A CASE STUDY OF THE TRUCK ASSIGNMENT PROBLEM IN A WHOLESALE BUSINESS

By
WARAYA PUNGPIT

A Final Report of the Six-Credit Course
SCM 2202 Graduate Project

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

Martin de Tours School of Management
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Martin de Tours School of Management
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Bangkok, Thailand

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Assumption University
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Master of Science in Supply Chain Management

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I, Waraya Pungpit declare that this thesis/project and the work presented in it are my own and has been generated by me as the result of my own original research. A case study of the truck assignment problem in a wholesale business

I confirm that:

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ID: _5029381___

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

Signed: ________________________________

Advisor Dr. Samarn Chantaravarapan

Date

December 1, 2010

ABSTRACT

The stock availability in each branch or store for responding to customers is significant. The transportation network between central distribution center and stores for replenishment stock at stores is also important. This study focuses on truck assignment. The purpose of this paper is to develop improved truck scheduling for the store's stock replenishment in order to increase truck utilization, resulting in logistic cost reduction. This study develops a transportation strategy, incorporating the current situation that has many constraints. The transport strategy includes vehicle routing and scheduling, routing sequencing, and implementation of a routing and scheduling method. A proposed algorithm is implemented and the result is compared with the current outcome and lower bound, which show significant improvement. The scope of this paper is to experiment with a model for establishing routing scheduling. The stores selected as pilot stores are located within 300 kilometers from a central distribution center, and carry products on pallets in containers.

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Waraya Pungpit

Assumption University

July, 2010

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CHAPTER I

GENERALITIES OF THE STUDY

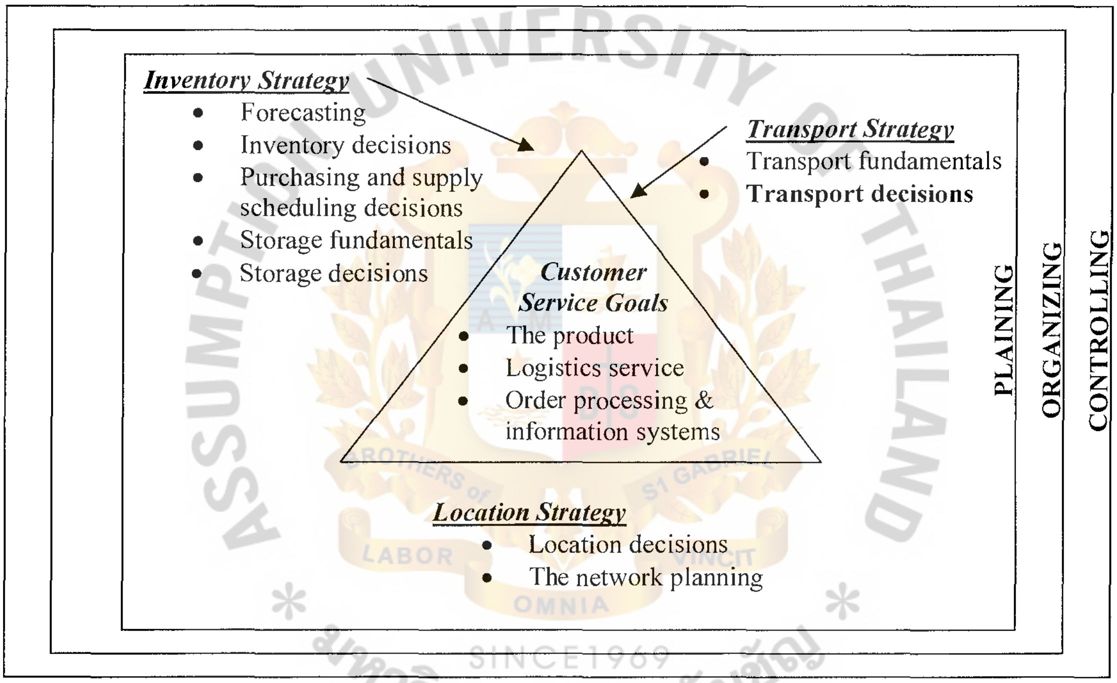
According to the real world situation, the transport problem in terms of transportation cost is a major problem for every firm. It is a big contributory cost of the overall business cost, except for the cost of purchased goods e.g. fuel cost, vehicle cost (ownership or rental), driver cost etc. Hence, transportation is a key decision for every business, as they try to minimize this cost by finding the optimal or the best solution for their business.

Recently, in Thailand the biggest retailers, called Hypermarket, Wholesaler, or Modern Trade (Big C, Tesco Lotus, Makro and Carrefour) have been involved in a high level of competition to provide customer satisfaction. The stock availability in each branch or store for responding to customer needs, is a significant factor. Transportation between a distribution center (DC) and stores to replenish stock at those stores is important also. These firms have a big transportation network and high cost because they have many stores located across the country. If they need to meet the customer service goals included with the product, then they must have logistics service order processing, information systems, and transportation planning.

Therefore, if they can reduce the transportation cost and meet customer demand by having good transport planning and a proper transport strategy they will be the winner in their business arena. In other words, transportation directly impacts the competition in the retail market in responding customer satisfaction and keeping market share.

Ballou (2004) explained that logistic planning includes three strategies: inventory strategy, location strategy, and transport strategy, and all of these support the business in meeting customer service goals. Part of transport strategy includes transport fundamentals and transport decisions that are a factor impacting on customer service goals, as expressed in Figure 1.1.

Figure 1.1: Logistic Planning



Source: Ballou (2004)

This paper especially focuses on those transport decisions involved in vehicle scheduling planning for a wholesale business, ABC Company. The ABC Company uses truck transportation every day to carry their merchandise from a DC (Distribution Center) to stores across the country (inland transportation). The type of truck used is an 18 wheeled vehicle (Semi- Trailer) and the type of ABC transportation network involved is door to door delivery. However, this paper is only concerned with route efficiency that affects transportation cost. Route efficiency means that on each route, compared to the current situation there can be a decrease in the number of trucks carrying full containers between a DC and stores. Efficient utilization of the number of tucks on each route needs to be significantly improved. Numerical experiments can be conducted to evaluate various models to solve this problem.

Therefore, the issue is how to adjust the current vehicle scheduling so as to increase efficiency of routes, under real constraints. These constraints include: different time windows, traveling times and distances, number of containers in each store, and the government ban which limits truck hours for urban stores.

1.1 Background of the Study

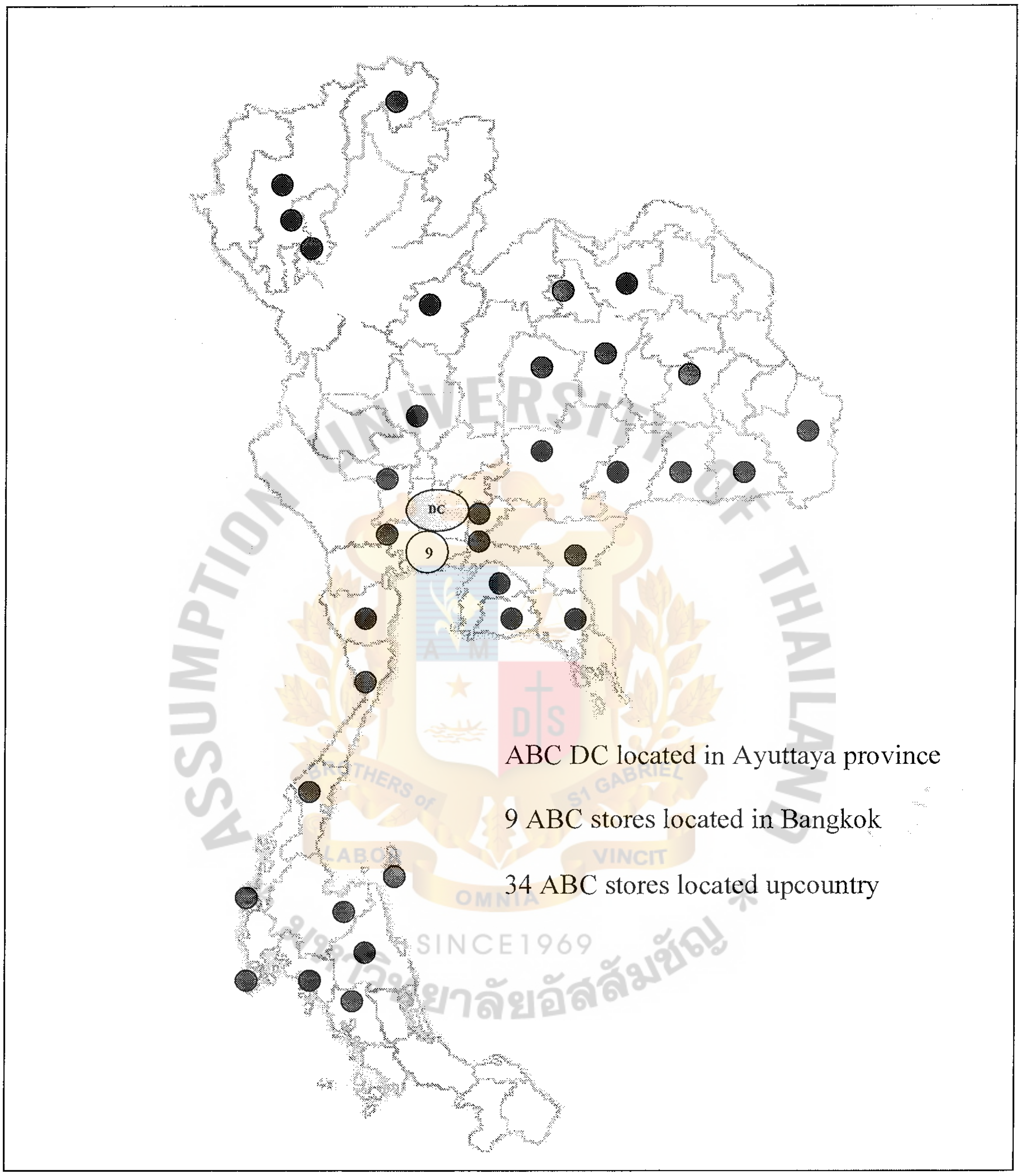
The principal business of ABC Company is the operation of wholesale trade centers throughout Thailand. Currently, there are 43 ABC stores of varying size. 9 stores are located within the Greater Bangkok area and 34 stores are in the provinces. Each store is ideally positioned geographically to be easily accessible for all customers. Every store offers a product range and assortment, designed specifically for the customer's changing needs and expectations. The ABC stores can be categorized by location and separated into Bangkok and Upcountry, as shown in Table 1.1 and Figure 1.2.

Table 1.1: ABC stores location separated into Bangkok and Upcountry i.e. 9 ABC stores in Bangkok and 34 ABC stores in Upcountry

Seq	Store Code.	Store Location	Loaction
1	1	Ladprao	BKK
2	2	Changwattana	BKK
3	3	Srinakarin	BKK
4	4	Bangbon	BKK
5	8	Rangsit	BKK
6	17	Charunsanitwong	BKK
7	18	Sathorn	BKK
8	21	Samsaen	BKK
9	42	Ramintra	BKK

Seq	Store Code.	Store Location	Loaction	Seq	Store Code.	Store Location	Loaction
1	5	Chonburi	UPC	9	14	Ubonratchanthanee	UPC
2	6	Chiangmai	UPC	10	15	Rayong	UPC
3	7	Korat	UPC	11	16	Nakonsawan	UPC
4	9	Hadyai	UPC	12	19	Nakonpathom	UPC
5	10	Udorn	UPC	13	20	Surin	UPC
6	11	Pisanulok	UPC	14	22	Nakonsrithamarat	UPC
7	12	Khonkaen	UPC	15	23	Chiangrai	UPC
8	13	Surat	UPC	16	24	Sakonnakorn	UPC
Seq	Store Code.	Store Location	Loaction	Seq	Store Code.	Store Location	Loaction
17	25	Supanburi	UPC	26	34	Lampoon	UPC
18	26	Chantaburi	UPC	27	35	Krabi	UPC
19	27	Phuket	UPC	28	36	Petchburi	UPC
20	28	Roiet	UPC	29	37	Chaiyapoom	UPC
21	29	Trang	UPC	30	38	Saraburi	UPC
22	30	Sakaew	UPC	31	39	Pranburi	UPC
23	31	Samui	UPC	32	40	Chachoengsao	UPC
24	32	Burirum	UPC	33	41	Chiangmai 2	UPC
25	33	Srisaket	UPC	34	43	Choomporn	UPC

Figure 1.2: ABC Configurations



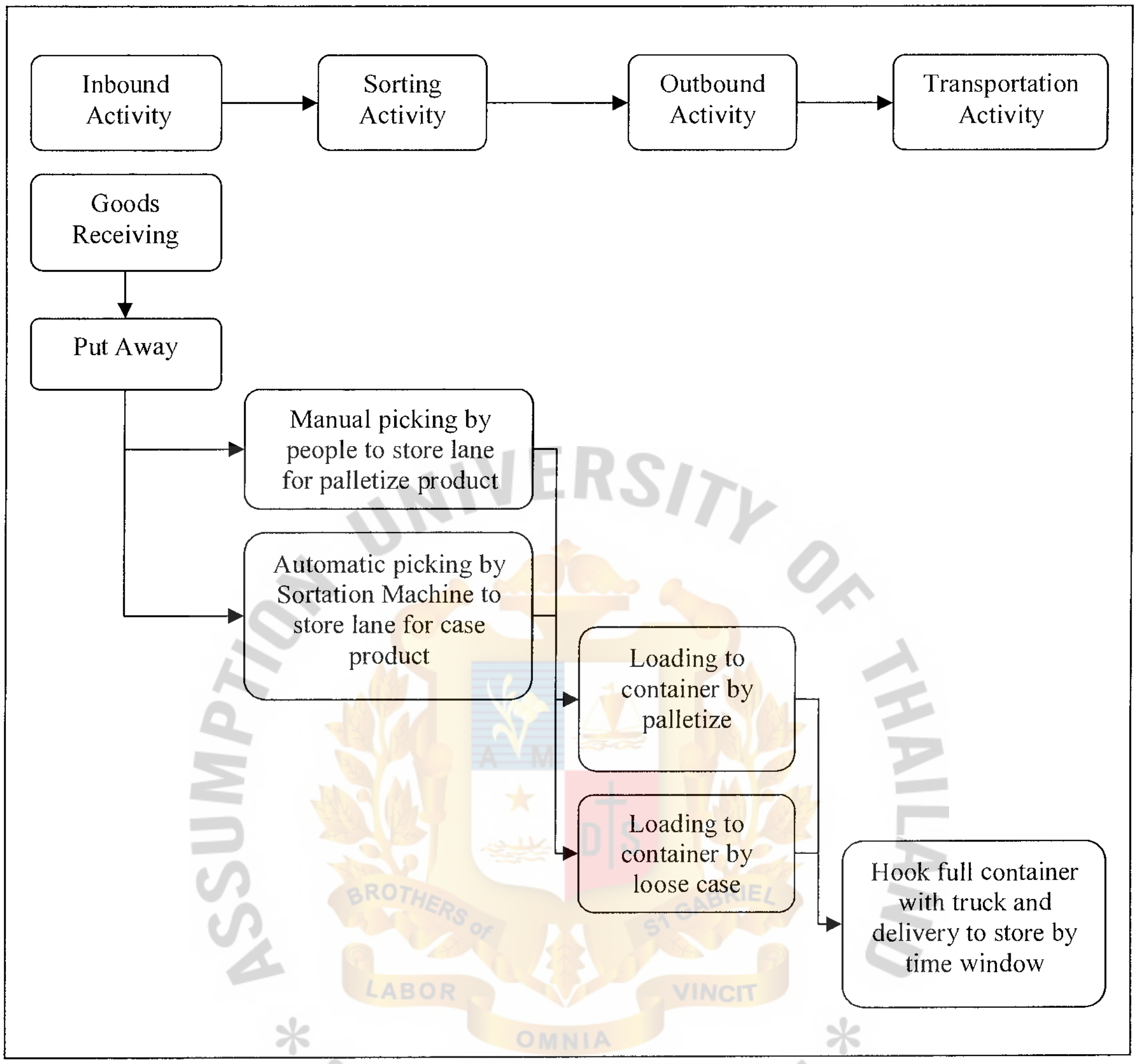
ABC Company continues to successfully sell food and non-food products to a multitude of clientele. The main focus is small-to-medium size businesses, predominantly small retailers, institutions, professionals, and the service sector.

ABC has set up two distribution centers (DC) to distribute quality product to stores across the country, according to whether they are Fresh Food or Ambient (Dry) Food . ABC's Distribution Centers are located in Ayutthaya province. This paper focuses only on transportation between the Dry Food DC and stores across the country.

