Chapter 4.

Technical Analysis

This project is a study of preliminary feasibility of the Northern refined petroleum products pipeline. The pipeline is a single pipeline in order to transporting the petroleum products that consist of Unleaded Gasoline (ULG), Unleaded Regular (ULR) and High Speed Diesel (HSD) into the Multi-Products Pipeline for providing service to the customers in the Northern part.

In this chapter, the study will be involved with the project feasibility with respect to the technical analysis in two sections : Oil Depot System and Pipeline System. For the first section on Oil Depot System, the study is undertaken to figure out and identify the suitable location of the oil depot through application of the Transportation Problem. Optimization of suitable oil depot location is computed with the main objective towards *Lowest Cost*. For the Pipeline System, the initial analysis will be made to figure out the approximate length and size of the pipeline, as well as the suitable line for pipeline laying and installation.

4.1 Oil Depot System

4.1.1 Factor related to the Decision on the Oil Depot to be constructed

The key factor related to the decision on the oil depot to be constructed is *the overall economy of expenses*. The study will apply the ***Transportation Problem*** technique to figure out *the least cost* of transportation for oil delivered from Saraburi oil depot to designated oil terminal to serve the customers in each province in Northern region. Besides, the road network is another supporting factor involved in the decision.

4.1.2 Initial Criteria in the Analysis

The initial assumptions employed in the analysis of the optimum location for construction of Oil Depots are as follows:

1) The application of the *Transportation Problem* is made under the *Least Cost Method* while demand is based on the provincial demand reported

by the ministry of Commerce in 1998 (detailed in Table 4.1-4.3). Supply of each oil terminal in designated provinces is derived from the overall the least cost.

2) Nakhon Sawan, Pitsanulok, Lampang and Chiang Mai, which are already located with an oil depot is designated to be a terminal oil depot.
3) Other provinces (13 provinces)[1] of the North are *assumed* to be the province with a terminal oil depot.
4) The least transportation cost is computed as follows:
    - From Saraburi oil depot to four terminal oil depots: using the delivery cost paid by PTT. for transport of oil with the truck service. From Saraburi oil depot to assumed oil depot in other provinces: using under the *Pro-rate method* (in table appendix C).
    - From oil terminal to customers. The transport cost paid by PTT. to the trucking service is assumed the distance range of 20 km. while the oil depot construction cost is assumed at 4 satang per litre for every depot.
5) The trucking service cost is made with reference to the retail price of PTT. diesel in Bangkok between 8.51-9.00 baht per litre[2].
6) The tank size is determined from the *Batch Size* of the petroleum products to be delivered plus *Dead Stock* of 15%.
7) The Batch size is at 5 days of Throughput (the volume of oil flowed through the pipeline).
8) Interface tank with containing capacity of 0.5 million-litres. For two tanks connecting to the depot for Low Flash Point interface and High Flash Point Interface.
9) ULP is cancelled by the National Energy Policy Office in 1998, so the customers of ULP have to switch to ULG.

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[1] Note: Northern region of Thailand consists of 17 provinces as mentioned in Chapter 3.

[2] Note: This rate, 8.51-9.00 St./Lt., is the average range of Diesel retail price between January 1, 1998-October 29, 1998 as shown in Appendix J.

Table 4.1 The consumption of Unleaded Gasoline (ULG : Octane 95) of the Northern region

From January 1, 1998 to December 31, 1998

UNIT: 1000 Lts.

