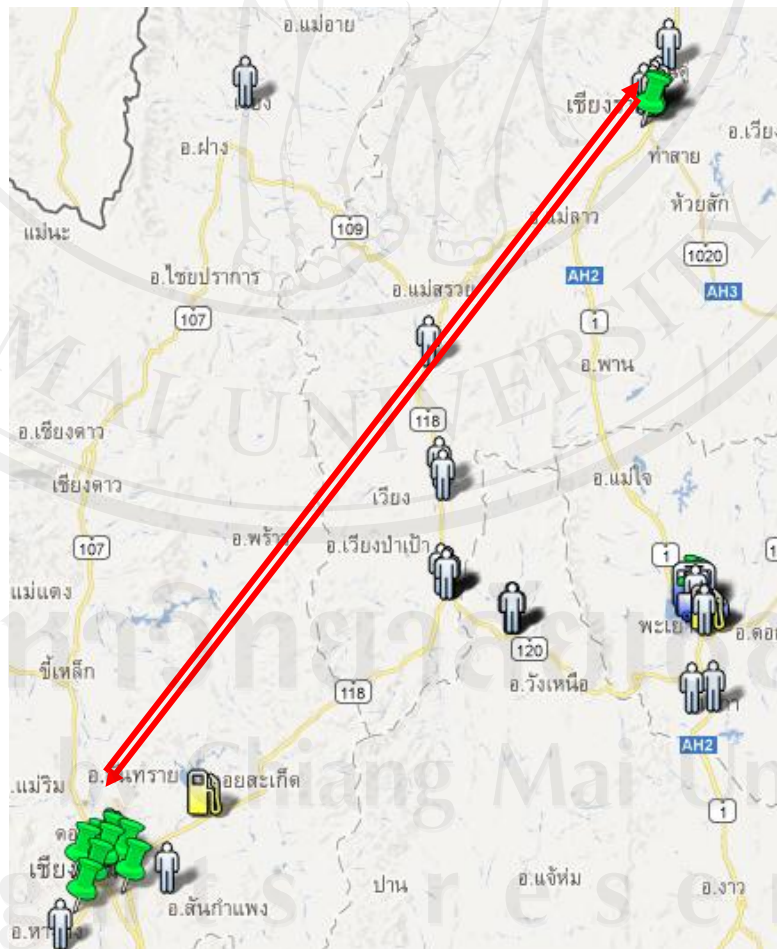


Figure 4-10: Illustration of example VRP without crossdock

Table 4-6: The example of sequence of new route VRP without crossdock

Ci	Place	Place Name	Demand
5	CM B 4	Big-C X-tra, Chiang Mai	16038
8	CM B 7	Som Prech Market, Chiang Mai	2981
2	CM B 1	Central Airport Plaza, Chiang Mai	50874
11	CM C 3	Big-C X-tra North Chiang Mai U.	12255
9	CM C 1	Behind CMU	8014
7	CM B 6	Central Kad Suan Kheaw	25145
18	CR B 2	Central Plaza, Chiang Rai	55296
41	PY C 4	Mae Tum, Phayao	9544
36	PY B 1	Charoen Pun Department Store, Phayao	25025
25	CR C 5	Kru Noom, Mae Kha Chan	813
26	CR C 6	K.Larh, Vieng Pa Pao Hospital	5301
24	CR C 4	Group of Mae Kha Chan's Customers	1544
23	CR C 3	K.Phung, Mae Kha Chan	980
29	CR C 9	Moo Hao Chalearn	255
27	CR C 7	K.Sasitorn, Vieng Pa Pao	2183
28	CR C 8	K.Ratchaneekorn, 108 shop Vieng Pa Pao	1758
6	CM B 5	Tesco Lotus, Kam Thieng	47434
4	CM B 3	Big-C Supercenter, Chiang Mai	32450
10	CM C 2	Boar Sang, Chiang Mai	4912
21	CR C 1	Bangchak Gas Staion, Doi Sa Ked	392
3	CM B 2	Big-C Supercenter, Hang Dong	46784

#### 4.4 Routing model with crossdock formulating

The possible crossdock locations were screened by selection of all stop point to be possible crossdock locations which had 59 points (58 delivery points and 1 depot) to be candidates. Then, selected feasible crossdocks by SAW method based on criteria in chapter 3; accessibility, safety, customer demand, proximity to customers, possibility of expansion and costs (table 3-3) which were rated by Likert scale and converted to proportion of each criteria (detail was below in table 4-7). List of all crossdock candidates were already in appendix B, table B-4.