1.1.1 The type of ABC Distribution Center

The typical ABC Distribution Center is a dry cross-docking distribution center which distributes consumable and consumer products with uncontrolled temperatures (Ambient Cross Docking Facility). It is a pure cross-docking facility and does not keep stock at the DC. It is operated by 3PLs (Third Party Logistic Service Providers). 3PLs provide the operation of the ABC DC in two ways: operational management inside the DC, and transportation management between a DC and ABC stores. The overall activity at ABC Dry DC is illustrated in Figure 1.3.

Figure 1.3: Overall activities at ABC Dry DC

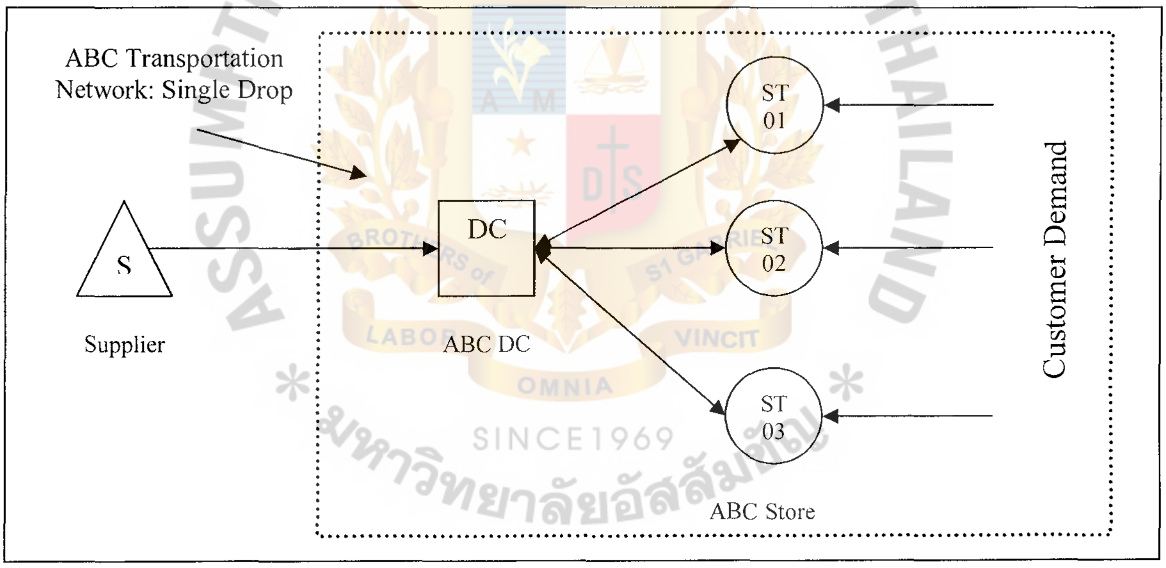


Recently, approximately 30 % of overall Dry Food items of ABC Company are distributed through DC to ABC stores across the country. ABC DC use semi-trailers, more than 180 head trucks and 250 containers, for transferring products in over 150,000 cases per day to ABC stores. Products which are distributed through the DC to ABC stores are products from big suppliers in Thailand which have a variety of products e.g. Unilever, Nestle, P&G, Thai Beverage, Colgate-Palm Olive, 3M Thailand.

1.1.2 The type of ABC Transportation Network between DC and Stores

The type of ABC transportation network for delivery products between a DC and ABC stores across the country is a single drop. A 'sing drop' is an activity where the truck travels from DC to store for unloading a full container at the store. After unloading is finished, the truck travels back to DC. On average, each day a truck can hook full containers and deliver 2 containers to ABC stores. The destination of 2 containers is separated into stores located within 300 kilometers from DC to ABC stores, and over 300 kilometers from DC to ABC stores. A single drop is shown in Figure 1.4.

Figure 1.4: The type of ABC transportation network: Single Drop

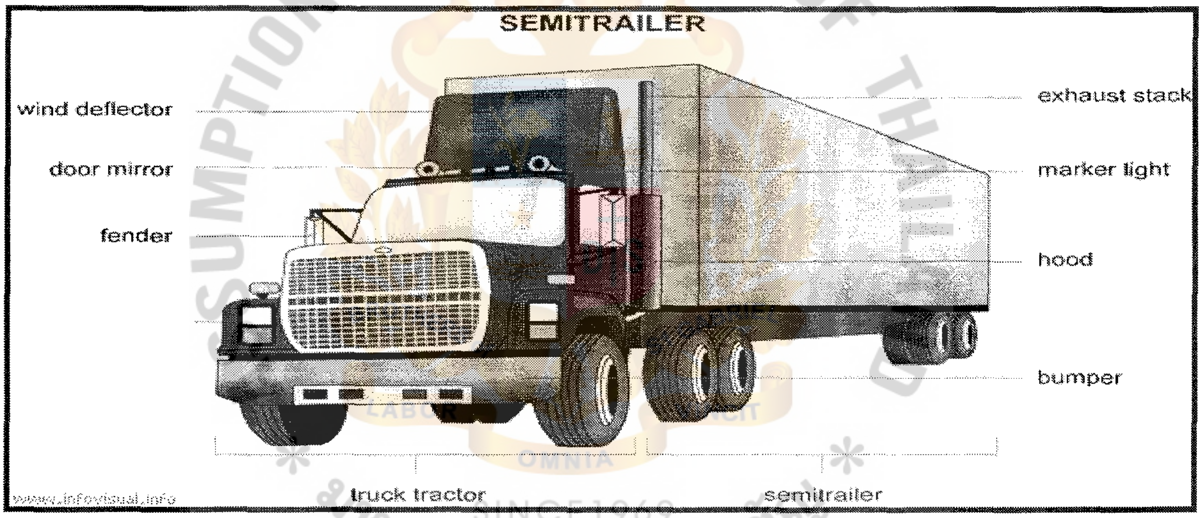


There are two types of loading products into container for delivery it to ABC stores from DC: Palletize, and Loose Case. Each ABC store has a different time window to receive a truck from DC depending on the appropriate policy in each store.

1.1.3 The type of truck used in the ABC Transportation Network

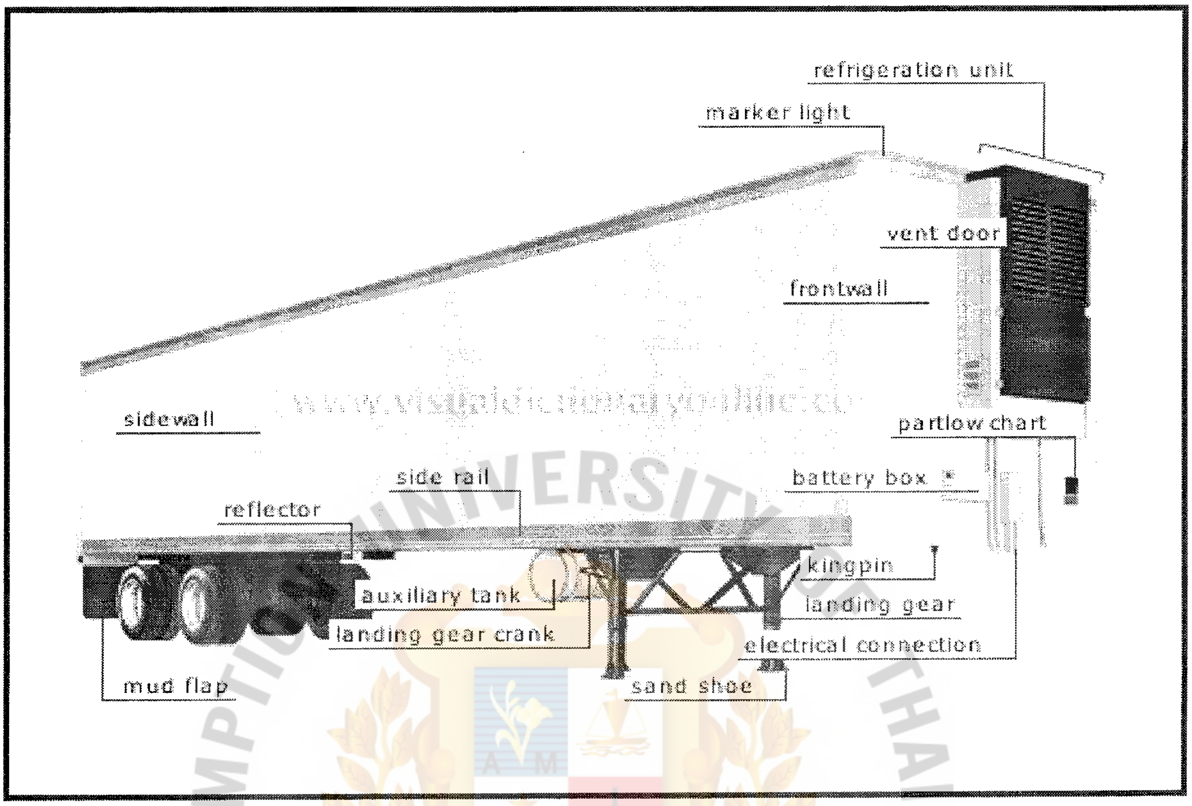
Semi-Trailers are used in the ABC transportation network for sending products from DC to ABC stores. Semi-Trailer is a trailer without a front axle and normally equipped with legs that can be lowered to support it when it is uncoupled. It can uncouple between the head-truck and the tail- trailer or container. It is typically between 26 and 53 Feet long (7.92 and 16.15M) and therefore requires a substantial amount of freight to make such transportation economical, as expressed in Figures 1.5 and 1.6

Figure 1.5: Semi-Trailer



Source: Visual Dictionary website: http://www.visualdictionaryonline.com

Figure 1.6: Tail-Trailer or Container



Source: Visual Dictionary website: http://www.visualdictionaryonline.com

The ABC Dry Distribution Center has the potential to support a high volume of products and consolidate the products from suppliers for distributing them to ABC stores across the country at the same time, which help to reduce the number of vehicles on the road and reduce the volume of fuel that is used in the real world current situation.

1.2 Statement of the Problem

The current status of stock availability at stores is significant for competing in the market by responding to customers' satisfaction. Hence, transportation is important for replenishment stock at stores also. The volume of products through a DC affects the number of containers for carrying products and the number of trucks for delivering them to stores every day.

Each day, DC has many full containers for delivering products to ABC stores to replenish their stock and increase their stock availability. Trucks will get assignments at a minimum of 2 containers per route for delivery of full containers from DC to ABC stores i.e. delivery of full containers to stores located within 300 kilometers or over 300 kilometers. For example, a truck is assigned for delivery of a full container to Ladprao branch in Bangkok and to Chaiang-Mai branch. Hence, this truck wastes 2 or 3 days on this route since the truck is dispatched from DC for delivery of the first full container to Ladprao branch, and then back to DC after delivering the full container at Ladprao branch. Then that truck hooks onto a new full container (the second container) for delivery to Chiang-Mai branch, and when that delivery is completed it goes back to DC.

In this example, this truck wastes 2 or 3 days per route. Then, DC will prepare an available truck at DC for supporting an incoming volume of products during the 2 or 3 days that the truck goes to Ladprao and Chaiang-Mai branch, and this affects the rental cost for an available truck at DC. DC cannot wait for the truck to come back from Chaiang-Mai for hooking a new full container at DC and delivery to a store because stock availability at ABC stores is important.

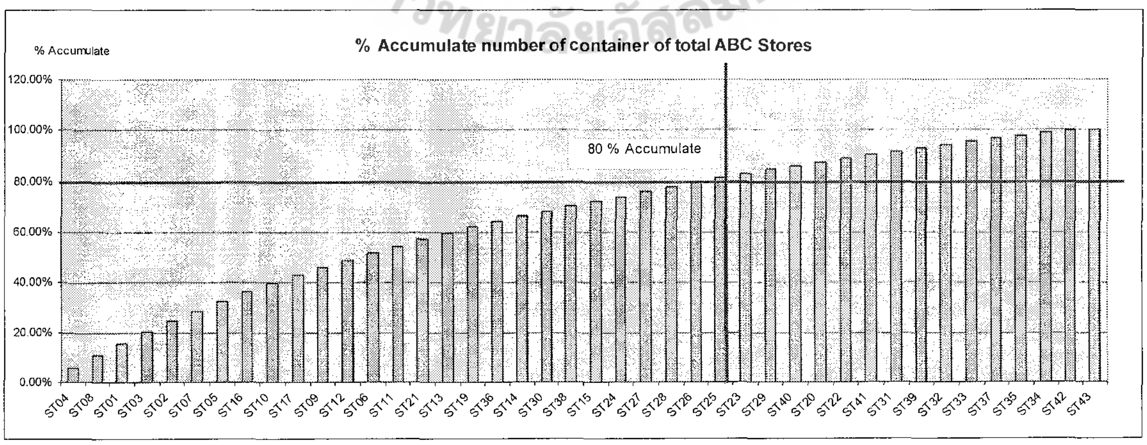
The question is: how to increase route efficiency for increase stock availability at ABC stores. By focusing on a route for ABC stores located around Bangkok and within 300 kilometers from DC, carrying by palletize which is easy to unload than for loose case, and traveling time is not over 6 hours from DC to ABC store, as illustrated in Table 1.2.

Table 1.2: ABC stores within 300 kilometers

Store	Store Location	BKK/UPC	Part	Palletize / Loose Case	Distance (KM)	Travel Time (Hour)
1	Ladprao	BKK	C	P	72	2:00
2	Changwattana	BKK	C	P	60	2:00
3	Srinakarin	BKK	C	P	72	2:00
4	Bangbon	BKK	C	P	72	2:00
5	Chonburi	UPC	E	P	120	3:00
7	Korat	UPC	NE	P	256	5:00
8	Rangsit	BKK	C	P	35	1:00
15	Rayong	UPC	E	P	239	5:00
16	Nakonsawan	UPC	N	P	240	5:00
17	Charunsanitwong	BKK	C	P	72	2:00
19	Nakonpathom	UPC	W	P	100	3:00
21	Samsaen	BKK	C	P	72	2:00
25	Supanburi	UPC	W	P	110	3:00
26	Chantaburi	UPC	E	P	300	6:00
30	Sakaew	UPC	E	P	237	5:00
36	Petchburi	UPC	W	P	160	4:00
38	Saraburi	UPC	NE	P	107	3:00
39	Pranburi	UPC	S	P	281	6:00
40	Chachoengsao	UPC	C	P	123	3:00
42	Ramintra	BKK	C	P	60	2:00

This paper focuses on ABC stores located within 300 kilometers because most ABC stores in this group are big branches that generate 80% sales to ABC Company and hold a high number of full containers at DC, as expressed in Figure 1.7.

Figure 1.7: Percent Accumulated number of containers of all ABC Stores



Furthermore, for a distance within 300 kilometers from DC, it is easy to turn around trucks between DC and an ABC store within a day.

Focusing on truck utilization to ABC stores located in the short distance group and carrying by palletization for each day during January – June 2009, is illustrated in Table 1.3. The number of trucks and full containers to ABC stores in the short distance group on daily basis during January – June 2009 and percent truck utilization (percent of number of trucks to number of full containers) is shown in Table 1.4.