AREA	PROVINCE	PTT	SHELL	ESSO	CALTEX	BCK	SIAM SAHA	COSMO	PT	MOBIL	PC SIAM	THAIOIL	CONOCO	MP.	CHAREON	TPI	Q8	TPI OIL	TOTAL
	NORTH TOTAL	158,074	98,481	84,329	43,762	28,831	6,952		1,043		172		19,717	20,424			14,674	5,157	481,616
	UPPER	102,468	61,331	55,203	22,771	20,339	3,858		1,043		68		17,200	17,708			9,010	2,476	313,475
19	Chiang Rai	15,171	7,266	11,672	2,838	2,654	1,866							802			894	43	43,206
20	Chiang Mai	35,338	29,531	21,068	13,306	9,119	372				68		16,073	5,913			6,137	365	137,290
21	Nan	2,682	3,376	1,872	337	603							79	675				4	9,628
22	Phayao	9,502	2,375	1,934	162	762	493							1,474					16,702
23	Phrae	4,794	5,896	2,680	2,370	2,508	693							6,595				14	25,550
24	Mae Hangson	4,444	871	406	15									1,044				28	6,808
25	Lampang	22,318	9,704	11,932	2,745	3,612	236		1,043					936			889	1,858	55,273
26	lamphun	8,219	2,312	3,639	998	1,081	198						1,048	289			1,090	164	19,018
	LOWER	55,606	37,150	29,126	20,991	8,492	3,094				104		2,517	2,716			5,664	2,681	168,141
27	Kamphheng Phet	4,052	1,262	3,589	2,193	925	27							142			1,366	884	14,440
28	Tak	5,509	4,247	3,340	1,132	634	140							45			1,732		16,779
29	Nakhon Sawan	13,206	7,803	7,280	3,804	1,264	221				104			1,994			623	1,471	37,770
30	Phichit	4,338	3,127	3,998	608	1,414	228							16				6	13,435
31	Pitsanulok	10,572	12,670	3,742	249	1,721	790						2,517	403			1,943	286	37,138
32	Phetchabun	3427	3,297	3,154	2,454	1,167	281							76				6	13,860
33	Sukhothai	4,947	2,810	2,527	7,264	28	229							4				19	17,828
34	Uttradit	6,685	1,282	1,796	354	829	1,178							36				9	12,169
35	Uthai Thani	2,870	652		690	510													4,722

Source : The Ministry of Commerce

Table 4.2 The consumption of Unleaded Regular (ULR : Octane 87 and 91) of the Northern region

From January 1, 1998 to December 31, 1998

UNIT 1000 Lts

AREA	PROVINCE	PTT	SHELL	ESSO	CALTEX	BCK	SIAM SAHA	COSMO	PT.	MOBIL	PC SIAM	THAIOIL	CONOCO	MP.	CHAREON	Q8	TPI.OIL	SIAM CHEMIC	TOTAL
	NORTH TOTAL	71,850	39,189	45,785	25,290	16,164	4,476		356		116		4,053	7,892		4,809	2,493		224,373
	UPPER	37,917	15,731	16,703	6,425	9,046	1,678		356		28		3,475	6,723		1,744	927		100,753
19	Chiang Rai	4,724	1,442	3,519	996	1,106	744							314		226	3		13,074
20	Chiang Mai	12,679	5,312	4,370	3,512	3,857	75				28		3,232	1,850		1,099	169		36,183
21	Nan	3,964	4,109	3,032	338	461							36	1,019			8		12,967
22	Phayao	3,272	392	221	27	355	230							598					5,095
23	Phrae	2,700	1,655	1,343	788	1,576	422							2,540			3		11,027
24	Mae Hangson	1,452	316	133	6									12			15		1,934
25	Lampang	6,138	2,138	3,345	486	1,168	77		356					254		186	661		14,809
26	lamphun	2,988	367	740	272	523	130							136		223	68		5,664
	LOWER	33,933	23,458	29,082	18,165	7118	2,798				88		578	1,169		3,065	1,566		121,720
27	Kamphheng Phet	2,407	1,041	4,866	1,932	826	169							59		1,233	632		13,165
28	Tak	2,466	1,545	1,725	347	261	84							31		821			8,280
29	Nakhon Sawan	6,075	4,270	5,026	3,059	587	208				88			753		477	677		21,220
30	Phichit	3,878	2,665	7,955	1,206	1,163	281							5			9		17,162
31	Pitsanulok	6,547	6,786	1,285	888	732	1,011							261		534	230		18,852
32	Phetchabun	2,432	1,861	3,733	2,414	2,530	278							55			3		13,306
33	Sukhothai	2,711	2,840	2,262	7,537	48	148							0			15		15,561
34	Uttradit	5,918	1,030	2,230	768	429	619							5					10,999
35	Uthai Thani	1,499	420		714	542													3,175

Source : The Ministry of Commerce

Table 4.3 The consumption of High Speed Diesel (HSD) of the Northern region

From January 1, 1998 to December 31, 1998

UNIT: 1000 Lts.