Table 4-7: Criteria weighting

Criteria	Score	Proportion	
C1	Accessibility	3	12%
C2	Safety	1	4%
C3	Demand	5	19%
C4	Distance	7	27%
C5	Possibility of expansion	3	12%
C6	Cost	7	27%

All candidate will be ranked by SAW method, the calculation was displayed in appendix B, table B-5. The highest rank of each province (8 provinces) (in table 4-8) will be analyzed by sensitivity analysis and continually cut the lowest demand crossdock one by one from 8 to 3 crossdocks and transferred demand of dominated crossdock(s) to nearest crossdock(s). Each method will be optimized by application of GA for VRP with crossdocking system and evaluation the best answer of each solution to find which scenario was the best solution.

Table 4-8: The highest rank of 8 provinces.

No.	Rank	Code	Location Name	Demand
1	1	LA B 1	Wholesale, Lamphun	268,773
2	2	PY D 1	Distribution Center, Phayao	132,172
3	3	CM PN	Distribution Center, Chiang Mai	275,192
4	4	LP B 1	Big-C Supercenter, Lampang	137,574
5	5	PL D 1	Distribution Center, Phitsanulok	146,609
6	10	CR B 1	Big-C Supercenter, Chiang Rai	118,661
7	16	PH B 1	Big-C Supercenter, Phrae	56,834
8	23	UD B 1	Friday Department Store, Uttaradit	267,793

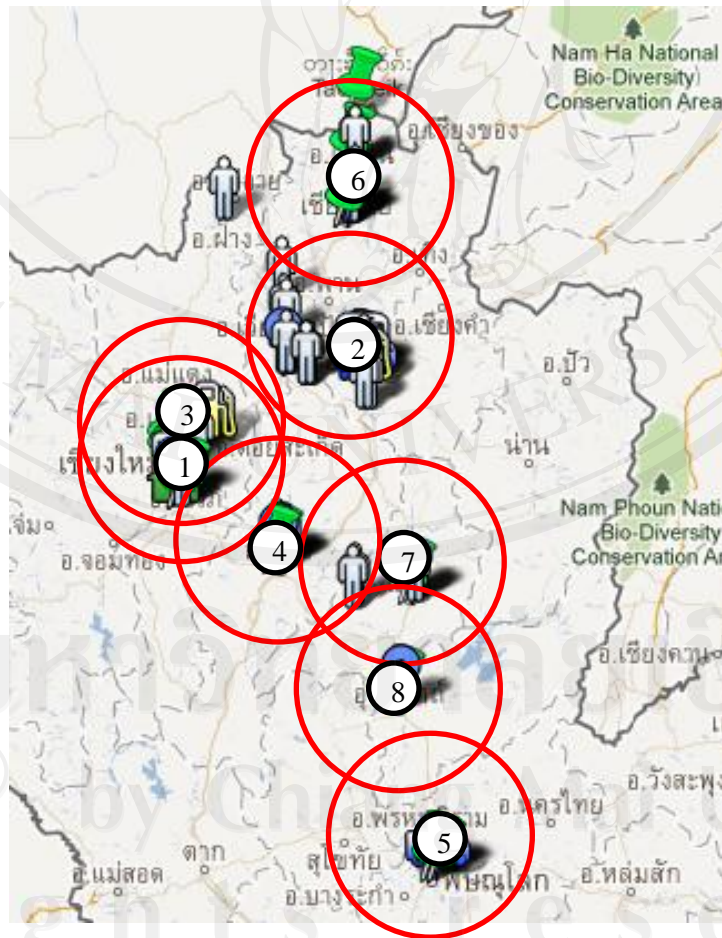


Figure 4-11: An illustration of 8 crossdocks with service area

Figure 4-11 was an illustration of the highest rank of 8 provinces and their service area displayed by a circle figure. The numbers label on the map were followed by number of each location in table 4-8 and in demand column of table was also showed demand of each crossdock which need to be fulfilled.

In this research VRP for crossdocking system was solved by 2 following steps. First, VRP of delivery from depot to crossdocks, it used the same model with the VRP without crossdock but the number of node was less, likewise, the population. After the new route of crossdock delivery was generated then followed by VRP of each crossdock to customers in their responsibility area.