Table 1.3: Number of trucks and full containers of ABC stores within 300 kilometers on daily basis during January – March 2009

January					February					March				
Date	Day	No.of truck	No.of full container	% truck to Container	Date	Day	No.of truck	No.of full container	% truck to Container	Date	Day	No.of truck	No.of full container	% truck to Container
1-Jan-09	Thu	-	-	0.00%	1-Feb-09	Sun	-	-	0.00%	1-Mar-09	Sun	-	-	0.00%
2-Jan-09	Fri	-	-	0.00%	2-Feb-09	Mon	38	40	95.00%	2-Mar-09	Mon	50	53	94.34%
3-Jan-09	Sat	7	7	100.00%	3-Feb-09	Tue	25	25	100.00%	3-Mar-09	Tue	26	26	100.00%
4-Jan-09	Sun	-	-	0.00%	4-Feb-09	Wed	25	25	100.00%	4-Mar-09	Wed	34	34	100.00%
5-Jan-09	Mon	11	11	100.00%	5-Feb-09	Thu	37	39	94.87%	5-Mar-09	Thu	29	30	96.67%
6-Jan-09	Tue	25	25	100.00%	6-Feb-09	Fri	45	50	90.00%	6-Mar-09	Fri	29	29	100.00%
7-Jan-09	Wed	33	33	100.00%	7-Feb-09	Sat	30	30	100.00%	7-Mar-09	Sat	30	30	100.00%
8-Jan-09	Thu	33	33	100.00%	8-Feb-09	Sun	-	-	0.00%	8-Mar-09	Sun	-	-	0.00%
9-Jan-09	Fri	34	37	91.89%	9-Feb-09	Mon	36	37	97.30%	9-Mar-09	Mon	35	36	97.22%
10-Jan-09	Sat	31	36	86.11%	10-Feb-09	Tue	22	22	100.00%	10-Mar-09	Tue	37	37	100.00%
11-Jan-09	Sun	-	-	0.00%	11-Feb-09	Wed	25	25	100.00%	11-Mar-09	Wed	27	27	100.00%
12-Jan-09	Mon	43	46	93.48%	12-Feb-09	Thu	36	36	100.00%	12-Mar-09	Thu	30	30	100.00%
13-Jan-09	Tue	28	28	100.00%	13-Feb-09	Fri	40	40	100.00%	13-Mar-09	Fri	47	49	95.92%
14-Jan-09	Wed	33	37	89.19%	14-Feb-09	Sat	51	54	94.44%	14-Mar-09	Sat	37	41	90.24%
15-Jan-09	Thu	33	34	97.06%	15-Feb-09	Sun	-	-	0.00%	15-Mar-09	Sun	-	-	0.00%
16-Jan-09	Fri	36	36	100.00%	16-Feb-09	Mon	29	29	100.00%	16-Mar-09	Mon	51	53	96.23%
17-Jan-09	Sat	39	41	95.12%	17-Feb-09	Tue	26	26	100.00%	17-Mar-09	Tue	47	49	95.92%
18-Jan-09	Sun	-	-	0.00%	18-Feb-09	Wed	36	36	100.00%	18-Mar-09	Wed	44	46	95.65%
19-Jan-09	Mon	42	43	97.67%	19-Feb-09	Thu	33	34	97.06%	19-Mar-09	Thu	52	56	92.86%
20-Jan-09	Tue	45	51	88.24%	20-Feb-09	Fri	36	36	100.00%	20-Mar-09	Fri	43	44	97.73%
21-Jan-09	Wed	43	51	84.31%	21-Feb-09	Sat	32	34	94.12%	21-Mar-09	Sat	39	40	97.50%
22-Jan-09	Thu	50	52	96.15%	22-Feb-09	Sun	-	-	0.00%	22-Mar-09	Sun	-	-	0.00%
23-Jan-09	Fri	42	42	100.00%	23-Feb-09	Mon	42	42	100.00%	23-Mar-09	Mon	42	43	97.67%
24-Jan-09	Sat	45	45	100.00%	24-Feb-09	Tue	45	45	100.00%	24-Mar-09	Tue	21	22	95.45%
25-Jan-09	Sun	-	-	0.00%	25-Feb-09	Wed	38	38	100.00%	25-Mar-09	Wed	38	39	97.44%
26-Jan-09	Mon	53	58	91.38%	26-Feb-09	Thu	38	39	97.44%	26-Mar-09	Thu	33	33	100.00%
27-Jan-09	Tue	34	35	97.14%	27-Feb-09	Fri	42	46	91.30%	27-Mar-09	Fri	34	34	100.00%
28-Jan-09	Wed	41	41	100.00%	28-Feb-09	Sat	47	50	94.00%	28-Mar-09	Sat	34	35	97.14%
29-Jan-09	Thu	17	17	100.00%					0.00%	29-Mar-09	Sun	-	-	0.00%
30-Jan-09	Fri	33	33	100.00%					0.00%	30-Mar-09	Mon	42	44	95.45%
31-Jan-09	Sat	43	45	95.56%					0.00%	31-Mar-09	Tue	28	29	96.55%
Total		874	917	95.31%	Total		854	878	97.27%	Total		959	989	96.97%

Table 1.3: Number of trucks and full containers of ABC stores within 300 kilometers on daily basis during April - June 2009

(Continuous)

April					May					June				
Date	Day	No.of truck	No.of full container	% truck to Container	Date	Day	No.of truck	No.of full container	% truck to Container	Date	Day	No.of truck	No.of full container	% truck to Container
1-Apr-09	Wed	16	17	94.12%	1-May-09	Fri	44	46	95.65%	1-Jun-09	Mon	47	54	87.04%
2-Apr-09	Thu	23	24	95.83%	2-May-09	Sat	35	37	94.59%	2-Jun-09	Tue	40	50	80.00%
3-Apr-09	Fri	31	34	91.18%	3-May-09	Sun	-	-	0.00%	3-Jun-09	Wed	35	46	76.09%
4-Apr-09	Sat	32	34	94.12%	4-May-09	Mon	32	32	100.00%	4-Jun-09	Thu	28	37	75.68%
5-Apr-09	Sun	-	-	0.00%	5-May-09	Tue	35	36	97.22%	5-Jun-09	Fri	22	31	70.97%
6-Apr-09	Mon	36	38	94.74%	6-May-09	Wed	26	28	92.86%	6-Jun-09	Sat	26	40	65.00%
7-Apr-09	Tue	28	29	96.55%	7-May-09	Thu	35	41	85.37%	7-Jun-09	Sun	-	-	0.00%
8-Apr-09	Wed	30	31	96.77%	8-May-09	Fri	33	35	94.29%	8-Jun-09	Mon	35	42	83.33%
9-Apr-09	Thu	35	38	92.11%	9-May-09	Sat	30	31	96.77%	9-Jun-09	Tue	18	29	62.07%
10-Apr-09	Fri	34	37	91.89%	10-May-09	Sun	-	-	0.00%	10-Jun-09	Wed	27	33	81.82%
11-Apr-09	Sat	54	68	79.41%	11-May-09	Mon	32	33	96.97%	11-Jun-09	Thu	32	44	72.73%
12-Apr-09	Sun	-	-	0.00%	12-May-09	Tue	39	39	100.00%	12-Jun-09	Fri	28	39	71.79%
13-Apr-09	Mon	-	-	0.00%	13-May-09	Wed	43	45	95.56%	13-Jun-09	Sat	26	36	72.22%
14-Apr-09	Tue	-	-	0.00%	14-May-09	Thu	39	40	97.50%	14-Jun-09	Sun	-	-	0.00%
15-Apr-09	Wed	-	-	0.00%	15-May-09	Fri	45	45	100.00%	15-Jun-09	Mon	23	32	71.88%
16-Apr-09	Thu	13	14	92.86%	16-May-09	Sat	44	44	100.00%	16-Jun-09	Tue	25	32	78.13%
17-Apr-09	Fri	11	11	100.00%	17-May-09	Sun	-	-	0.00%	17-Jun-09	Wed	31	35	88.57%
18-Apr-09	Sat	18	18	100.00%	18-May-09	Mon	42	43	97.67%	18-Jun-09	Thu	41	44	93.18%
19-Apr-09	Sun	-	-	0.00%	19-May-09	Tue	40	54	74.07%	19-Jun-09	Fri	45	52	86.54%
20-Apr-09	Mon	32	32	100.00%	20-May-09	Wed	30	42	71.43%	20-Jun-09	Sat	41	45	91.11%
21-Apr-09	Tue	33	35	94.29%	21-May-09	Thu	29	37	78.38%	21-Jun-09	Sun	-	-	0.00%
22-Apr-09	Wed	34	36	94.44%	22-May-09	Fri	39	50	78.00%	22-Jun-09	Mon	56	57	98.25%
23-Apr-09	Thu	35	38	92.11%	23-May-09	Sat	34	43	79.07%	23-Jun-09	Tue	45	45	100.00%
24-Apr-09	Fri	40	42	95.24%	24-May-09	Sun	-	-	0.00%	24-Jun-09	Wed	28	28	100.00%
25-Apr-09	Sat	52	55	94.55%	25-May-09	Mon	48	59	81.36%	25-Jun-09	Thu	37	39	94.87%
26-Apr-09	Sun	-	-	0.00%	26-May-09	Tue	42	54	77.78%	26-Jun-09	Fri	47	51	92.16%
27-Apr-09	Mon	37	38	97.37%	27-May-09	Wed	26	36	72.22%	27-Jun-09	Sat	38	38	100.00%
28-Apr-09	Tue	41	42	97.62%	28-May-09	Thu	47	55	85.45%	28-Jun-09	Sun	39	40	97.50%
29-Apr-09	Wed	41	42	97.62%	29-May-09	Fri	42	57	73.68%	29-Jun-09	Mon	43	50	86.00%
30-Apr-09	Thu	48	52	92.31%	30-May-09	Sat	34	43	79.07%	30-Jun-09	Tue	43	52	82.69%
				0.00%	31-May-09	Sun	16	17	94.12%					0.00%
Total		754	805	93.66%	Total		981	1,122	87.43%	Total		946	1,121	84.39%

Table 1.4: Summary of number of trucks and full containers of ABC stores located within 300 kilometers from DC, by month between January - June 2009 and Percent truck utilization (percent number of trucks to number of full containers)

Month	Number of full container	Number of truck	% Truck to Full Container
01.January	917	874	95.31%
02.February	878	854	97.27%
03.March	989	959	96.97%
04.Apr	805	754	93.66%
05.May	1122	981	87.43%
06.June	1121	946	84.39%
Avg./Month	972	895	92.04%

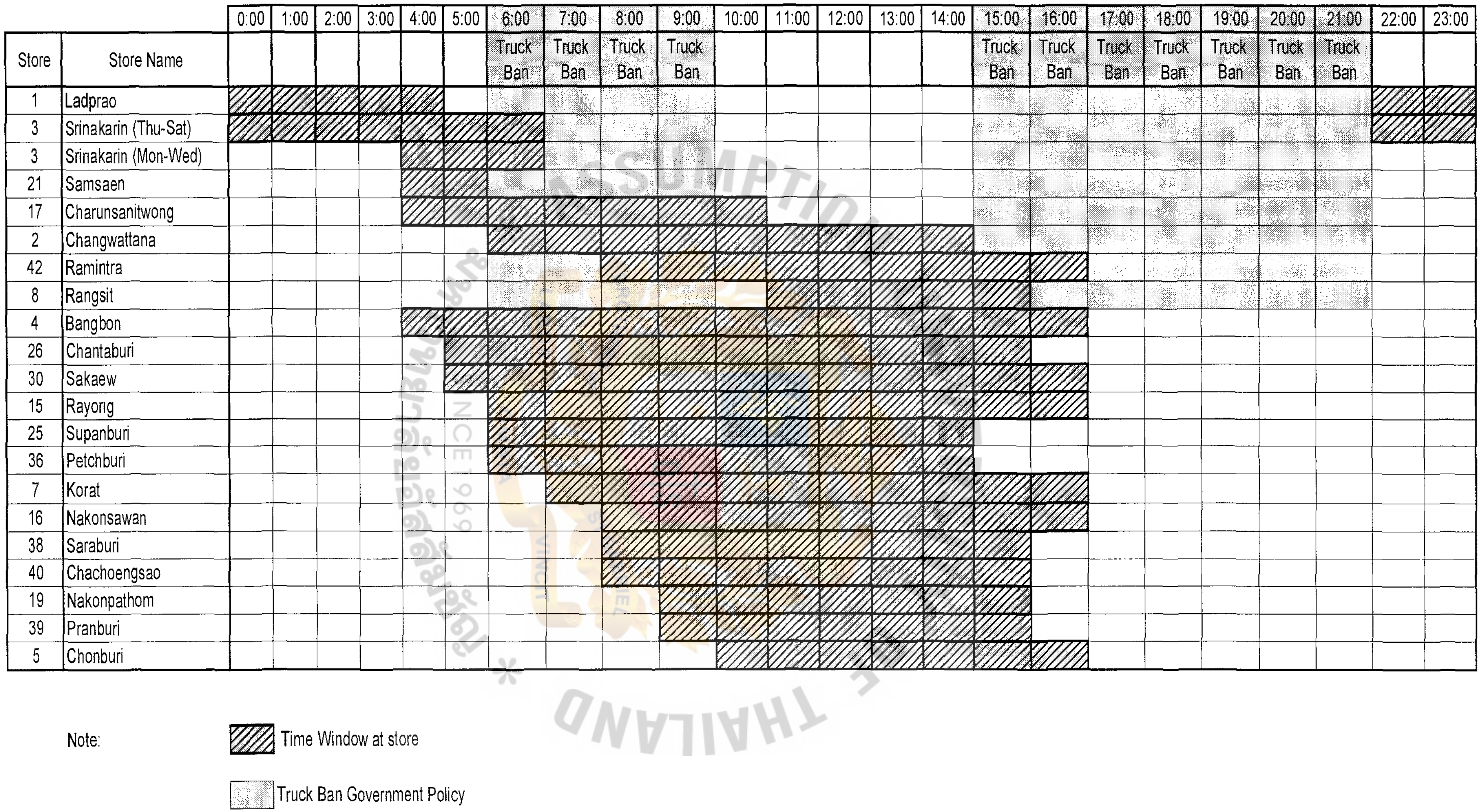
The truck utilization is bad because the figures illustrate a high percentage of the number of trucks to the number of full containers. It means that a head truck was assigned approximately one destination per route (one container) and does not turn around to hook up another container. Examples of daily truck assignment are illustrated in Table 1.5 (each container number represents one truck).

Table 1.5: Example of truck assignments each day

Delivery Date	No	Truck No.	Container No.	Destination
3 Jan 09	1	XX-0336	XX-9344	Srinakarin
	2	XX-2522	XX-9942	Bangborn
	3	XX-0425	XX-1734	Chaengwattana
	4	XX-2102	XX-2137	Ladprao
	5	XX-2104	XX-9890	Ladprao
	6	XX-2470	XX-2379	Nakornsawan
	7	XX-8221	XX-2231	Saraburi
5 Jan 09	1	XX-0559	XX-2135	Srinakarin
	2	XX-2395	XX-9942	Bangborn
	3	XX-3435	XX-2372	Bangborn
	4	XX-3436	XX-9344	Bangborn
	5	XX-2146	XX-5454	Cholburi
	6	XX-3562	XX-1219	Ladprao
	7	XX-6437	XX-4101	Nakornrachasima
	8	XX-9914	XX-1741	Nakornrachasima
	9	XX-0136	XX-4296	Nakornsawan
	10	XX-8441	XX-4881	Nakornsawan
	11	XX-2287	XX-4489	Rangsit

Furthermore, different time windows in each store and the government truck ban policy for urban stores are factors in setting up routing scheduling and affect the percentage number of trucks to number of full containers in Table 1.4. That is why a truck was assigned only one container for one distance each day. The reasons are duplication of time windows between stores, different time windows in each store, and the government truck ban policy for store located in urban areas, as shown in Figure 1.8.

Figure 1.8: Time Window and Truck Ban Government Policy



Hence, if we reduce the percentage of trucks to full containers, the company could increase routing efficiency and increase stock availability at stores in this top sales company, by having a good routing scheduling.

Consequently, this study focuses on using a model to set up routing scheduling for stores located within 300 kilometers which have high volume sales and a high number of full containers at the DC. Furthermore, the model operates under real constraints so that it can be implemented in the real world.

1.3 Research Objective

Towards the completion of this paper, the objective is to find the best model for setting up routing scheduling under real constraints for increased route efficiency and stock availability at ABC stores in a top sales company. The Transport Manager could use it as a suggestion for operating the trucks on a daily basis. The real constraints are:

1. Dispatching time (the time for dispatching the truck from DC to store)
2. Traveling time from DC to store, and store back to DC
3. Unloading time at store
4. Waiting time for a time window in each store
5. Waiting time for timing according to the government urban truck ban
6. Waiting time to hook a new container and prepare a document (delivery docket) at DC.

1.4 Scope of the Research

The project experiments with a model for setting up routing scheduling. The ABC stores selected as pilots are required to be located within 300 kilometers from DC, that covers stores in a top sales company and carrying products in containers on pallets. The data of historical number of trucks and full containers at DC is for six months, January – June 2009. The data is used for testing the model to set up scheduling. The variations included are: preparation delivery docket and hook container at DC, distance or traveling time during DC and ABC stores (go and back), waiting for a time window at a store, unloading time at store, and waiting time for the government urban truck ban. The scope of this project is finding a model for setting up the best routing scheduling for the company. The study fully aims to find a model that can increase route efficiency, stock availability at ABC stores, be appropriate for the company, and can be implemented in the real world.

1.5 Limitations of the Research

For this paper, the restrictions are factors not under control, i.e. time window at store and government truck ban policy for urban stores. However, the results of study can be generalized as a routing scheduling model that is the best suggestion for the company.

1.6 Significance of the Study

This study aims at finding a routing scheduling model that is the best solution for the company. Hence, the usefulness of the study is described as follows:

1. The routing scheduling model can be used to set up truck scheduling each day to meet the objective of increase routing efficiency and increased stock availability at ABC stores in the top sales company.
2. Good routing scheduling can reduce substitute trucks at DC because the trucks can turn around to DC better than the current situation.
3. Transport manager know the estimated traveling time from the release of trucks from a DC to stores until the trucks are back again at the DC. They can use the model as the best suggestion for operating the truck on a daily basis.