AREA	PROVINCE	PTT	SHELL	ESSO	CALTEX	BCK	SIAM GAS	SIAM SAHA	WORLD	COSMO	BP.	PT.	MOBIL	PC. SIAM	THAI OIL	SUKHOT	MP	TIPCO	TPI	Q8	TPI.OIL	SIAM CHEMIC	CHAREON	CONOCO	RAYONG	TOTAL
	NORTH TATAL	445,776	299,929	311,002	180,221	144,630		27,789			48	2,672		2,301		64	62,743	1,104		26,052	23,808	1,780		21,835	8,416	1,560,170
	UPPER	255,413	129,948	131,932	52,385	63,288		12,773				2,672		602			44,063	792		13,180	10,048	491		18,901	532	737,020
19	Chiang Rai	26,614	16,399	33,944	8,082	9,731		2,793									3,758			2,274	1,066	412			96	105,169
20	Chiang Mai	63,651	43,950	37,441	25,342	20,531		783						602			14,137	48		6,422	3,409			16,791		233,107
21	Nan	7,581	11,965	7,120	987	2,670											1,466				4			172		31,965
22	Phayao	14,924	3,488	5,748	366	3,520		2,042									4,560				1,424					36,072
23	Phrao	6,411	15,289	7,420	8,449	6,714		3,937									17,024				63	79				65,386
24	Mae Hangson	7,142	1,303	934	63	543											40				70					10,095
25	Lampang	104,356	32,695	31,747	6,279	12,703		1,449				2,672					2,151	744		2,089	2,830				270	199,985
26	Lamphun	24,734	4,859	7,578	2,817	6,876		1,769									927			2,395	1,182			1,938	166	55,241
	LOWER	190,363	169,981	179,070	127,836	81,342		15,016			48			1,699		64	18,680	312		12,872	13,760	1,289		2,934	7,884	82,150
27	Kamphheng Phet	18,418	13,046	28,730	17,417	8,868		1,046									5,094			2,719	3,097	83			266	98,838
28	Tak	17,123	13,871	17,116	6,784	4,579		351									196			4,346	192	252				64,810
29	Nakhon Sawan	45,942	32,047	37,996	17,217	11,030		2,093			48			1,699			11,122			1,888	5,837	743			4,867	172,529
30	Phichit	19,528	18,403	31,597	6,573	14,332		1,776									455				191				357	93,212
31	Pitsanulok	40,459	53,916	16,640	8,729	8,146		5,020									966	24		3,919	3,091			2,699	749	144,358
32	Phetchabun	11,359	17,213	17,998	6,618	20,391		1,050								64	836	288			371	211		235	94	76,728
33	Sukhothai	16,810	15,771	11,263	60,322	4,493		1,005													126				75	109,865
34	Uttradit	14,058	4,349	16,584	2,856	3,717		2,675									11				567				1,476	46,293
35	Uthai Thani	6,666	1,365	1,146	1,266	5,786															228					16,517

4.1.3 The Least Cost Method and Minimal Column Value Method

The minimal column value is one of Transportation problem method for finding an optimum initial feasible solution that in this section is the suitable site for construction of Oil depot. This method includes the costs in determining an initial basic feasible solution and therefore usually generates a cheaper solution. This method requires the search of each column for the lowest cost.

The decision-making process to select the suitable location of the oil depot is dependent on the minimum transportation cost. The most-suitable site may be theoretically analyse and translated into the following relation (the analysis under this relation is provided in Table 4.4).

From Transportation problem as mentioned in Chapter 2, we assume that is total supply equals total demand.

Total Supply	=	Total Demand

In the least cost method and minimal column method, the unit or transportation cost array, is scanned of each column for the lowest C_{ij}, and the first basic variable is chosen to be X_d. The optimum location for oil depot depends on supply of each oil terminal in designated provinces that are derived from the overall the least transportation cost.