The depot to crossdocks VRP was still using the same experimental method with the VRP without crossdock but number of population was changed. First experiment, there were 8 crossdocks with 3 types of truck so  $n = 24$  ( $8 \times 3 = 24$ ). The experimental was using population at  $n$ ,  $n + (n/2)$ ,  $2n$  which were equal to 24, 36 and 48 correspondingly. Possible solutions equaled to  $24! \times 3 = 1.86 \times 10^{24}$ . The experiment was run by using 20,000 trials per run time.

Table 4-9: Conclusion of the results of 8 crossdocks VRP experimental

Mutation rate	Crossover rate	Population	Best Answer
0.05	0.6	24	<b>356,944</b>
		36	358,129
		48	358,150
	0.7	24	358,129
		36	<b>356,944</b>
		48	358,150
	0.8	24	<b>356,944</b>
		36	359,032
		48	357,091

Table 4-10: Routing of the best answer of 8 crossdocks VRP

No.	Ci	Place	Location Name	Cumulative truck use	
				Medium	Large
1	1	CM PN	Distribution Center, Chiang Mai		
2	2	LA B 1	Wholesale, Lamphun	1	0
3	8	PL D 1	Distribution Center, Phitsanulok	3	0
4	7	UD B 1	Friday Department Store, Uttaradit	3	0
5	6	PH B 1	Big-C Supercenter, Phrae	4	0
6	4	PY D 1	Distribution Center, Phayao	5	0
7	5	LP B 1	Big-C Supercenter, Lampang	6	0
8	3	CR B 1	Big-C Supercenter, Chiang Rai	6	1

Table 4-9 was a conclusion of 8 crossdocks VRP results (for more detail please see in appendix B, table B-6. The best answers of the experiment were 356,944 Baht by the same solution of 3 cases. All 3 cases used mutation rate = 0.05 with crossover rate = 0.6 population = 24, crossover rate = 0.7 population = 36, and crossover rate = 0.8 population = 24. The solution was showed in table 4-10 above. The sequence of route was displayed in column  $C_i$ , code and location name. The cumulative truck use showed the number of truck used in each node by cumulative until the last row. For example, in the third row it means Lamphun crossdock was the first stop and was delivered by 1 medium truck, so cumulative truck used was 1 truck then the second stop was Phitsanulok was delivered by another 2 medium truck, now cumulative truck used = 3 trucks. Next, Uttaradit was delivered by the last medium truck from recently trip thus cumulative = 3 trucks. The next stop, Phrae, Phayao and Lampang need 1 medium truck per stop to delivered. The last stop used 1 large truck, so, at the moment the cumulative truck used had 2 types of truck which were medium truck = 6 and large truck = 1.

Table 4-11: VRP of CM PN crossdock to customers

<b>C i</b>	<b>Code</b>	<b>Location Name</b>	<b>Demand</b>	<b>Sequence</b>	<b>Pick- up</b>	<b>Cum. Distance</b>
1	CM PN	Distribution Center, Chiang Mai	268,773			459.2
2	CM B 1	Central Airport Plaza, Chiang Mai	50,874	7	1	11.6
3	CM B 2	Big-C Supercenter, Hang Dong	46,784	2	1	27.1
4	CM B 3	Big-C Supercenter, Chiang Mai	32,450	5	2	32.9
5	CM B 4	Big-C X-tra, Chiang Mai	16,038	8	3	49.6
6	CM B 5	Tesco Lotus, Kam Thieng	47,434	10	3	64.6
7	CM B 6	Central Kad Suan Kheaw	25,145	6	3	77.2
8	CM B 7	Som Prech Market, Chiang Mai	2,981	1	4	230.3
9	CM C 1	Behind CMU	8,014	11	5	401.3
10	CM C 2	Boar Sang, Chiang Mai	4,912	4	5	415.6
11	CM C 3	Big-C X-tra North Chiang Mai U.	12,255	3	6	423.3
12	CM C 4	Tesco Lotus, Fang	21,494	9	6	438.1
13	CR C 1	Bangchak Gas Staion, Doi Sa Ked	392	12	6	459.2

Next, each crossdock had customers in their service area which needed to be delivered and this problem can be considered to VRP. The table previous, table 4-11 were the example of calculation table, for more detail of every crossdock of each case (3-8 crossdocks), please find in appendix B, table B-6 – table B-11.

The tables (Table 4-12 – table 4-16) below were the experimental of every case which had details in table same as table 4-10; the result of 8 crossdocks VPR experimental. From the results, the variance of answer from any rate of each experimental was reduced in the same way with number of crossdock. Because of when number of crossdock ( $n$ ) reduced possible solution ( $n!$ ) also reduced.