1.7 Definition of Terms

1. Hypermarket: is a superstore that combines being a supermarket and department store. It is a very large retail facility which sells full lines of grocery products and general merchandise.
2. Wholesaler: is a person or company who sells a goods or merchandise to retailers, and to industrial, commercial or other professional users.
3. Distribution Center (DC): is a facility to distribute products (goods) to retailers, wholesalers or directly to customers. A distribution center can also be called a warehouse, DC, fulfillment center, break bulk center, package handling center or cross docking facility. A facility is a specialized building e.g. refrigeration or air conditioning, ambient facility etc.

4. Semi-Trailer: is an 18 wheels vehicle. It is a trailer without a front axle and normally equipped with legs that can be lowered to support it when it is uncoupled. It can uncouple from the head-truck and tail-trailer or container. It is typically between 26 and 53 Feet (7.92 and 16.15M) and thereby requires a substantial amount of freight to make to such transportation economical.
5. Time window: is the time period of a store for receiving products (goods) from the DC each day
6. Truck Ban: is a government policy to ban trucks from travelling in urban areas according to a time period i.e. from 6am-9am in the morning and 3pm-9pm in the evening.
7. HoReCa product: is a product in terms of Hotels, Restaurants and Caterers products that are sold in ABC
8. Palletize: is a typical of loading products into a container that is a fully lined pallet truck
9. Loose Cases: is a type of loading products into a container that is a fully lined case truck
10. Cross Docking: is an activity in logistics of unloading merchandise or material from an incoming vehicle and loading the merchandise or material directly into an outbound vehicle with little or no storage in the facility
11. Less-Than-Truckful Load (LTL) carriers: is the transportation of relatively small freight. LTL carriers are parcel carriers or full truckload carriers. Parcel carriers usually handle small package and freight that can be broken down into units less than 150 Pounds (68 Kg.) Full truck load carriers move freight that is loaded into a semi- trailer.

12. Truck-Load (TL) carriers: is the movement of large amounts of homogeneous cargo, generally the amount necessary to fill an entire semi-trailer or intermodal container.
13. Vehicle Routing Problem (VRP): is a combination of optimization and nonlinear programming problems seeking to service a number of customers with a fleet of vehicles. Proposed by Dantzig and Ramser in 1959. VRP is an important problem in the fields of transportation, destination and logistics. Often the context is that of delivering goods located at a central depot to customers who have placed orders for such goods. Implicit is the goal of minimizing the cost of distributing goods. Many methods have been developed for searching for a good solution to the problem but for all but the smallest problems, finding a global minimum for the cost function is computationally complex.

CHAPTER II

REVIEW OF RELATED LITERATURE, AND RESEARCH FRAMEWORKS

This paper focuses on motor transportation planning in how to set up routing scheduling which it is the best model for the company, related theories, and previous research. It covers:

1. Fundamentals of Transportation
2. The Mode of Transportation: Motor Carriers
3. Logistic Network: Network Design
4. Logistics Planning – Transport Strategy: Vehicle Routing, Vehicle Routing and Scheduling, Route Sequencing and Implementation of Vehicle Routing and Scheduling Method
5. Review of Literature

2.1 Fundamentals of Transportation

The definition of transportation as described Wisner, Leong and Tan (2005) is that it is necessary for both moving purchased goods from suppliers to the buying organization, and moving finished goods to the customer. An efficient and effective transportation system is needed for commerce to occur in any industrialized manner. Products have little value to customer until they are moved to the customer's point of consumption. Transportation creates the efficient flow of goods between supply chain partners, allowing profits and competitive advantage to be maximized. The transportation elements included are: the objective of transportation, transportation classification, the modes of transportation, pricing, third-party transportation service, regulation and deregulation, and intermodal transportation.

2.1.1 The Objective of Transportation

Wisner et al. (2005) explain that the most important objective of transportation is moving merchandise from point A to point B. The transportation objectives should be centered on satisfying customers while minimizing costs and making a profit contribution. Hence, transportation managers must decide forms of transportation, material handling and storage along with the most appropriate vehicle scheduling and routing to use.

2.1.2 The Impact of transportation on Supply Chain Management

Wisner et al. (2005) described the impact of transportation on supply chain management in the following:

Transportation is moving a product from point of origin to point of consumption throughout the supply chain, and is thus responsible for creating time utility and place utility. Time utility or time value is created when customers get products delivered at precisely the right time, not earlier and not later. The transportation function creates time utility by determining how fast products are delivered and how long they are held in storage prior to delivery. Place utility is created when customers get products delivered to the desired location and again, it is the transportation function that accomplishes this. Thus, transportation in a supply chain setting is extremely important in that products must be routinely delivered to each supply chain partner on time and to the correct location. As mistakes occur in deliveries along the supply chain, more safety stocks must be held, and customer service levels deteriorate, eventually causing higher costs and lower customer satisfaction for end customers. To make up for lost time, overnight deliveries are also frequently used, causing transportation costs to escalate.

Thus, value in the supply chain is created by transportation. It effectively links each supply chain partner. Poor transportation management can bring a supply chain to its knees, regardless of the production cost or quality of the products. Alternatively, good transportation management can be one of the elements creating competitive advantage for supply chains.

2.2 The Modes of Transportation

Wisner et al. (2005) classify the modes of transportation into five basic modes: motor, rail, air, water and pipeline carriers. They explain the motor carriers by the following.

A Motor Carrier, also known as a truck carrier, is the most flexible means of transportation. Motor carriage provides door-to-door delivery, local pickup and delivery, and small / large shipment hauling. It has a very low fixed and variable cost and can complete favorably with rail and air carriers for short to medium distances (less than 1,000 miles) and are still competitive with other forms of transportation for cross-country shipments if there are multiple delivery destinations. The disadvantage for motor carriers is the weather. Motor carriers can offer a variety of specialized services from refrigerated, to livestock, to automobile hauling.

Motor carriers are most often classified as less-than-truckload (LTL) carriers or truck load (TL) carriers. LTL carriers move small packages or shipments that take up less than one truckload, and the shipping fees are higher per hundredweight (cwt) than TL fees, since the carrier must consolidate many small shipments into one truckload, then break the truckload back down into individual shipments at the destination for individual deliveries. However, for small item shippers, using LTL carriers is still a more expensive alternative than using a TL carrier. Rohman (2002) in Logistics Management 42, no.2 (2002), page 33-36, said that the LTL industry in the United States is made up of nation al LTL carriers like Yellow Transportation, Roadway Express, and ABF Freight System, and regional LTL carriers (specializing in shipment of less than 500 miles). Most of the regionals are small, privately owned companies that specialize in overnight and second-day deliveries. Today, they must contend with increased competition from the national carriers, since regional carriage represents the fastest-growing segment of the trucking industry. In fact, the majority of tonnage hauled by motor carriers today travels fewer than 500 miles.

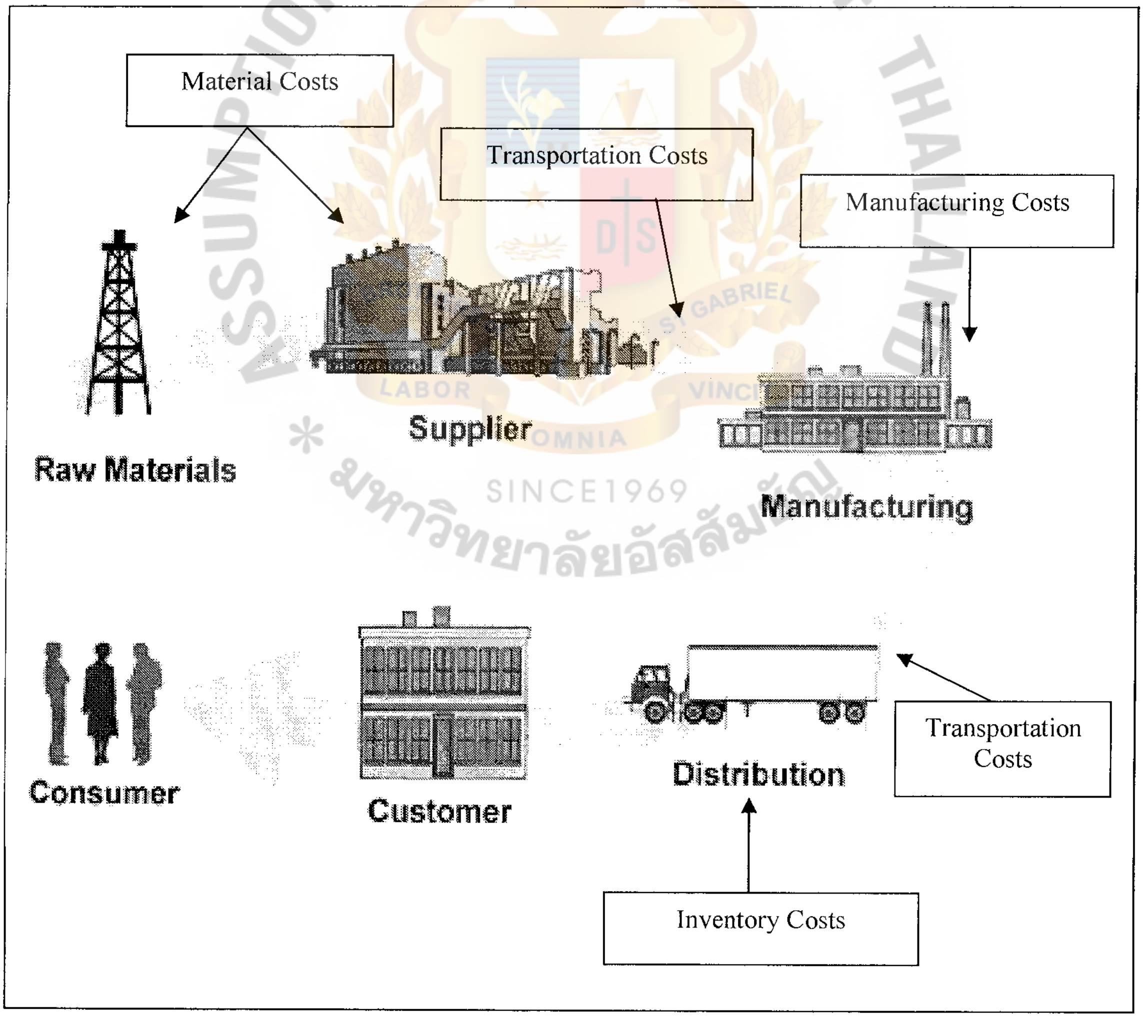
Wisner et al. (2005) explained that motor carriers can be classified based on the type of goods they haul. General freight carriers carry the majority of goods shipped and include common carriers, while specialized carriers transport liquid petroleum, household goods, agricultural commodities, building materials, and other specialized items.

Belman and Monco (2001) said that motor carriers offer fast, reliable, relatively inexpensive service with low levels of shipment damage. Their geographic coverage is very good; and for short trips, no other mode can complete.

2.3 Logistics Network

According to Simchi-Levi et al. (2008) the supply chain is also referred to as the logistics networks consisting of suppliers, manufacturing center, warehouses, distribution centers and retail outlets as well as raw materials, work-in-process inventory and finished products that flow between the facilities connected by transportation and storage activities and integrated through information planning and integration activities. This is , expressed in Figure 2.1.

Figure 2.1 Logistics Network



Source: Simchi-Levi et al. (2008).

Moreover, they explained which networks design is a strategic decision that has a long-lasting effect on the firm. It involves decisions relating to plant and warehouse location as well as distribution and sourcing. The key strategic decisions for network design are as follows:

1. Determining the appropriate number of facilities such as plants and warehouses
2. Determining the location of each facility
3. Determining the size of each facility
4. Allocating space for products in each facility
5. Determining sourcing requirements
6. Determining distribution strategies

The objective of network design is to design or reconfigure the logistic network in order to minimize annual system-wide cost, including production and purchasing costs, inventory holding costs, facility costs (storage, handling and fixed costs) and transportation costs subject to a variety of service level requirements.

2.4 Logistics Planning – Transport Strategy: Vehicle Routing, Vehicle Routing and Scheduling, Route Sequencing and Implementation of Vehicle Routing and Scheduling Method

There is a Chinese proverb, recalled by Ballou (2004): "If you are planning for one year, grow rice. If you are planning for 20 years, grow trees. If you are planning for centuries, grow men". Hence, if we have the best planning, we will achieve our goal. Ballou said that transportation is a key decision area within the logistics mix, and except for the cost of purchased goods, transportation absorbs on average a higher percentage of logistics cost than any other logistics activity. Transport decisions express themselves in a variety of forms i.e. chief among these are mode selection, carrier routing, vehicle scheduling and shipment consolidation. For this paper, the focus is on some methods that deal with transport decisions i.e. Vehicle Routing, Routing and Scheduling and Routing Sequencing, described by following.

2.4.1 Vehicle Routing

Ballou (2004) explained that because transportation costs typically range between one-third and two-thirds of total logistics costs, improving efficiency through the maximum utilization of transportation equipment and personnel is a major concern. The length of time that goods are in transit reflects on the number of shipments that can be made with a vehicle within a given period and the total transportation costs for all shipments. To reduce transportation cost and improve customer service, finding the best paths that a vehicle should follow through a network of roads, rail lines, shipping lanes or air navigational routes that will minimize time or distance is a frequent decision problem. Although there many variations of routing problems, we can reduce them to a few basic types. Ballou (2004) explained a separate and single origin and destination point as follows:

2.4.2 Separate and Single Origin and Destination Point

The problem of routing a vehicle through a network has been nicely solved by methods designed specifically for it. Perhaps the simplest and most straightforward technique is the shortest route method. The approach may be paraphrased as follows. First, given a network represented by links and nodes, where the nodes are connecting points between links, and the links are the costs (distances, times, or a combination of both formed as a weighted average of time and distance) to traverse between modes. Initially, all nodes are considered unsolved, that is, they are not yet in a defined route. A solved node is on the route. Starting with the origin as a solved node, then:

- Objective of the nth iteration. Find the nth nearest node to the origin. Repeat for n = 1,2, …until the nearest node is the destination
- Input for nth iteration. (n-1) nearest nodes to the origin, solved for by previous iterations, including their shortest route and distance from origin. These nodes plus the origin, will be called solved nodes; the others are unsolved nodes.
- Candidates for the nth nearest node. Each solved node that is directly connected by a branch to one or more unsolved nodes provided one candidate - the unsolved node with the shortest connecting branch. Ties provide additional candidates.
- Calculation of nth neatest node. For each solved node and its candidate, add the distance between them and the distance of the shortest route to the solved node from the origin. The candidate with the smallest such total distance is the nth nearest node (ties provide additional solved nodes) and its shortest route is the one generating this distance.

2.4.3 Vehicle Routing and Scheduling

Ballou (2004) explained that Vehicle Routing and Scheduling is an extension of the basic vehicle routing ("traveling salesman") problem (VRP). Realistic restrictions are now included such as (1) each stop may have volume to be picked up as well as delivered; (2) multiple vehicles may be used having different capacity limitations to both weight and volume; (3) a maximum total driving time is allowed on a route before a rest period of at least ten hours (Department of Transportation safety restriction); (4) stops may permit pick-ups and deliveries only at certain times of the day (called 'time windows'); (5) pickups may be permitted on a route only after deliveries are made; and (6) drivers may be allowed to take short rests or lunch breaks at certain times of the day. These restrictions add a great deal of complexity to the problem and frustrate our efforts to find an optimal solution. However, good solutions to such problems can be found by applying principles for good routing and scheduling. The principle for Good Routing and Scheduling outlined as expressed by following

1. Load trucks with stop volumes that are in the closest proximity to each other.
2. Stops on different days should be arranged to produce tight clusters.
3. Building routes beginning with the farthest stop from the depot
4. The sequence of stops in a truck route should from a teardrop pattern
5. The most efficient route are built using the largest vehicles available
6. Pickups should be mixed into delivery routes rather than assigned to the end of routes.
7. A stop that is greatly removed from a route cluster is a good candidate for an alternate means of delivery
8. Narrow stop time window restrictions should be avoided.

2.4.4 Routing Sequencing

Ballou (2004) explained that the number of vehicles needed is determined by sequentially placing routes end-to-end so that the vehicles have minimum slack time. Suppose that a truck routing problem, with the same-size trucks. Sequencing these routes over the period of one day to minimize truck downtime might lead to the plan. Sequencing in this manner minimizes the number of trucks required to serve all routes.

2.4.5 Implementation of Vehicle Routing and Scheduling Methods

Ballou (2004) said that vehicle routing and scheduling problems are rich in variety and endless in the number and types of restrictions that can be placed on them. The problems of moving less-than-truckload freight between networks of terminals are quite different from routing school buses and individually responsive transport such as Dial-A-Ride. In addition, there are always exceptions to the typical problem that must be handled as a part of normal operations. Every vehicle routing and scheduling problem seems to require its own special approach to a solution. Even so, the resulting methods are not likely to handle the entirety of the problem. If they are to be used in practice, care must be taken in the manner in which they are implemented.