Thus, the relation for finding the optimum location for construction of Oil depot is as follow:

Optimum Location =	Maximum Supply	=	Max S_i

Where; S_i = Supply in each source i (oil depot)

Max S_i = Maximum supply of each assumed terminal oil depot

i = 1, 2, 3,..., 7 (sources that are oil depots)

$$S_i = \Sigma X_d$$

$$\Sigma X_d = \min_{(i,j)} C_{ij}$$

Where; S_i = Supply in each source i (oil depot)

X_d = Demand of the provinces with total least transportation cost in each source oil depot i

C_{ij} = The least transportation cost in each column or each province

d = 1, 2, 3, ..., 17 (demand of each province)

i = 1, 2, 3,..., 7 (sources that are oil depots)

j = 1, 2, 3,..., 17 (destinations that are provinces)

$$\text{The Least total transportation cost} = A_{ij} + C_{ij}$$

Where; A_{ij} = Transportation cost from Saraburi oil depot to terminal oil depots

C_{ij} = The Lowest Transportation cost from designated terminal oil depots to customer in each province

From these relations, the optimum locations for construction terminal oil depots depend upon Demand of each province and Transportation Cost.

From the Least Cost method or Minimal Column Value method theory, this method will be applied in order to find and select the optimum solution of the least transportation cost between oil depots to the customers in each province. The application of this method is by searching only for the lowest transportation cost in each column (each province), and the lowest cost determines the location from which the oil depot originates.

4.1.4 The Calculation for finding the Optimum location for construction oil depots

Prior to using these relations, all variables that involved with these relations should be calculated first. And all calculations are resulted in Table 4.4.

(1) Demand of each province (17 provinces)

Demand of each province is computed from the provincial demand reported by the Ministry of Commerce in 1998 (Table 4.1-4.3)

Demand of each province = Demand of ULG + ULR + HSD in each province

For example, demand of Chaing Mai = 137,290+36,183+233,107 = 406,580 thousand-litres or 407 million-litres.

(2) Distance between provinces

Distance between province is from the Thailand highway map of the Highway Department as shown in Appendix A.

(3) Transportation cost from Saraburi to designated 7 terminal oil depots

(3.1) Transportation from Saraburi to terminal oil depots in Chaing Mai, Lampang, Pitsanulok and Nakhon Sawan : using the transportation cost that is designated by PTT referring to initial criteria Clause 4.1.1 (no. 2 and 4). This cost is shown in Appendix B.

(3.2) Transportation cost from Saraburi to assumed terminal oil depots in Chaing Rai, Phrae and Tak : using the interpolation method from distance and cost table in Appendix C., and distance between provinces in Appendix A.

For example, the transportation cost from Saraburi to Chaing Rai.
- from Appendix A; distance from Saraburi to Chaing Rai = 718 km.
So, from Appendix C; At 710 km. Transportation cost = 48.40 st/lts.
At 720 km. Transportation cost = 49.06 st/lts.
From interpolation; The Transportation cost from Saraburi to Chaing Rai = [(49.06-48.40)/(720-718) x (718-710)] + 48.4 = 48.93 satang/litres.

(4) Transportation cost from terminal oil depots to customer in each province : Using the interpolation method as in (3.2)

For example, the transportation cost from Chaing Rai to Chaing Mai.

- from Appendix A; distance from Chaing Rai to Chaing Mai = 182 km.

So, from Appendix C; At 180 km. Transportation cost = 16.71 st/lts.

At 190 km. Transportation cost = 17.36 st/lts.

From interpolation; The Transportation cost from Chaing Rai to Chaing Mai

$= \left[(17.36-16.71)/(190-180) \times (182-180)\right] + 16.71 = 16.84$ satang/litres.

(5) Total transportation cost

Total Transportation cost = $A_{ij} + B_{ij}$

Where; A_{ij} = Transportation cost from Saraburi oil depot to terminal oil depots

B_{ij} = Transportation cost from designated terminal oil depots to customer in each province

4.1.5 Location Suitable for construction of Oil Depot

From the above relation, the decision to select the suitable location of oil depots is based on Optimization of the least cost. Thus, the following variables have been involved in the computation.