Table 4-12: Conclusion of the results of 7 crossdocks VRP experimental

Mutation rate	Crossover rate	Population	Best Answer
0.05	0.6	21	<b>356,236</b>
		32	358,263
		42	358,263
	0.7	21	358,263
		32	358,263
		42	358,263
	0.8	21	358,263
		32	358,263
		42	358,263

Table 4-13: Conclusion of the results of 6 crossdocks VRP experimental

Mutation rate	Crossover rate	Population	Best Answer
0.05	0.6	18	316,014
		27	<b>312,872</b>
		36	316,014
	0.7	18	316,014
		27	316,014
		36	<b>312,872</b>
	0.8	18	314,900
		27	313,818
		36	313,818

Table 4-14: Conclusion of the results of 5 crossdocks VRP experimental

Mutation rate	Crossover rate	Population	Best Answer
0.05	0.6, 0.7, 0.8	15	271,762
		23	271,762
		30	271,762

Table 4-15: Conclusion of the results of 4 crossdocks VRP experimental

Mutation rate	Crossover rate	Population	Best Answer
0.05	0.6, 0.7, 0.8	12	272,922
		18	272,922
		24	272,922

Table 4-16: Conclusion of the results of 3 crossdocks VRP experimental

Mutation rate	Crossover rate	Population	Best Answer
0.05	0.6, 0.7, 0.8	9	315,677
		14	315,677
		18	315,677

VRPs of crossdock to customer of every crossdock were solved by the same method and the results were showed in table B-12 to table B-17, appendix B. The conclusion of the results was displayed in table 4-17 and plotted in figure 4-12. The relative between number of crossdock with cost and distance was down and after reached 4, 5 crossdocks it was up again. The objective was minimum total cost so the selected crossdocking system should be VRP with 4 crossdocks which used 1 pick-up truck, 5 medium trucks and 2 large trucks. Total distance of chosen system was 3,158 kilometers with total cost 442,435 Baht.

Table 4-17: Conclusion of total distance and cost of VRP with crossdocking system

Crossdock	Pick-up	Medium	Large	Distance	Cost
8	6	7	1	2,906	600,004
7	5	8	1	2,874	610,466
6	3	8	1	2,818	545,745
5	2	5	2	2,815	473,145
<b>4</b>	<b>1</b>	<b>5</b>	<b>2</b>	<b>3,158</b>	<b>442,435</b>
3	0	6	2	4,131	457,932

In figure 4-13 was illustrated VRP of 8 crossdocks route based on data in table 4-10. The normal was represented medium truck and dash line was represented large truck. For example, first sequence was a route between depot to Lamphun by medium truck and then return back to depot. Phitsanulok route was a double trips, it used 2 of medium trucks and continue with the same truck to next stop Uttaradit. The last trip was a large truck from depot to Chiang Rai.

Next state will be a cost-benefits analysis to compare and evaluate which solution between VRP with or without crossdocking system will be chosen, please continually find in the next title.