One practical approach to quantitative solution methodology implementation in an operating environment is the three-stage preview-solve-review technique. A model is constructed that will capture as much of a real problem as practical, given the need to solve it within a reasonable time and with a quality solution. Optimization methods can often be used for this purpose, since the features that are most difficult to handle optimally are not included in the model formulation. Practical solutions to the real problems are developed in a three-step process. First, the analyst previews the problem for expectations (deliveries requiring special handling) or deliveries and pick ups that are obvious (full truckload movements). Next, usually with the aid of a computer, the problem is solved and the solution made available to the analyst. Finally, the analyst reviews the mathematical solution and makes modifications to it as necessary, to make it practical.

2.5 Review of Literature

This paper aims to study motor or truck transportation by focusing on finding the best routing and scheduling model for solving the vehicle routing problem (VRP) of business. Hence, it is relevant to study the literatures or previous studies related to the topic under study, in two parts i.e. theoretical study and a case study.

2.5.1 Theoretical Study

Laporte, (1992) studied the vehicle routing problem and presented some of the main known results, which included (1) definition, (2) exact algorithms, and (3) heuristic algorithms. Laporte described the vehicle routing problem (VRP) is as the problem of designing optimal delivery or collection routes from one or several depots to a number of geographically scattered cites or customer, subject to side constraints. The VRP plays a central role in the field of physical distribution and logistics. The method conducted in this paper is to survey the main exact and approximate algorithms developed for the VRP. In the result from the survey, the exact algorithms for the VRP can be classified into three broad categories: (1) direct tree search methods, (2) dynamic programming and (3) integer linear programming. As the number of proposed algorithms is very large, they will be illustrated by six representative examples, with only two direct tree search methods based on different relaxations, a dynamic programming formulation, and three integer linear programming algorithms, as expressed by the following:

1. The assignment lower bound and related branch and bound algorithm
2. The k-degree center tree and a related algorithm
3. Dynamic programming
4. Set partitioning and column generation

5. A tree-index vehicle flow formulation
6. A two index vehicle flow formulation

After studying this, Laporte (1992) described heuristic algorithms for the VRP as often being derived from the Traveling Salesman Problem (TSP). Laporte described four heuristics specially developed for the VRP, as follows:

1. The Clark and Wright (1994) algorithm. This is the classical algorithm first proposed in 1964 by Clark and Wright to solve CVRPs (Capacity-constrained VRPs) in which the number of vehicles is free. The method starts with routes containing the depot and one other vertex. At each step, two routes are merged according to the largest saving that can be generated.
2. The sweep algorithm (Wren, 1971: Wren and Holliday, 1972; Gillett and Miller, 1974). This is an algorithm for CVRPs with one or several depots and vertices located in the Euclidean plane. The method is commonly attributed to Gillett and Miller (1974) who gave it its name. In order to ease the implementation of this method, it is preferable to represent vertices by their polar coordinates (θ_i, ρ_i), where θ_i is the angle and ρ_i is the ray length. Assign a value $\theta_i{}^* = 0$ to arbitrary vertex i^* and compute the remaining angles from (1, i^*) Rank the vertices increasing order of their θ_i
3. The Christofides-Mingozzi-Toth (1979) two-phase algorithm. This is basically designed for CVRPs and DVRPs (Distance-constrained VRPs). It produces two alternative solutions for given parameters $\lambda \geq 1$ and $\mu \geq 1$ set by the user. The better of the two solutions can then be selected. This procedure can be repeated for several values of λ and μ

4. A tabu search algorithm (Gendreau, Hertz and Laporte, 1991): is a heuristic which constructs of a sequence of solutions and then executes an improvement step. The successive vehicle routes produced by the algorithm may not be feasible: their degree of departure from feasibility is measured by means of a penalty in the objective faction.

Finally, the Vehicle Routing Problem lines at the heart of distribution management. There exist several versions of the problem, and a wide variety of exact and approximate algorithms have been proposed for a solution. Laporte (1992) said exact that algorithms can only solve relatively small problems but a number of approximate algorithms have proved very satisfactory. However, several promising avenues of research deserve more attention, such as tabu search methods.

Beck, Prosser and Selensky, (2003) studied vehicle routing and job shop scheduling:, and their differences. They said that vehicle routing problem and scheduling problems are typically solved with different techniques. Hence, in their paper, they undertake a systematic study of problem characteristics that differ between vehicle routing and scheduling problems in order to identify those that are important for the performance of typical vehicle routing and scheduling techniques. They find that the addition of temporal constraints among visits or addition of tight vehicle specialization constraints significantly improves the performance of scheduling techniques relative to vehicle routing techniques. They identified five problem characteristics that were considered sufficient to explain the performance difference between VRP and scheduling technology : (1) Alternative resources; they expect few resource alternative to scheduling techniques while many should improve the performance of VRP techniques,

(2) Temporal Constraints; many and more complex temporal constraints are characteristics of scheduling problems, and therefore they predict the scheduling technology should improve problems where there are complex temporal constraints, (3) Operation duration vs. transition time; transition time can be vanishingly small in scheduling problems while task duration can be similarly insignificant in VRP. Therefore, the smaller the ratio of operation duration to transition time, the better the VRP techniques should perform relative to the scheduling techniques, (4) Optimization criterion; when the optimization criterion is the minimization of make span as opposed to the minimization of total transition time, they predict that the performance of the scheduling should be favored, and (5) Temporal Slack; slack tends to be large in VRP, if only because the duration of visits are small. Scheduling technology has developed special purpose propagators and heuristics to cope with slack. How will variations in slack effect technology performance? The five problem characteristics actually have an effect on the relative performance of scheduling techniques compared to VRP techniques. Researchers study pure VRP instances and examine the effect of varying one problem characteristic at a time. They generate instances of VRP, and proposed a method to solve each problem twice: first, they modeled the problem as a VRP and solved it using routing technology; second they modeled the VRP as a scheduling problem and solved it with scheduling technology. The results of this study show that researchers have varied five different parameters, each in isolation. When they increase the specialization of the fleets, they discovered that the routing technology failed to produce a solution. However, the scheduling technology did find a solution, and this solution could then be improved by the routing technology. Again, routing technology failed when presented with problems with only a modest number of procedural constraints. Scheduling technology came to the rescue, producing an initial solution that could again be improved by routing technology.

In both scenarios, they think of the scheduling technology as giving a “smart start”. However, when they increased the number of precedence constraints the scope for improvement diminished. When they increased the speed of vehicles, essentially compressing the routing problem into a smaller space, they expected the VRP to become more like a scheduling problem with short transit times. To their surprise, they said it does not happen. The VRP appeared to continue to behave as a VRP. Hence, short travel distances do not appear to detract from VRP essential features. They expect this technology will perform well in urban as well as suburban routing problems. The optimization criterion had a profound effect. When they need to minimize travel, VRP technology was their choice, but when they need to make all visits as soon as possible i.e. minimize make span the scheduling, technology was clear winner. Slack is a property of both VRP and scheduling problems alike. Nevertheless, as they reduced slack, scheduling technology appeared to improve relative to routing technology, but was still dominated by the routing technology. Furthermore, they observe the saving heuristic used to find a first solution for VRP solving seems particularly sensitive to impurities in a VRP. Reducing the number of resource alternatives or adding precedence constraints results in many problems for which the savings heuristic could not generate a feasible solution.

2.5.2 Case Study

Kim and Lee (2006) studied scheduling trucks in local depots for a door-to-door delivery service They proposed a scheduling model for trucks delivering and picking up merchandise at branch offices and a regional depot in a door-to-door delivery service. The objective function of their paper is that different levels of customer service resulting from different timing of deliveries to/from branch offices are considered as well as the travel cost of trucks. Useful properties of the optimal timing of deliveries and pickups are derived to reduce the size of the search space significantly. This research proposed heuristic algorithms to be the method. Because it is very time consuming to obtain the optimal solution of a problem, three heuristic procedures are suggested: (1) Stochastic insertion heuristic (SIH), (2) TABU search (TABU) and (3) TABU search using Adaptive Memory (TABUAM). The result of this research is that a mixed integer programming model was suggested. Useful properties of the optimal timing of deliveries and pickups are derived to reduce the size of the search space significantly. Hence, three heuristic algorithms were suggested to solve the mathematical model: SIH, TABU and TABUAM. However, this scheduling method is suggested only for trucks delivering and picking up freight between branch offices and a regional depot in door-to-door delivery service, and the problem is similar to the vehicle routing problem.

Hachemi, Gendreau and Rousseau, (2007) studied solving a Log-Truck scheduling problem with constraint programming. They proposed a solution method based on constraint programming and mathematical programming. The problem consisted of scheduling the transportation of logs between forest areas and wood-mills, as well as routing a fleet of vehicles to satisfy the transportation requests. The objective of their paper was to minimize the total cost of non-productive activities such as a waiting time of trucks and forest log-loaders and the empty driven distance of vehicles. Researchers propose a constraint programming model to address the combined scheduling and routing problem, and an integer programming model to deal with the optimization of deadheads. For these methods, the researchers present a Constraint Programming (CP) model for the Log-Truck Scheduling Problem (LTSP) along the lines of the paradigm, and present a hybrid approach, which is a decomposition approach, where research modeled the circulation of trucks between the mills and the forest as a network flow problem (with some additional constraints). The model can easily be used as an Integer Program (IP). In the results of their paper, the deadhead costs, the waiting cost of trucks queuing to get loaded or unloaded, the waiting cost of log-loaders while waiting for a truck to arrive and finally the total cost of all these are unproductive activities. Although the smaller instances are relative easy, the difficulty to synchronize efficiency of the truck and the log loaders increases rapidly with the length of the instances. In the several cases studied, the decomposition method provides a better overall solution than the straightforward approach. Finally, in their paper, Hachemi et al. (2007) presented a Log-Truck scheduling problem with the objective of minimizing the cost of unproductive time. They propose a decomposition approach involving a Constraint Programming model and an Integer Programming model that allows them to compute the optimal global circulation of the vehicles. This circulation is then communicated to the CP model by introducing global cardinality constraints.

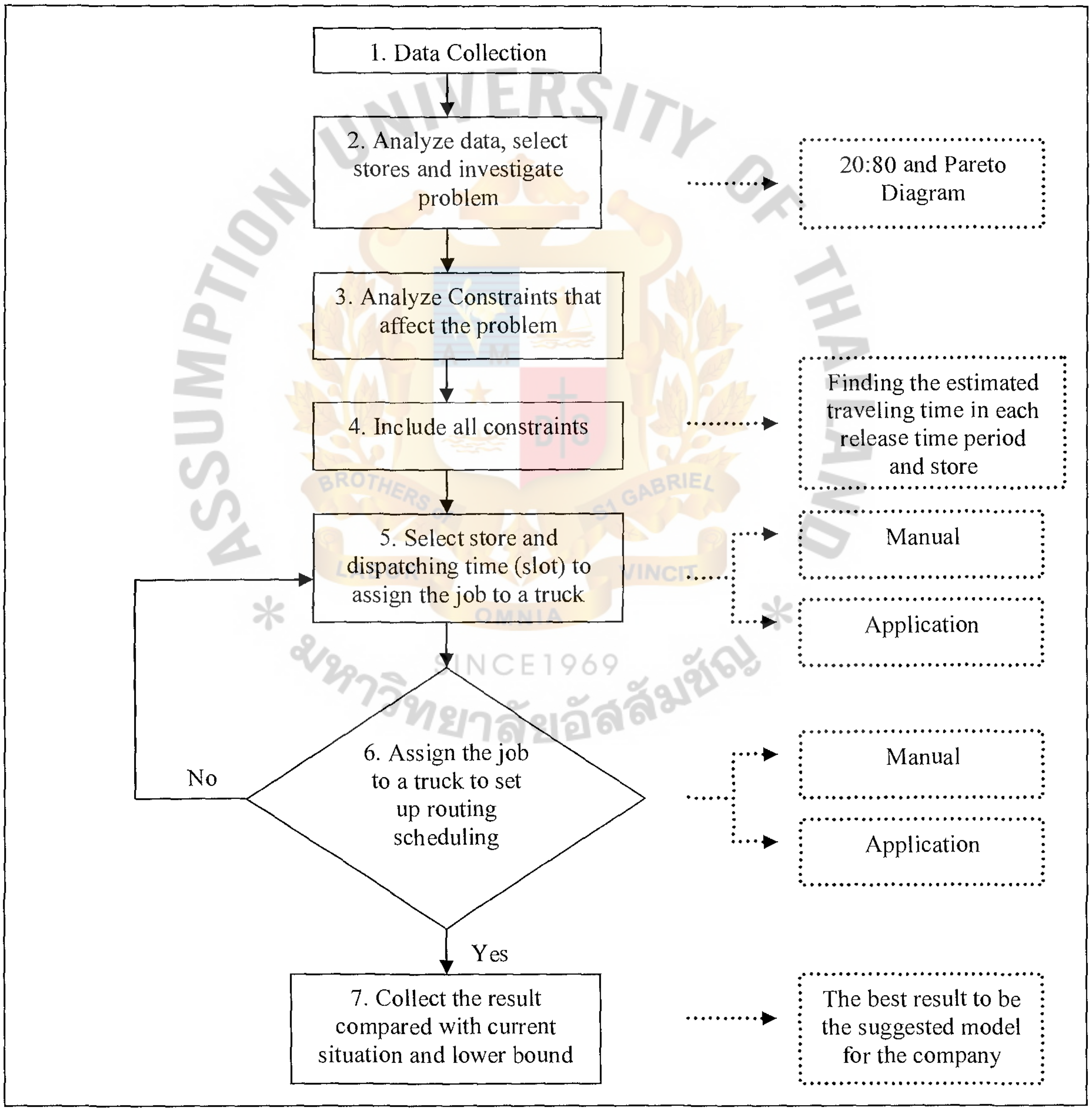
Cao, Shi, and Lee, (2008) studied a decision support method for the truck scheduling and storage allocation problem. The problem studied was truck scheduling and storage allocation, as these two separate sub-problems in port operations have been deeply studied in past decades. From the operational point of view, researchers said they are highly interdependent. Storage allocation for import containers has balanced the travel time and queuing time of each container in yard. The objective of this paper was to present a model which would reduce congestion and waiting time of container trucks in the terminal so as to decrease the make span of discharging containers. The researchers proposed two methods for an optimal solution: a genetic algorithm and a greedy heuristic algorithm. An integer programming model for truck scheduling and storage allocation problem was formulated. In the model, a fleet of trucks were assigned to transport discharging containers from the ship to one of the storage yard blocks. The objective of the problem was to achieve the minimum make span for all discharging containers. The processing time of trucks discharging containers consists of travel time on the network and waiting time at quayside and yard side. Moreover, this paper said that quayside waiting was time due to the technical performance of quay cranes, and the unloading sequence is considered according to the different readiness times of containers. The waiting time and travel time are explicitly considerate in the model. Compared with previous research, this model is more practical and comprehensive by considering different items of processing time of the dispatching containers. By balancing the travel time and waiting time, minimum make span is achieved. Finally, a genetic algorithm and a greedy heuristic algorithm were designed to handle the case problem.

CHAPTER III

RESEARCH METHODOLOGY

This paper focuses on finding an appropriate routing scheduling model for increasing routing efficiency in term of a truck transportation network between a central DC and ABC stores. The research framework is illustrated in Figure 3.1

Figure 3.1: Research Framework



3.1 Data Collection

3.1.1 Databases of ABC store

The database of ABC stores includes six items of information, as follows and an example is illustrated in Table 3.1

- Store number and name
- Store location
- Types of carrier products in container i.e. Palletize or Loose Case
- Distance in kilometer between central DC and ABC stores
- Traveling time between central DC and stores
- Time Window at store for receiving goods from DC

Table 3.1: The example of stores information database

							Dispatch from DC		Receiving time at Store		
Store	Store Location	BKK/UPC	Part	Palletize / Loose Case	Distance (KM)	Travel Time (Hour)	First Truck	Last Truck	Start	End	Document
1	Ladprao	BKK	C	P	72	2:00	20:00	1:50	22:00	3:50	3:50
2	Changwattana	BKK	C	P	60	2:00	4:00	12:00	6:00	14:00	14:00
3	Srinakarin (Mon-Wed)	BKK	C	P	72	2:00	2:00	4:00	4:00	6:00	6:00
4	Bangbon	BKK	C	P	72	2:00	2:00	14:00	4:00	17:00	16:00
5	Chonburi	UPC	E	P	120	3:00	7:00	13:00	10:00	16:00	16:00
6	Chiangmai	UPC	N	L	696	15:30	16:30	0:30	8:00	17:00	16:00
7	Korat	UPC	NE	p	256	5:00	2:00	11:00	7:00	17:00	16:00
8	Rangsit	BKK	C	p	35	1:00	10:00	14:00	11:00	17:00	15:00

3.1.2 Timing of Truck Ban (government policy)

This is government policy for stores located in urban (Bangkok). The timing of the Truck Ban is separated into two periods: 6am – 9am in the morning, and 3pm-9pm in the evening, from Monday to Friday (as in Figure 1.8, in Chapter 1).