1. Distance between provinces (according to the map of the Highways Department) - Distances are constant.
2. Oil transportation cost from Saraburi oil depot to terminal oil depot in designated provinces.
3. Oil transportation cost between provinces - subject to distances and price restriction of PTT.
4. Demand of each province in 1998.

From the computation Table 4.4, it is evident that if the distance is fixed, the transportation cost in (2) and (3) may vary due to different factors such as the government or the private business may invest or initiate a large investment n such province. Thus, economic growth and developments will rapidly incur in such province. Energy consumption, particularly oil, will grow up and the transportation cost will go down because the transportation cost is directly varied with demand. Besides, the computed transportation costs is the unit cost (as illustrated in Figure 1.1 in chapter 1). Variation in both transportation costs will evitably affect the decision.

For example, if the transportation cost from Saraburi to the oil depot in Lampang has grown up (like from 38.91 satang/litre to 40 satang/litre), the total minimum transportation cost in terminal customer province for oil transported from Lampang oil depot will go up as well. Originally, the assumption that Lampang oil depot should be the distribution center for Chaing Mai, Lampang and Lamphun. Because the analysis indicates that the oil transported from Lampang to those three provinces would result in the minimum transportation cost may be changed to Phrae oil depot, which would result in the lowest transportation cost for oil transported to the customers in those three provinces. That will really affect the decision. Oil demand in each province is definitely another major factor. If the oil demand in Phrae has changed that will affect the total supply. However, the most important variable involved in the decision is the transportation costs in (2) and (3) as indicated above the selection criteria on the suitable location of oil depot is cost minimization.