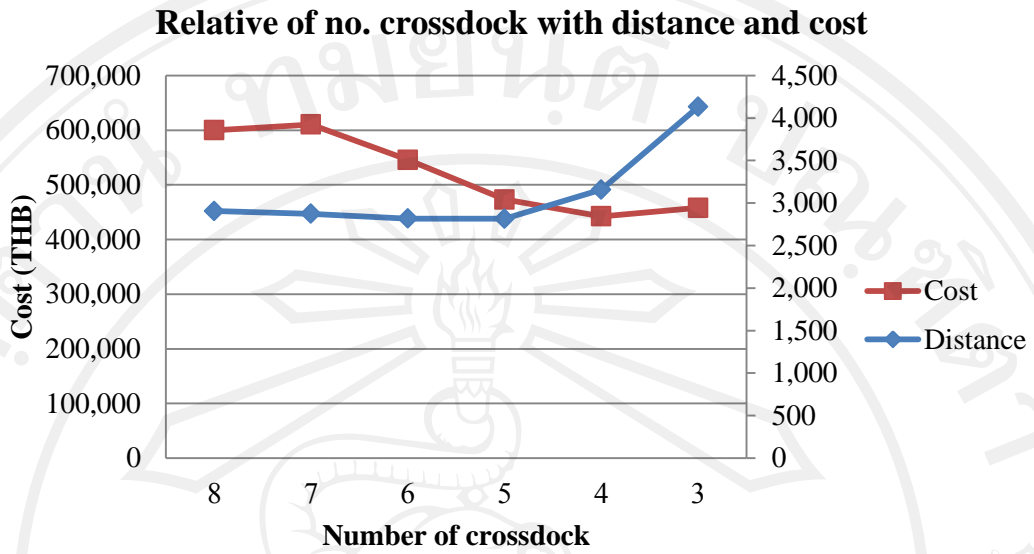


Figure 4-12: The relative of number of crossdock with distance and cost

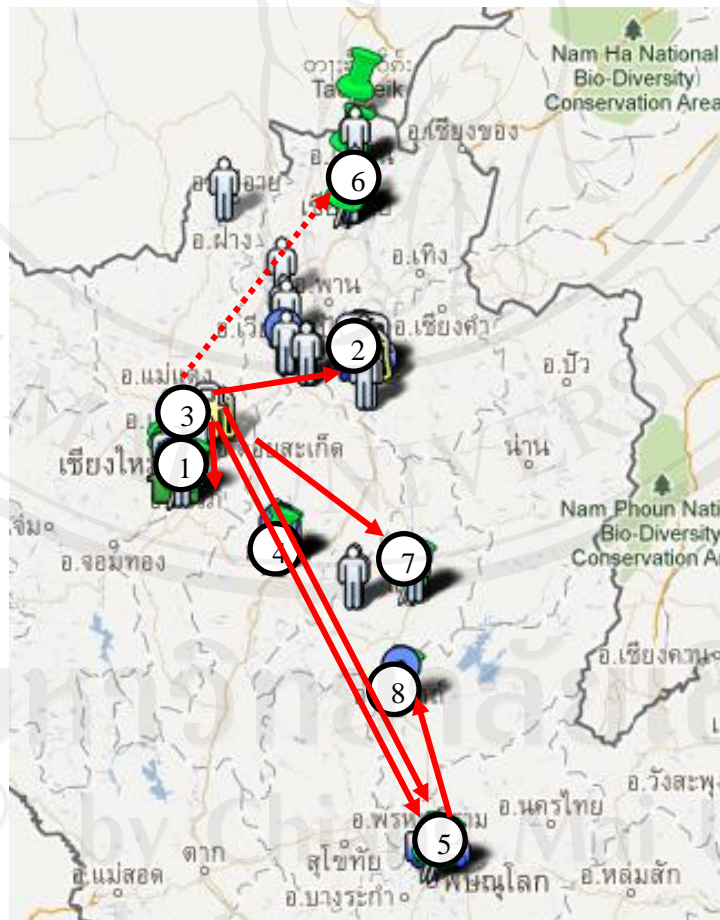


Figure 4-13: Illustration of routing between crossdock to crossdock

#### 4.5 Economic costs benefit analysis

In this title, economic costs benefit analysis will be compared in 2 dimensions the first dimension was efficiency point of view; total distance and number of truck. Second dimension was financial dimension; IRR, BEP, and PB. The results were already below.

There was 3 types of truck; pick-up, medium and large truck, classified by fleet information in table 4-3. In this research, capacity and fuel consumption number were based on the average of each truck type data from table 4-3 data showed in table 4-18. Cost of outsource in table 4-18 was from interviewing of vehicle procurement and maintenance manager from Kerry Distribution Company. Total cost, total distance and fleet number of current method and 2 solutions were shown in table 4-19.

Table 4-18: Truck cost per type

Truck Type	Capacity	Fuel Consumption	Outsource Cost		
			Truck	Driver	Total
Pick-up	51,657	8	14,700	18,000	32,700
Medium	179,267	5	25,000	18,000	43,000
Large	360,533	4	70,000	18,000	88,000

Table 4-19: Conclusion of solutions

Solution	Fleet			Total Distance	Total cost
	Pick-up	Medium	Large		
Current	7	8	2	6,354	783,928
VRP without crossdock	2	6	1	3,944	411,400
VRP with crossdock	1	5	2	3,158	423,700

##### 4.5.1 Example of daily transportation cost calculation

###### Current method

$$\text{Fuel cost} = \text{total distance} / \text{fuel consumption} * \text{oil price} \quad (4.1)$$

$$\text{Outsource cost} = \text{number of each truck type} * \text{outsource cost in table 4-18} \quad (4.2)$$