3.1.3 Number of containers and trucks database

This is collected from the Transport KPI report on a daily basis from January 2009 to June 2009, a total of six months. An example of the database is in Table 3.2

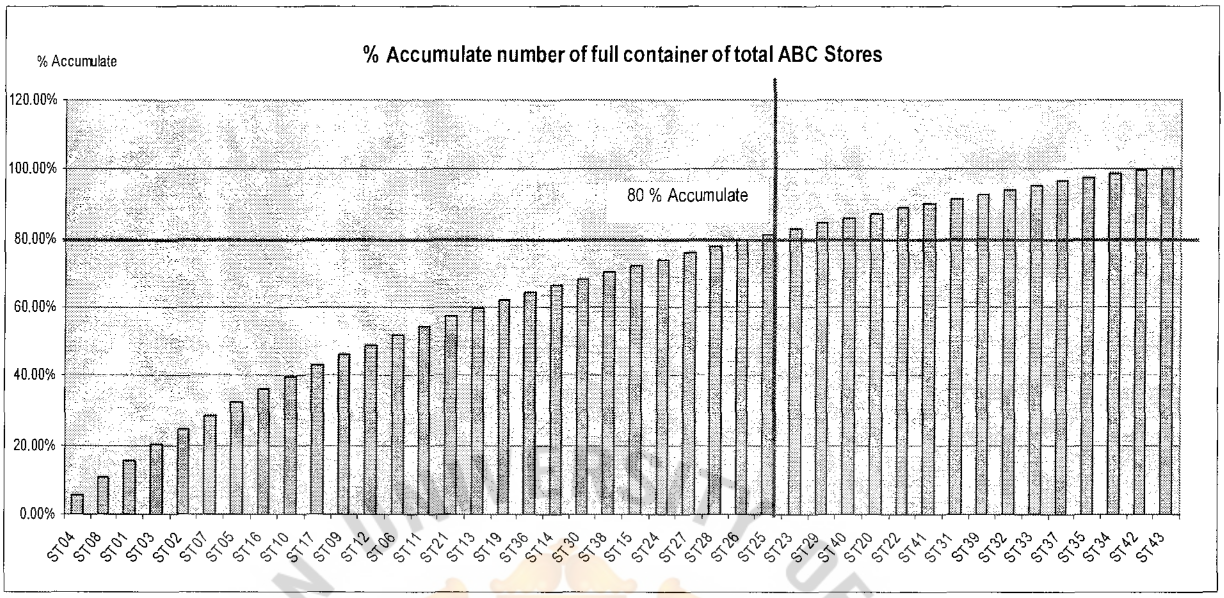
Table 3.2: An example of number of containers and trucks database

Month 2009	Delivery Date	Deatination	Truck No.	Trailer No.
01.January	3 Jan 09	Ladprao	XX-2104	XX-9890
01.January	3 Jan 09	Ladprao	XX-2104	XX-9890
01.January	3 Jan 09	Ladprao	XX-2102	XX-2137
01.January	3 Jan 09	Chaengwattana	XX-0425	XX-1734
01.January	3 Jan 09	Srinakarin	XX-0336	XX-9344
01.January	3 Jan 09	Bangborn	XX-2522	XX-9942

3.2 Analyze data, select stores and investigate problem

After collecting the information in Section 3.1, the database was analyzed to find which ABC stores hold a large number of full containers at the DC. It is related to high contribution of sales to the ABC company by using the percentage of accumulate number of full containers of total ABC stores divided into a 20:80 ratio according to Pareto's theory and diagram, as shown in Figure 3.2.

Figure 3.2: Percent accumulated number of containers of total ABC stores at DC



After identifying the 80% of ABC stores that generate high sales to the company and have a large number of full containers at the DC, the stores are analyzed according to location and type of stores (existing stores and new stores), and type of carried products in containers for delivery to stores. Then, stores are selected to analyze their routing efficiency under the following four criteria:

1. They should be ABC stores in the 80% category which generate sales to the company and hold high volumes of full containers at the DC
2. They should be new ABC stores, because the replenishment stock for testing customer satisfaction, and stock availability of a store during a new store period (around six months to one year) is important. New ABC stores are at Pranburi, Chachoengsao and Ramintra
3. They should be ABC stores located near a distribution center i.e. within 300 kilometers, with traveling time within six hours.

4. They should be ABC palletize stores (using pallets) because that makes it easier to unload than with the loose case method.

ABC stores was selected to analyze routing efficiency, as shown in Table 3.3.

Table 3.3: ABC stores were selected to analyzed routing efficiency

Store	Store Location	BKK/UPC	Part	Palletize / Loose Case	Distance (KM)	Travel Time (Hour)
1	Ladprao	BKK	C	P	72	2:00
2	Changwattana	BKK	C	P	60	2:00
3	Srinakarin	BKK	C	P	72	2:00
4	Bangbon	BKK	C	P	72	2:00
5	Chonburi	UPC	E	P	120	3:00
7	Korat	UPC	NE	P	256	5:00
8	Rangsit	BKK	C	P	35	1:00
15	Rayong	UPC	E	P	239	5:00
16	Nakonsawan	UPC	N	P	240	5:00
17	Charunsanitwong	BKK	C	P	72	2:00
19	Nakonpathom	UPC	W	P	100	3:00
21	Samsaen	BKK	C	P	72	2:00
25	Supanburi	UPC	W	P	110	3:00
26	Chantaburi	UPC	E	P	300	6:00
30	Sakaew	UPC	E	P	237	5:00
36	Petchburi	UPC	W	P	160	4:00
38	Saraburi	UPC	NE	P	107	3:00
39	Pranburi	UPC	S	P	281	6:00
40	Chachoengsao	UPC	C	P	123	3:00
42	Ramintra	BKK	C	P	60	2:00

Finally, problems were investigated of the ABC stores that were selected under the four criteria. We investigated the problems by analyze routing efficiency and using percentage truck utilization (Percentage number of trucks to number of full containers). The issue regarding routing efficiency is expressed in Table 3.4, as explained in Chapter 1.

Table 3.4: Percent truck utilization or Percent truck to full containers of ABC stores, under 4 criteria during January 2009 – June 2009

Month	Number of full container	Number of truck	% Truck to Full Container
01.January	917	874	95.31%
02.February	878	854	97.27%
03.March	989	959	96.97%
04.Apr	805	754	93.66%
05.May	1122	981	87.43%
06.June	1121	946	84.39%
Avg./Month	972	895	92.04%

3.3 Analyzed constraints that affect the problem

After gathering all the information from the data collection in Section 3.1, the constraints were analyzed which affect the problem in Section 3.2, as in the following:

1. Dispatching time: this is the time for dispatching the truck from a DC to delivery of full containers to ABC stores.
2. Traveling time: this is the time which a truck uses to travel from DC to store and travel back from store to DC. Each destination has a different distance, hence travel time is different also.
3. Unloading time: this is the time which a truck waits at a store for unloading products from the container to the store goods receiving area. The company policy fixes one hour for unloading products for ABC stores where those products are carried on pallets.
4. Waiting time for a time window in each store: is the time which truck waits to start unloading products in each store. Each store has a different time window for receiving product from DC depending on the appropriate policy in each store.

The details of time windows of each ABC store are shown in Figure 1.8, in Chapter 1.

5. Waiting time because of the government truck ban policy for urban stores in Bangkok province: this is the time which a truck has to wait before it can deliver products to urban ABC stores in Bangkok. The times allowed for trucks to travel within this area are separated into two periods:. 6am – 9am in the morning and 3pm-9pm in the evening, Monday to Friday (as in Figure 1.8, in Chapter 1).
6. Waiting time for hooking new container and preparing the delivery docket at a DC: this is the time which a truck has to wait at a DC for hooking a new container and waiting to get the delivery docket to travel on a new route.

3.4 Include all constraints

After the constraints are identified which affect the problem in Section 3.3, these constraints are included by calculating the estimated travel time in each release time period. It includes timing in six steps:

1. Traveling time from DC to ABC stores
2. Unloading time at ABC stores
3. Traveling time from ABC store to DC after finished unloading
4. Waiting time for time window in each store
5. Waiting time for truck ban for store in urban area
6. Waiting time for hooking new full container and preparing delivery docket

The methodology includes all constraints, and is the summation the timing in six steps. An example is that if we dispatch a truck from DC at 2am., we can calculate the estimated traveling time as follows:

1. Traveling time from DC to this store is 2 hours.
2. Unloading products at store is 1 hour.
3. Traveling time from this store back to DC is 2 hours.
4. Waiting time window is 18 hours because the truck is dispatched form DC at 2am, traveling time is 2 hours, so the truck hits the store at 4am. The time window of this store is between 10pm yesterday to 3am today. Then, the truck waiting since 4am in morning until 10pm in the evening, making a total waiting time of 18 hours
5. Waiting time for the truck ban is 0 hour because this store has a time window in the night period.
6. Waiting time for hooking a new container and preparing the docket is an average of 1 hour.

Hence, the summation of estimate traveling time when we dispatch truck from a DC at 2am in the morning for this store is 24 hours (2+1+2+18+0+1), as expressed in Table 3.5. The example of calculation, and the example of overall of estimated traveling time when dispatch the truck from DC in each dispatching period, are expressed in Table 3.6

Table 3.5: Example of calculation of all constraints

Release Time	Travel Time	Unloading Time	Travel Time	Unloading at ST		Back to DC	TT (DC to Store)	Unloading Time	TT (Back to DC)	Waiting Window Time	Waiting Truck Ban	Waiting for Hook new container and Document at DC	TTL (Hour)
				Start	End								
0:00	2:00	1:00	2:00	2:00	3:00	5:00	2	1	2	0	0	1	6
1:00	2:00	1:00	2:00	3:00	4:00	6:00	2	1	2	0	0	1	6
2:00	2:00	1:00	2:00	4:00	5:00	7:00	2	1	2	18	0	1	24
3:00	2:00	1:00	2:00	5:00	6:00	8:00	2	1	2	17	0	1	23
4:00	2:00	1:00	2:00	6:00	7:00	9:00	2	1	2	16	0	1	22
5:00	2:00	1:00	2:00	7:00	8:00	10:00	2	1	2	15	0	1	21
6:00	2:00	1:00	2:00	8:00	9:00	11:00	2	1	2	14	0	1	20
7:00	2:00	1:00	2:00	9:00	10:00	12:00	2	1	2	13	0	1	19
8:00	2:00	1:00	2:00	10:00	11:00	13:00	2	1	2	12	0	1	18
9:00	2:00	1:00	2:00	11:00	12:00	14:00	2	1	2	11	0	1	17
10:00	2:00	1:00	2:00	12:00	13:00	15:00	2	1	2	10	0	1	16
11:00	2:00	1:00	2:00	13:00	14:00	16:00	2	1	2	9	0	1	15
12:00	2:00	1:00	2:00	14:00	15:00	17:00	2	1	2	8	0	1	14
13:00	2:00	1:00	2:00	15:00	16:00	18:00	2	1	2	7	0	1	13
14:00	2:00	1:00	2:00	16:00	17:00	19:00	2	1	2	6	0	1	12
15:00	2:00	1:00	2:00	17:00	18:00	20:00	2	1	2	5	0	1	11
16:00	2:00	1:00	2:00	18:00	19:00	21:00	2	1	2	4	0	1	10
17:00	2:00	1:00	2:00	19:00	20:00	22:00	2	1	2	3	0	1	9
18:00	2:00	1:00	2:00	20:00	21:00	23:00	2	1	2	2	0	1	8
19:00	2:00	1:00	2:00	21:00	22:00	0:00	2	1	2	1	0	1	7
20:00	2:00	1:00	2:00	22:00	23:00	1:00	2	1	2	0	0	1	6
21:00	2:00	1:00	2:00	23:00	0:00	2:00	2	1	2	0	0	1	6
22:00	2:00	1:00	2:00	0:00	1:00	3:00	2	1	2	0	0	1	6
23:00	2:00	1:00	2:00	1:00	2:00	4:00	2	1	2	0	0	1	6

Table 3.6: The overall estimated traveling time in each dispatching period

Store No.	Store Location	Time																							
		0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
ST01	Ladprao	6	6	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	6	6	6
ST02	Changwattana	12	11	10	9	8	8	7	6	6	6	6	6	6	23	22	21	20	19	18	17	16	15	14	13
ST03	Srinakarin	6	6	6	6	8	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	6	6	6
ST04	Bangbon	8	7	6	6	6	6	6	6	6	6	6	6	6	6	6	6	16	15	14	13	12	11	10	9
ST05	Chonburi	15	14	13	12	11	10	9	8	8	8	8	8	8	8	25	24	23	22	21	20	19	18	17	16
ST07	Korat	14	13	12	12	12	12	12	12	12	12	12	12	26	25	24	23	22	21	20	19	18	17	16	15
ST08	Rangsit	14	13	12	11	10	9	8	7	6	5	4	4	4	4	9	23	22	21	20	19	18	17	16	15
ST15	Rayong	13	12	12	12	12	12	12	12	12	12	12	12	25	24	23	22	21	20	19	18	17	16	15	14
ST16	Nakonsawan	15	14	13	12	12	12	12	12	12	12	12	12	27	26	25	24	23	22	21	20	19	18	17	16
ST17	Charunsanitwong	8	7	6	6	8	8	7	6	6	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9
ST19	Nakonpathom	14	13	12	11	10	9	8	8	8	8	8	8	8	25	24	23	22	21	20	19	18	17	16	15
ST21	Samsaen	8	7	6	6	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9
ST25	Supanburi	11	10	9	8	8	8	8	8	8	8	8	8	23	22	21	20	19	18	17	16	15	14	13	12
ST26	Chantaburi	14	14	14	14	14	14	14	14	14	14	27	26	25	24	23	22	21	20	19	18	17	16	15	14
ST30	Sakaew	12	12	12	12	12	12	12	12	12	12	12	12	24	23	22	21	20	19	18	17	16	15	14	13
ST36	Petchburi	12	11	10	10	10	10	10	10	10	10	10	25	24	23	22	21	20	19	18	17	16	15	14	13
ST38	Saraburi	13	12	11	10	9	8	8	8	8	8	8	8	8	24	23	22	21	20	19	18	17	16	15	14
ST39	Pranburi	17	16	15	14	14	14	14	14	14	14	31	30	29	28	27	26	25	24	23	22	21	20	19	18
ST40	Chachoengsao	13	12	11	10	9	8	8	8	8	8	8	8	8	24	23	22	21	20	19	18	17	16	15	14
ST42	Ramintra	12	11	10	9	8	8	7	6	6	6	6	6	6	11	22	21	20	19	18	17	16	15	14	13

3.5 Selected store and dispatching time for assigned the job to the truck

After the traveling time for all stores is estimated in Section 3.4, in this section we examine the selected store and dispatching time for assigning a job to a truck and set up routing scheduling. The objective of setting up routing scheduling is to increase routing efficiency. Hence, when we selected stores and dispatching time for assigning a job to a truck in the first route, it must affect the store and dispatching time selection in the next route. Furthermore, each store holds a different number of full containers at the DC and each day its number of full containers at the DC is different. Therefore, the number of full containers at the DC affects the setting up of routing scheduling. The number of full containers at the DC is shown in Table 3.7

Table 3.7: Number of full containers at DC

Store No.	Store Location	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Total
		1-May-09	2-May-09	3-May-09	4-May-09	5-May-09	6-May-09	7-May-09	
88001	Ladprao	4	3	-	2	3	2	4	18
88002	Changwattana	3	3	-	1	4	1	3	15
88003	Srinakarin	3	6	-	1	3	-	4	17
88004	Bangbon	3	3	-	3	2	5	3	19
88005	Chonburi	3	-	-	3	2	2	2	12
88007	Korat	6	4	-	2	3	2	4	21
88008	Rangsit	7	3	-	3	2	3	2	20
88015	Rayong	1	1	-	1	2	1	1	7
88016	Nakonsawan	2	2	-	3	2	3	1	13
88017	Charunsanitwong	1	2	-	1	2	1	2	9
88019	Nakonpathom	2	2	-	1	1	1	1	8
88021	Samsaen	2	2	-	3	1	1	2	11
88025	Supanburi	1	1	-	-	2	-	1	5
88026	Chantaburi	2	-	-	2	1	1	2	8
88030	Sakaew	2	1	-	1	1	1	1	7
88036	Petchburi	1	1	-	3	3	1	3	12
88038	Saraburi	2	1	-	-	1	1	1	6
88039	Pranburi	-	-	-	2	-	1	2	5
88040	Chachoengsao	1	2	-	-	1	1	2	7
Total		46	37	-	32	36	28	41	220

When we know three factors i.e. store or destination, dispatching time and number of full containers, we can see their effect on routing scheduling. Hence, we create a logic to select stores and dispatching times (slots) for setting up routing scheduling. For this study we have two experiments for testing the logic: manual selection (manual assignment) ,and random section by application, which is now explained:

3.5.1 Manual Selection

1. Selection of store by ranging store number, as in the current situation
2. When we know the store after selection in number 1, we select the dispatching time (slot) of that store for dispatching the truck by using the total traveling time according Table 3.6.