Table 4.4 The Optimum Location for Construction of Oil Depot Analysis

Unit : Satang/Litre

Terminal Oil Depot	Chiang Mai	Chiang Rai	Nan	Phayao	Phrae	Mae Hongson	Lampang	Customer Lamphun	in each Kampheng Phet	Province Tak	Nakhon Sawan	Phichit	Pitsanulok	Phetchabun	Sukhothai	Uttradit	Uthai Thani	Supply'98 (mml.)
SRB. To Chiang Mai	51.92	63.54	72.38	66.15	64.78	74.31	57.23	51.99	73.60	69.05	80.33	77.79	73.34	83.69	71.18	66.73	83.33	0
46.70	5.22	16.84	25.68	19.45	18.08	27.61	10.53	5.29	26.90	22.35	33.63	31.09	26.64	36.99	24.48	20.03	36.63	
Chiang Rai	69.77	58.15	75.59	63.61	73.22	97.09	72.57	77.22	88.22	83.55	91.92	88.03	84.44	94.22	83.67	78.00	94.69	161
52.93	16.84	5.22	22.66	10.68	20.29	44.16	19.64	24.29	35.29	30.62	38.99	35.10	31.51	41.29	30.74	25.07	41.76	
Nan	71.97	68.95	51.51	62.72	58.66	90.74	66.06	70.71	74.50	74.69	78.52	74.50	70.58	80.86	69.65	33.86	81.39	55
46.29	25.68	22.66	5.22	16.43	12.37	44.45	19.77	24.42	28.21	28.40	32.23	28.21	24.29	34.57	23.36	17.43	35.10	
Phayao	66.97	58.20	63.96	52.74	61.48	86.57	60.79	65.61	77.19	72.36	81.10	77.01	73.26	83.51	74.42	32.89	83.98	0
47.52	19.45	10.68	16.43	5.22	13.96	39.05	13.27	18.08	29.67	24.84	33.57	29.49	25.74	35.99	26.90	18.92	36.46	
Phrae	57.72	59.93	52.01	53.60	44.86	77.51	51.41	56.35	60.32	60.53	64.66	60.19	56.21	67.19	55.33	48.81	67.63	0
39.64	18.08	20.29	12.37	13.96	5.22	37.87	11.77	16.71	20.68	20.89	25.02	20.55	16.57	27.55	15.69	9.17	28.09	
Mae Hongson	88.24	104.79	105.08	99.68	98.50	65.85	92.08	87.84	101.15	97.20	107.44	106.00	104.97	115.01	101.63	71.02	110.08	19
60.63	27.61	44.16	44.45	39.05	37.87	5.22	31.45	27.21	40.52	36.57	46.81	45.37	44.34	54.38	41.00	39.57	49.85	
Lampang	49.44	58.55	58.68	52.18	50.68	70.36	44.13	47.85	59.59	55.21	67.12	65.48	59.80	70.48	57.38	52.79	70.12	815
38.91	10.53	19.64	19.77	13.27	11.77	31.45	5.22	8.94	20.68	16.30	28.21	26.57	20.89	31.57	18.47	13.88	31.21	
Lamphun	51.80	70.79	70.92	64.59	63.21	73.71	55.45	51.72	72.06	67.39	78.90	76.35	71.81	82.26	69.55	44.22	81.91	0
46.60	5.29	24.29	24.42	18.08	16.71	27.21	8.94	5.22	25.56	20.89	32.40	29.85	25.31	35.76	23.05	18.66	35.41	
Kampheng Phet	55.06	63.45	56.37	57.83	48.84	68.68	48.84	53.72	33.38	36.89	40.46	38.53	39.53	50.99	37.55	25.23	43.98	90
28.16	26.90	35.29	28.21	29.67	20.68	40.52	20.68	25.56	5.22	8.73	12.30	10.37	11.36	22.83	9.39	16.50	15.82	
Tak	54.69	62.96	60.74	57.16	53.23	69.01	48.64	53.23	41.07	37.56	49.38	47.49	46.08	57.41	41.88	48.98	52.56	0
32.34	22.35	30.62	28.40	24.82	20.89	36.57	16.30	20.89	8.73	5.22	17.04	15.15	13.74	25.07	9.54	16.64	20.22	
Nakhon Sawan	53.77	59.13	52.37	53.71	45.16	66.95	48.35	52.54	32.44	37.18	25.36	32.18	33.27	37.63	37.37	41.24	27.55	418
20.14	33.63	38.99	32.33	33.57	25.02	46.81	28.21	32.40	12.30	17.04	5.22	12.04	13.13	17.49	17.23	21.10	7.41	
Phitchit	58.99	63.00	56.60	57.38	48.44	73.27	54.46	57.74	38.26	43.05	39.93	33.11	36.99	41.02	40.74	26.39	43.45	0
27.90	31.09	35.10	28.21	29.49	20.55	45.37	26.57	29.85	10.37	15.15	12.04	5.22	9.09	13.13	12.85	17.30	15.55	
Pitsanulok	54.55	59.42	52.20	53.65	44.48	72.25	48.80	53.22	39.27	41.65	41.04	37.00	33.13	43.93	35.99	40.28	44.55	445
27.91	26.64	31.51	24.29	25.74	16.57	44.34	20.89	25.31	11.36	13.74	13.13	9.09	5.22	16.02	8.08	12.37	16.64	
Petchabun	61.54	65.83	59.12	60.54	52.10	78.92	56.12	60.31	47.37	49.62	42.04	37.68	40.57	29.77	44.44	43.71	44.70	104
24.55	36.99	41.29	34.57	35.99	27.55	54.38	31.57	35.76	22.83	25.07	17.49	13.13	16.02	5.22	19.90	23.82	20.16	
Sukhothai	56.88	63.14	55.76	59.30	48.49	73.40	50.87	55.45	41.79	41.94	49.63	45.25	40.48	52.30	37.62	22.32	52.88	69
35.40	24.48	30.74	23.36	26.90	15.69	41.00	18.47	23.05	9.39	9.54	17.23	12.85	8.08	19.90	5.22	11.16	20.48	
Uttradit	56.13	61.18	53.53	55.03	45.27	75.68	49.99	54.77	52.61	62.75	57.21	53.40	48.48	59.93	47.27	41.33	60.53	0
36.10	20.03	25.07	17.43	18.92	9.17	39.57	13.88	18.66	16.50	16.64	21.10	17.30	12.37	23.82	11.16	5.22	24.42	
Uthai Thani	55.78	60.91	54.26	55.61	47.24	69.01	50.36	54.56	34.97	39.37	26.56	34.70	35.79	39.31	39.63	43.57	24.37	24
19.15	36.63	41.76	35.10	36.46	28.09	49.85	31.21	35.41	15.82	20.22	7.41	15.55	16.64	20.16	20.48	24.42	5.22	
Demand'98 (mml.)	**407**	**161**	**55**	**58**	**102**	**19**	**270**	**80**	**126**	**90**	**231**	**124**	**200**	**104**	**143**	**69**	**24**	**2,263**