- 7 pick-up trucks;

$$(4.1) \quad \text{Fuel cost} = 2,098.65/8*29.99 = 7,869 \text{ Baht}$$

$$(4.2) \quad \text{Outsource cost} = 7*32,700 = 228,900 \text{ Baht}$$

- 8 medium trucks;

$$(4.1) \quad \text{Fuel cost} = 3,163/5*29.99 = 18,972 \text{ Baht}$$

$$(4.2) \quad \text{Outsource cost} = 8*43,000 = 344,000 \text{ Baht}$$

- 2 large trucks;
    - (4.3) Fuel cost =  $1092/4 * 29.99 = 8,187$  Baht
    - (4.4) Outsource cost =  $2 * 88,000 = 176,000$  Baht
- Summation all cost for current method  
 $= 7,869 + 228,900 + 18,972 + 344,000 + 8,187 + 176,000$   
 $= 783,928$  Baht

Equation 4.1 was fuel cost which can be calculated by total distance (kilometer) multiply by fuel consumption (kilometer per liter) result was amount of fuel usage for the distance (liter). Afterward, used fuel amount (liter) time to fuel price (Baht per liter), the summation was fuel cost usage in the distance (Baht)

Equation 4.2 was outsource cost came from daily outsource cost in table 4-18 (baht per truck) multiply by number of vehicle owned (truck), result was outsource cost of each type.

The last table of this chapter was cost and benefits analysis by the 3 financial analysis methods; Break-Even Point (BEP) in the first column of analysis method, Internal Rate of Return (IRR) in the second, and the third was Payback Period known as PB ratio. In total invest column was the investment that need to add more from current state. For example, VRP medium used 9 medium trucks per currently 8 trucks so this method need one more medium truck and cost of adding 1 medium truck was THB 43,000.

#### 4.5.2 Example of BEP calculation

From equation 2.12 in chapter 2; BEP can be calculated manually by this equation. For VRP without crossdocking system was invested 411,400 baht and income was equaled to 11,469 baht (Current cost 35,028 – Proposed cost 23,559 = Cost reduced 11,469). All BEP results of 2 solutions were in table 4-20.

$$(2.12) \quad X = FC / (P - VC)$$

$$X = 411,400 / (11,469)$$

$$X = 35.8 \text{ days} \approx 36 \text{ days at total cost.}$$

#### 4.5.3 Example of IRR calculation

From equation 2.15 in chapter 2; IRR can be calculated manually by this equation. For VRP without crossdocking system investment was 411,400

Baht equal to outflow NPV, monthly income was 11,469 baht (Current cost 35,028 – Proposed cost 23,559 = Cost reduced 11,469). All IRR results of 3 methods were in table 4-20.

$$\begin{aligned}
 (2.15) \quad NPV_{\text{out}} &= \sum_{n=1}^n \frac{\text{Income}}{(1+\text{IRR})^n} \\
 411,400 &= \frac{11,469}{(1+\text{IRR})^1} + \frac{11,469}{(1+\text{IRR})^2} + \frac{11,469}{(1+\text{IRR})^3} + \dots + \frac{11,469}{(1+\text{IRR})^{30}} \\
 \text{IRR} &= 18\%
 \end{aligned}$$

#### 4.5.4 Example of PB calculation

For example, from equation 2.16 in chapter 2; Payback Period can be calculated manually by this equation. For VRP without crossdocking system was invested 411,400 baht and income was equaled to 11,469 baht (Current cost 35,028 – Proposed cost 23,559 = Cost reduced 11,469). All PB results of 3 methods were in table 4-20.

$$\begin{aligned}
 (2.16) \quad \text{Payback period} &= \text{Investment required} / \text{Net annual cash inflow} \\
 \text{Payback period} &= 411,400 / 11,469 \\
 \text{Payback period} &= 35.8 \text{ days} \approx 36 \text{ days returned of investment.}
 \end{aligned}$$

All 3 analysis methods of 3 solutions were demonstrated in table 4-20 and for more detail please find in appendix B, BEP and PB were the same results because BEP used the same unit with PB. BEP usually uses pieces unit of product but in this case used working day unit to calculate BEP.

Table 4-20: Cost-benefit analysis

Solution	Analysis Method			Total Invest (THB)
	BEP	IRR	PB	
VRP without Crossdock	36	18%	36	411,400
VRP with Crossdock	29	20%	29	423,700

All of the results and analysis was handed over to the next chapter (Chapter 5: Conclusion) to conclude; it will be displayed and described which solution will be the chosen choice for this case study and why it has been choose.