3.5.2 Random Selection by application

1. Random selection to select a store for assigning a job to a truck
2. After we select a store randomly, we select the dispatching time (slot) of this store for dispatching the truck from DC to store. This step when we select the slot, will also tell us the traveling time according Table 3.6. Hence, to increase routing efficiency as the objective for this step we range the traveling time of each slot in each store from low to high. The focus is a slot hold low total traveling time. It is selected first – selecting by sequence from low to high because low traveling time is the best time. However, for increasing flexibility of selection, the first selection affects the next selection. Hence, we added a slot that is the second priority to be an alternative selection. An example of setting up an optimal slot is explained in the following;

Let X be the first priority slot that is selected first

X^+ is the second priority slot (alternative selection)

Ranging number of traveling time from low to high						Number of full container
6	6	6	7	7	7	
X	X^+	X^+				1
X	X	X^+				2
X	X	X				3
X	X	X	X	X^+	X^+	4

If the number of full containers at DC of this store that will be sent is 1, and low traveling time is 6 hours that has 3 slots, first X is a first priority slot that will be selected, and other 2 X^+ are a second priority slot that is an alternative selection. X^+ is added when we remain empty slot under the same as traveling time of the last slot that assigns X. For another example, if the number of full containers at DC of this store that will be sent is 3, and low traveling time is 6 hours that have 3 slots, 3 X is the first 3 slots that will be selected. Others slot are not important for adding X^+ because we have jobs for only 3 containers for sending to this store, which is equal to the best slot 3 slots.

3.6 Assigned jobs to trucks for setting up routing scheduling

After we selected the store and release time (slot) from Section 3.5, we assign the job to the truck for setting up routing scheduling. For this study we separated experiments into two methods i.e. manual assignment and assignment by application

3.6.1 Manual Assignment

We assigned job to the truck by plotting the point into the chart under 5 criteria, as follows:

1. Each truck has capacity to get job in 24 hours and more than 1 job should be assigned to the truck according to the study objective.
2. The starting time of each truck at midnight is not mandatory.
3. When the job is assigned to the truck, the job is ended for this slot and cannot be assigned other jobs at this slot for this truck.
4. If the job can be assigned to the truck, the job is finished, but if it cannot, we go back to Section 3.5 for re selection of a new store and slot.
5. All containers in each day must be assigned to a truck; that means the routing scheduling is completed

3.6.2 Assigned by application

After we know store and slot in Section 3.5 the job is assigned to the truck under 7 criteria, as follows:

1. For each truck which has capacity to get a job for 24 hours, and more than 1 job should be assigned to the truck according to the study objective.
2. For each truck, we calculated a score to determine the number of stores being serviced by a selected truck, using the steps described next;

   2.1 Number of trips per truck: the score is 5

   2.2 Waste time: This is time wasted for dispatching a new trip on the same route. For example, for this route a truck has two job assignments: the first job assignment finished at 1pm and second job assignment started at 5pm. Thus, four hours between 1pm and 5pm is wasted time. The score is 3.

2.3 Remaining time: This is the time that remains after finishing the last trip on the same route. For example, a truck has a capacity 24 hours for delivering a container from DC to store. If this truck gets three job assignments and the first job assignment starts at midnight, and the last job assignment finished at 7pm, the remaining time is 5 hours from 7pm to midnight. The score is 2.

After we set up a score in each subject, we calculate the total score for each truck as in the following method:

Score of number of trips per truck = (number of trips per truck. x 5)^2 … (1)

Score of waste time = number of hours x 3 … (2)

Score of remaining time = number of hours x 2 … (3)

Total score = (1) – (2) – (3)

An example follows:

- Truck number 01 can be assigned four jobs

Store (Destination)	Starting Time	Finished Time	Time Used (Hours)
01	20:00	02:00	6
03	02:00	08:00	6
02	08:00	14:00	6
04	14.00	20:00	6
		Total	24

Total score = Score of number of trips per truck = (4 destinations x 5)^2 = 400

- Truck number 02 can be assigned two jobs

Store (Destination)	Starting Time	Finished Time	Time Used (Hours)
19	12:00	20:00	8
21	02:00	08:00	6
		Total	14

Score of number of trips per truck = (2 destinations x 5)^2 = 100

Score of waste time (from 20:00 until 02:00) = 6 x 3 = 18

Score of remaining time (from 08:00 until 12:00) = 4 x 2 = 8

Total Score = 100-18-8 = 72

3. The starting time of each truck at midnight is not mandatory.
4. When the job is assigned to the truck, the job is ended for this slot and other jobs at this slot cannot be assigned to this truck.
5. The available time for the truck is calculated after the first job is assigned to the truck already. The method is as follows:

The available time for Job #1 = 24 hours

The available time for Job #2 = 24 – total traveling time of Job #1 … (1)

The available time for Job #3 = (1) – total traveling time of Job #2 … (2)

…

Another example:

- Truck number 01 can be assigned four jobs

Job Number	Starting Time	Finished Time	Time Used (Hours)	Available Time
1	20:00	02:00	6	24-6 = 18
2	02:00	08:00	6	18-6 = 12
3	08:00	14:00	6	12-6 = 6
4	14:00	20:00	6	6-6 = 0

6. If the job can be assigned to the truck, the job is finished. However, if the job cannot be assigned to the truck under the 5 criteria above, we go back to Section 3.5 for re selection of a new store and slot.
7. All containers in each day must be assigned to a truck, and that means the routing scheduling is completed.

3.7 Collect the result compared with the current situation and lower bound

After we gain the result from Section 3.6, we collect and compare the number of trucks used to deliver containers to stores each day with the current situation and lower bound. For lower bound, we use it to be the baseline. If the outcomes from experiments are better than the current situation that it is a good result but it is not the best results because we do not have a base line. However, if the outcomes from experiments are better than the current situation and near the base line, it is the best result because the base line or lower bound might not be feasible in the real world. Lower bound is calculated by the following method:

Lower Bound (Number of trucks) = X / Truck Capacity

Let - X = totally number of requirement hours

- Number of requirement hours = A * B

Let A = Minimum number of hours of total traveling time in each store

B = Total number of full containers in each store and day

- Truck Capacity separated into two types

Truck capacity for store within Truck Ban policy = 13 hours

(Truck ban is 11 hours per day; 24 – 11 = 13 hours)

Truck capacity for store without Truck Ban policy = 24 hours

For example, on May 1st, 2009 we have 46 full containers at DC and the total required number of hours is 372 hours, separated into 112 hours of stores within the truck ban policy, and 260 hours of store outside the truck ban policy. Hence, the number of trucks calculated under the lower bound methodology is 20 trucks ((112/13) + (260/24) = 20). A summary of lower bound calculations is shown in Table 3.8.

Table 3.8: Summary of Lower Bound calculations

Date	Day	Number of Trucks
1-May-09	Fri	20
2-May-09	Sat	16
4-May-09	Mon	14
5-May-09	Tue	16
6-May-09	Wed	12
7-May-09	Thu	18
Total		96

Hence, if the percentage of the number of trucks to the number of full containers at DC decreases from the current situation and is near the lower bound, it means we can increase truck efficiency. We must use this logic as the best suggestion for routing scheduling for the company.

CHAPTER IV

Presentation and Critical Discussion of Results

In Chapter III, the routing scheduling was developed, the impact of all constraints was calculated and included in the total traveling time. According to the objective a methodology was applied for setting up routing scheduling to balance with the real situation. Methods for setting up routing scheduling were two experiments i.e. manual assignment and assignment by application. The implementation and the results of each experiment are investigated in the following sections.

4.1 Experiment of Each Method

The calculation to find the result of setting up routing scheduling, means the number of trucks, which was calculated using a spreadsheet. For this study we tested in the period 1-7 May, 2009. The details of each experiment are explained in the following section.

4.1.1 Manual Assignment

The routing scheduling was set up by plotting the point into the spreadsheet. The destination or store in each rout was selected by ranging the store number according to the current situation. The slot for dispatching the truck or release time was selected by use total traveling time (see Table 3.6 in Chapter 3). The experiment was test in the period 1-7 May, 2009 and the total job assigned involved 220 containers. An example of manual assignment is expressed in Figure 4.1:

Figure 4.1: Example of Manual Assignment

Time Slot	Thu					Fri														
	30-Apr-09					1-May-09														
	20:00	21:00	22:00	23:00	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00
	Truck Ban	Truck Ban									Truck Ban	Truck Ban	Truck Ban	Truck Ban						Truck Ban
Truck No.1	To store		St1/1	Back to DC					To store		St2/1		waiting time		Back to DC		To store	St8/5	Back to DC	
Truck No.2		To store		St1/2	Back to DC				To store		Waiting time	St2/2	Waiting time		Back to DC		To store	St8/6	Back to DC	
Truck No.3			To store		St1/3	Back to DC			To store		Waiting time		St2/3		Back to DC		To store	St8/7	Back to DC	
Truck No.4				To store		St1/4	Back to DC						To store		St5/1		Back to DC			
Truck No.5	To store		St3/1	Back to DC			To store		St4/1		Back to DC			To store		St5/2		Back to DC		
Truck No.6		To store		St3/2	Back to DC				To store	St4/2	Back to DC				To store		St5/3		Back to DC	
Truck No.7			To store		St3/3	Back to DC			To store		St4/3		Back to DC		To store	St8/1	Back to DC			
Truck No.8										To store		St7/1			Back to DC					
Truck No.9											To store		St7/2			Back to DC				
Truck No.10											To store			St7/3			Back to DC			
Truck No.11												To store			St7/4			Back to DC		

4.1.2 Assigned by Application

For this experiment, we applied the logic after testing job assignment to the trucks by the manual assignment method. We developed the application under the logic in Chapter 3 for testing a set up of routing scheduling. The application is Visual Basic on Excel Spreadsheet, and an example of an application was shown in Figure 4.2 and Table 4.1.

Figure 4.2, is an example of assignment by application. It included four sections, as follow:

1. Process: in this section included four tasks:
   - Calculate Traveling Time: the application will calculate total traveling time in each destination (store) and each release time (slot).
   - Create Master slot: the application will create aaster slot for each destination (store) and each release time (slot)
   - Select Slot: the application will select the best slot i.e. X and X^+
   - Set up Routing Scheduling: The application will set up routing

A column of status show % completed in each task, the starting and ending time, and the timing of each task.

2. Input: it included two sections i.e.
   - Plan Date: it is the date that we hold full containers at DC and need to set up routing scheduling. For example, we input data to application May 1st, 2009, and it means we have 46 full containers at DC and need to set up routing scheduling.

- Truck on Queue: it is the number of trucks that you can use the application to set up routing scheduling, using computer capacity.

3. Details in each store of the number of full containers at DC. During a run application you can see the remaining number full containers, if routing scheduling is not completed. The remaining number of full containers at DC is 0, which means a container is assigned to the truck already.
4. Outcome: the application shows results in three issues as follow:
   - Number of stores (Destinations): it show total destination in each day that we set up routing scheduling.
   - Number of remaining containers / Total: it shows the total number of containers in each day, and during run application you can see the remaining number of full containers if routing scheduling is not completed.
   - Number of trucks: it is the result after assigning containers to trucks and the set up routing scheduling is finished.

Start and a Continue buttons are to run applications, and a Refresh button is to refresh the data of the number of full containers at DC. When we start to run an application we press a Start button, and if we need to run it again we press a Continue button.

Figure 4.2: Example of Assigned by Application

Process

Status	Task	Time Start	Time End
Done	Calculate Delivery Time	11:01:11	11:01:12
Done	Build Master of Delivery Slot	11:01:12	11:03:06
Done	Set Optimal Slot	11:03:06	11:03:33
100.00%	Routing Simulation	11:03:33	21:35:09

Result

No of Store	:	19
No of Remain/Total Container	:	0 / 46
No of Optimal/Total Slot	:	148 / 480
Size of Min/Max Time/Slot	:	4 / 31
No of Truck	:	26

Input

Plan Date	1-May-09
Truck on Queue	1

Store No.	Store Location	Container		
		Total	Remain	Plan
ST01	Ladprao	4	-	4
ST02	Changwattana	3	-	3
ST03	Srinakarin	3	-	3
ST04	Bangbon	3	-	3
ST05	Chonburi	3	-	3
ST07	Korat	6	-	6
ST08	Rangsit	7	-	7
ST15	Rayong	1	-	1
ST16	Nakonsawan	2	-	2
ST17	Charunsanitwong	1	-	1
ST19	Nakonpathom	2	-	2
ST21	Samsaen	2	-	2
ST25	Supanburi	1	-	1
ST26	Chantaburi	2	-	2
ST30	Sakaew	2	-	2
ST36	Petchburi	1	-	1
ST38	Saraburi	2	-	2
ST39	Pranburi	-	-	-
ST40	Chachoengsao	1	-	1
		46	-	46

Table 4.1, is an example of Truck Scheduling after assignment by application under the logic in Chapter 3. This table shows the result of May 1st, 2009 after 46 containers were assigned the truck. For example, truck number 01 in the first line: it was assigned to four destinations. First, the destination is store 01 Ladprao, starting time at 8 P.M. on May 01st, 2009, waste for this store until the trucks are back at DC is 6 hours. Then, hook a new full container at DC and deliver to store 03 Srinakarin, starting time at DC 2 A.M. on May 02nd, 2009, waste for this store until trucks are back at DC is 6 hours. Next, hook new full containers at DC and deliver to store 02 Changwatthana, starting time at DC 8 A.M. on May 2nd, 2009, waste for this store until trucks were back at DC was 6 hours. Finally, hook new full containers at DC and deliver to store 04 Bangborn, starting time at DC 2 P.M. on May 2nd, 2009, waste for this store until trucks were back at DC was 6 hours. Hence, the trucks will be back tat DC after finishing the last assignment at 8 P.M. on May 2nd, 2009. The total time of this truck after this assignment was completed is 24 hours. However, there were 46 full containers at DC of May 1st, 2009. All these containers were assigned. Thus, the total number of trucks for this day, after containers were assigned, is 26 trucks.

Table 4.1: Example of Truck Scheduling after assigned by application (May 01st, 2009)

Truck ID	No.of Assigments	Container 1			Container 2			Container 3			Container 4		
		ST	Time Used	Start Time	ST	Time Used	Start Time	ST	Time Used	Start Time	ST	Time Used	Start Time
T01	4	ST01	6	5/1/09 20:00	ST03	6	5/2/09 2:00	ST02	6	5/2/09 8:00	ST04	6	5/2/09 14:00
T02	4	ST02	6	5/1/09 8:00	ST04	6	5/1/09 14:00	ST03	6	5/1/09 20:00	ST04	6	5/2/09 2:00
T03	4	ST25	8	5/1/09 5:00	ST08	4	5/1/09 13:00	ST01	6	5/1/09 21:00	ST03	6	5/2/09 3:00
T04	3	ST38	8	5/1/09 5:00	ST05	8	5/1/09 13:00	ST01	6	5/1/09 22:00			
T05	3	ST01	6	5/1/09 23:00	ST38	8	5/2/09 5:00	ST08	4	5/2/09 13:00			
T06	2	ST26	14	5/1/09 23:00	ST05	8	5/2/09 13:00						
T07	2	ST30	12	5/2/09 0:00	ST08	4	5/2/09 12:00						
T08	2	ST30	12	5/1/09 0:00	ST08	4	5/1/09 12:00						
T09	2	ST17	6	5/1/09 2:00	ST08	6	5/1/09 8:00						
T10	2	ST21	6	5/1/09 2:00	ST05	8	5/1/09 8:00						
T11	2	ST36	10	5/1/09 2:00	ST02	6	5/1/09 12:00						
T12	2	ST19	8	5/1/09 12:00	ST21	6	5/2/09 2:00						
T13	1	ST26	14	5/1/09 0:00									
T14	1	ST15	12	5/2/09 1:00									
T15	1	ST07	12	5/2/09 2:00									
T16	1	ST07	12	5/1/09 7:00									
T17	1	ST07	12	5/1/09 2:00									
T18	1	ST07	12	5/2/09 3:00									
T19	1	ST07	12	5/1/09 3:00									
T20	1	ST16	12	5/2/09 3:00									
T21	1	ST07	12	5/2/09 4:00									
T22	1	ST16	12	5/2/09 4:00									
T23	1	ST40	8	5/2/09 5:00									
T24	1	ST19	8	5/2/09 6:00									
T25	1	ST08	7	5/1/09 7:00									
T26	1	ST08	7	5/2/09 7:00									
Total	46												

4.2 Result, Evaluation and Analysis

4.2.1 Result of experiment

In the current situation we have 220 full containers at DC between May 1st and May 7th and 207 trucks are used to deliver products from DC to stores, and the lower bound was 96 trucks (calculated according to Section 3.7 in Chapter 3). In the experiment using the logic in Chapter 3, we focused on trucks for delivering containers from DC to stores by using the manual assignment method for setting up routing scheduling for 136 trucks. For assignment by the application method, we ran test applications for three iterations and we used trucks for delivery containers from DC to stores, amounting to 117 trucks, 116 trucks and 120 trucks, as shown in Table 4.2

The outcome from Table 4.2 is that the percentage number of trucks to number of containers decreased from the current situation. The current percentage is 94.09% of trucks to containers 94.09%. After testing by the manual assignment method the percentage of trucks to containers decreased to 61.82%; and after testing by the assignment application the percentage of trucks to containers decreased to 53.18%, 52.73% and 54.55%, and lower bound was 43.64%. However, if we consider the number of trucks in lower bound and experiments, the number of trucks used to deliver products from DC to stores deceased from the current situation. The number of trucks in the manual assignment method decreased from the current 71 trucks, and testing assigned by application in three iterations showed that the number of trucks decreased from current situation 90, 91 and 87 trucks. The lower bound number of trucks decreased the from current situation 111 trucks.

Table 4.2: The results of experiments

1. Result of number of trucks

Date	Day	Number of Containers	Current Assigned (number of trucks)	Lower bound (number of trucks)	Testing assgined truck to container (Number of trucks)			
					Manual Assignment	Iteration # 1	Iteration # 2	Iteration # 3
1-May-09	Fri	46	44	20	28	26	27	27
2-May-09	Sat	37	35	16	19	16	19	18
4-May-09	Mon	32	32	14	23	19	16	19
5-May-09	Tue	36	35	16	23	20	20	20
6-May-09	Wed	28	26	12	20	15	15	15
7-May-09	Thu	41	35	18	23	21	19	21
Total		220	207	96	136	117	116	120

2. Percent Number of trucks to Number of containers

Date	Day	Number of Containers	Current Assigned (number of trucks)	Lower bound (number of trucks)	Testing assgined truck to container (Number of trucks)			
					Manual Assignment	Iteration # 1	Iteration # 2	Iteration # 3
1-May-09	Fri		95.65%	43.48%	60.87%	56.52%	58.70%	58.70%
2-May-09	Sat		94.59%	43.24%	51.35%	43.24%	51.35%	48.65%
4-May-09	Mon		100.00%	43.75%	71.88%	59.38%	50.00%	59.38%
5-May-09	Tue		97.22%	44.44%	63.89%	55.56%	55.56%	55.56%
6-May-09	Wed		92.86%	42.86%	71.43%	53.57%	53.57%	53.57%
7-May-09	Thu		85.37%	43.90%	56.10%	51.22%	46.34%	51.22%
Total			94.09%	43.64%	61.82%	53.18%	52.73%	54.55%

3. Compare of number of trucks between Current, Lower bound and Testing assignment

Date	Day	Number of Containers	Current Assigned (number of trucks)	Lower bound (number of trucks)	Testing assgined truck to container (Number of trucks)			
					Manual Assignment	Iteration # 1	Iteration # 2	Iteration # 3
1-May-09	Fri			- 24	- 16	- 18	- 17	- 17
2-May-09	Sat			- 19	- 16	- 19	- 16	- 17
4-May-09	Mon			- 18	- 9	- 13	- 16	- 13
5-May-09	Tue			- 19	- 12	- 15	- 15	- 15
6-May-09	Wed			- 14	- 6	- 11	- 11	- 11
7-May-09	Thu			- 17	- 12	- 14	- 16	- 14
Total		-	-	- 111	- 71	- 90	- 91	- 87

4.2.1 Evaluate and Analysis

According to the experimental results in Section 4.2.1, we can decrease the number of trucks from current situation and they are near the lower bound, as expressed in Table 4.3 and Figure 4.3

Table 4.3: Percent Comparison between Current situation and Experiments and Percent Comparison between Lower Bound and Experiments

Percent comparision between Current Situation and Experiments

1) Manual Assigment

Date	Day	Current Situation	Manual	% Comparision
1-May-09	Fri	44	28	-36.36%
2-May-09	Sat	35	19	-45.71%
4-May-09	Mon	32	23	-28.13%
5-May-09	Tue	35	23	-34.29%
6-May-09	Wed	26	20	-23.08%
7-May-09	Thu	35	23	-34.29%
Total		207	136	-34.30%

2) Assigned by application (Iteration #1)

Date	Day	Current Situation	Iteration #1	% Comparision
1-May-09	Fri	44	26	-40.91%
2-May-09	Sat	35	16	-54.29%
4-May-09	Mon	32	19	-40.63%
5-May-09	Tue	35	20	-42.86%
6-May-09	Wed	26	15	-42.31%
7-May-09	Thu	35	21	-40.00%
Total		207	117	-43.48%

3) Assigned by application (Iteration #2)

Date	Day	Current Situation	Iteration #2	% Comparision
1-May-09	Fri	44	27	-38.64%
2-May-09	Sat	35	19	-45.71%
4-May-09	Mon	32	16	-50.00%
5-May-09	Tue	35	20	-42.86%
6-May-09	Wed	26	15	-42.31%
7-May-09	Thu	35	19	-45.71%
Total		207	116	-43.96%

4) Assigned by application (Iteration #3)

Date	Day	Current Situation	Iteration #3	% Comparision
1-May-09	Fri	44	27	-38.64%
2-May-09	Sat	35	18	-48.57%
4-May-09	Mon	32	19	-40.63%
5-May-09	Tue	35	20	-42.86%
6-May-09	Wed	26	15	-42.31%
7-May-09	Thu	35	21	-40.00%
Total		207	120	-42.03%

Percent comparision between Lower bound and Experiments

1) Manual Assigment

Date	Day	Lower bound	Manual	% Comparision
1-May-09	Fri	20	28	40.00%
2-May-09	Sat	16	19	18.75%
4-May-09	Mon	14	23	64.29%
5-May-09	Tue	16	23	43.75%
6-May-09	Wed	12	20	66.67%
7-May-09	Thu	18	23	27.78%
Total		96	136	41.67%

2) Assigned by application (Iteration #1)

Date	Day	Lower bound	Iteration #1	% Comparision
1-May-09	Fri	20	26	30.00%
2-May-09	Sat	16	16	0.00%
4-May-09	Mon	14	19	35.71%
5-May-09	Tue	16	20	25.00%
6-May-09	Wed	12	15	25.00%
7-May-09	Thu	18	21	16.67%
Total		96	117	21.88%

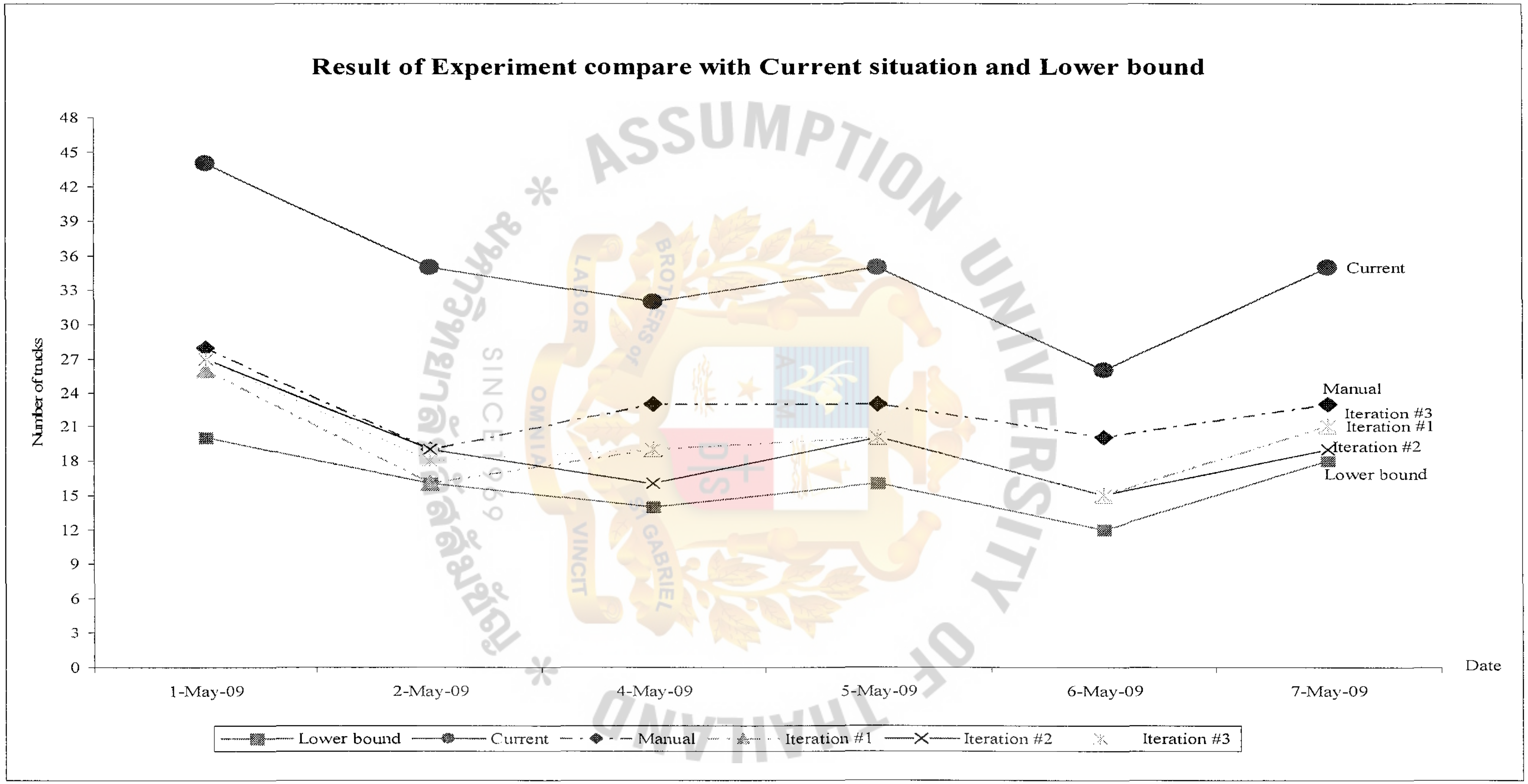
3) Assigned by application (Iteration #2)

Date	Day	Lower bound	Iteration #2	% Comparision
1-May-09	Fri	20	27	35.00%
2-May-09	Sat	16	19	18.75%
4-May-09	Mon	14	16	14.29%
5-May-09	Tue	16	20	25.00%
6-May-09	Wed	12	15	25.00%
7-May-09	Thu	18	19	5.56%
Total		96	116	20.83%

4) Assigned by application (Iteration #3)

Date	Day	Lower bound	Iteration #3	% Comparision
1-May-09	Fri	20	27	35.00%
2-May-09	Sat	16	18	12.50%
4-May-09	Mon	14	19	35.71%
5-May-09	Tue	16	20	25.00%
6-May-09	Wed	12	15	25.00%
7-May-09	Thu	18	21	16.67%
Total		96	120	25.00%

Figure 4.3: Results of experiments compared with current situation and lower bound



As in Table 4.3, when we compare the current situation and lower bound with experiments between May 1st and May 7th, 2009, we see the number of trucks decrease from current situation by 34.30% and with lower bound by 41.67% by the manual assignment method. For the assignment by application method, in iteration 1 the number of trucks decreased from the current situation by 43.48% and the lower bound by 21.88%. In iteration 2, the number of trucks decreased from the current situation by 43.96% and the lower bound by 20.83%. In iteration 3, the number of trucks decreased from the current situation by 42.03% and the lower bound by 25%.

In conclusion, after analysis of the results from the logic in Chapter 3, we can use this application for setting up routing scheduling and increasing routing efficiency. We can reduce the number of trucks for delivering full containers from DC to stores from the current situation, and all result are near the baseline (lower bound).

CHAPTER V

Summary Findings, Conclusions and Recommendations

The findings, conclusions and the recommendations of this paper are that:

5.1 Summary of Findings and Conclusions

According this paper, the main objective is finding a model for increased routing efficiency, which means finding a model which can reduce the number of trucks from the current situation for delivering full containers from DC to stores. Furthermore, this method uses the real situation, and therefore a transport manager can use this model as a suggestion for operating the trucks on a daily basis. In summary, the findings and conclusions of this case study are:

1. This study started with gathering historical data from the general database of ABC stores and KPI transport. After that, we analyzed the database to define the problem, and selected ABC stores for experiment by using Pareto's 20:80 ratio theory and diagram
2. All constraints that affect the problem were analyzed, i.e. Dispatching time, Traveling time from DC to store and back to DC, Unloading time at store, Waiting time for time window in each store, Waiting time because of the government truck ban policy for urban stores, and Waiting time for hooking new containers and preparing documents at DC.

3. All constraints were included to the total traveling time for each dispatching period and store. For this section, the transport manager will know the estimated traveling for operating a truck.
4. Logics for setting up routing scheduling were created, and the first experiment was by manual assignment. The results from this showed that we can reduce the number of trucks from the current situation. Hence, we applied this logic and created the application on Excel Spreadsheet by use Visual Basic to create the application. The results from testing by application can reduce the number of trucks for delivering full containers form DC to stores from the current situation. Furthermore, the results from assignment by application are near the baseline (lower bound). Hence, it suggested that this is the best model for the transport manager to operate trucks on a daily basis.
5. The results from these experiments show it is possible to reduce the number of trucks for delivering full containers from DC to ABC stores, which means minimizing transportation cost in term of fixed cost i.e. the Head tractor (Truck) rental cost and driver cost. According to Table 5.1, if the company pays 2,000 Baht per day per truck for Head tractor rental cost, and 200 Baht per day per truck per manpower for Driver cost, then will be 2,200 Baht for fixed cost. Hence, the cost reduction from the experiment by manual assignment can reduce fixed cost by an average of 8,263,200 Baht per year from the current situation. For testing assignment by application in three iterations, the average fixed cost can be reduced by 10,329,000 Baht per year from the current situation. The detail of cost reduction is shown in Table 5.1.

Table 5.1: Cost Reduction

Cost Reduction

Fixed Cost Description :

- Head tractor (Tuck) rental cost	2,000.00	Baht / Day / Truck
- Driver cost (12,000 Baht per month / 30 days)	400.00	Baht / Day / Truck / Manpower
- Total cost	2,400.00	Baht / Day

	Number of trucks		Fixed Cost (Baht)		
1) Manual Assigment	Current Situation	Manual	Current Situation	Manual	Cost Reduction
Experiment period 01-07 May 2009	207	136	496,800	326,400	170,400
Average per day	35	23	84,000	55,200	28,800
Average per year	10,955	7,199	26,292,000	17,277,600	9,014,400

	Number of trucks		Fixed Cost (Baht)		
2) Assigned by application (Iteration #1)	Current Situation	Iteration #1	Current Situation	Iteration #1	Cost Reduction
Experiment period 01-07 May 2009	207	117	496,800	280,800	216,000
Average per day	35	20	84,000	48,000	36,000
Average per year	10,955	6,260	26,292,000	15,024,000	11,268,000

	Number of trucks		Fixed Cost (Baht)		
3) Assigned by application (Iteration #2)	Current Situation	Iteration #2	Current Situation	Iteration #2	Cost Reduction
Experiment period 01-07 May 2009	207	116	496,800	278,400	218,400
Average per day	35	20	84,000	48,000	36,000
Average per year	10,955	6,260	26,292,000	15,024,000	11,268,000

	Number of trucks		Fixed Cost (Baht)		
4) Assigned by application (Iteration #3)	Current Situation	Iteration #3	Current Situation	Iteration #3	Cost Reduction
Experiment period 01-07 May 2009	207	120	496,800	288,000	208,800
Average per day	35	20	84,000	48,000	36,000
Average per year	10,955	6,260	26,292,000	15,024,000	11,268,000

5.2 Recommendations and future study

1. This study tried to simulate the application as though in a real situation, to increase routing efficiency. However, this application can apply to others businesses. The application can use other company's raw database related to that business and set up routing scheduling as in this study.
2. The logic for creating an application on Excel Spreadsheet can also apply to others programs that may be more efficacious than Excel Spreadsheet.

3. For future study, this model can apply to an overall company transportation network across the country. The model can suggest available time for each truck, and can be used to find other opportunities and give other types of income to the company e.g. after truck delivery of products to stores is finished, that truck going back to DC for a new assignment with an empty container can instead be used to backhaul products from suppliers to DC etc..
4. This study is environmentally because it can reduce the number of vehicles on the road.

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