Note : A 4.00 satang/litres terminal oil depot service charge is added to the transportation rate at each oil depot.

Note : Symbol - 1. Terminal Oil Depot
2. Transportation Cost from Saraburi to Terminal Oil Depot
3. Transportation Cost from Terminal Oil Depot to customer in each provinces
4. Total Transportation Cost (2 + 3)

EX: Lampang is the Terminal Oil Depot.
38.91 st/lts is Transportation Cost from SRB. To Lampang.
10.53 st/lts is Transportation Cost from Lampang to customer in Chaing Mai.
49.44 st/lts is Total Transportation Cost from SRB through Lampang oil depot to customer in Chaing Mai.

SRB. TO

1	4
2	3

Lampang	49.44
38.91	10.53

With the application of the *Transportation Problem* under the *Least Cost Method and minimal column value* to figure out the minimum delivery cost from Saraburi oil depot to the customers through oil terminals, it is evident that (detailed in Table 4.4) :

Terminal Oil Depot	**Volume (million-litres)**
Lampang	815
Nakhon Sawan	418
Pitsanulok	445
Chaing Rai	161
Phetchabun	104
Kampheang Phet	90
Other Provinces (Nan, Mae Hongson, Sukhothai, and Uthai Thani)	167
Total	**2,263**

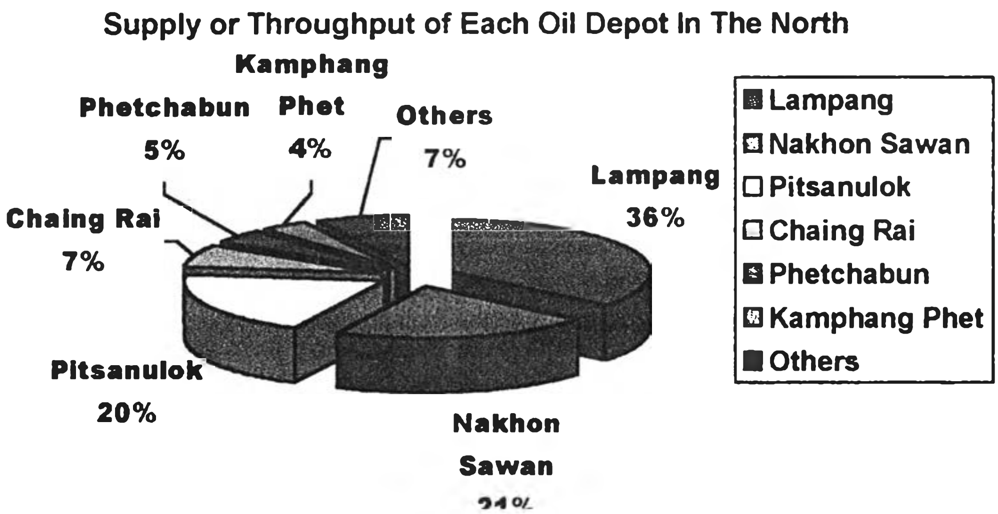


Figure 4.1 Percentage of Supply or Throughput

In addition, the selection criteria on the service area of each oil depot are also the lowest transportation cost. Each oil depot will service the provinces with the minimum transportation cost and shall be the province suitable for location of the oil depot. If such province has the lowest transportation cost but it is not suitable to locate the oil depot, the option is to pick up the second or next minimum transportation cost (next order), whether such province is located with the oil depot. If yes, pick up such provinces in the service area of such oil tank (as table below).

Rank	Terminal Oil Depot	Volume (million-litres)
1st	Lampang	976
2nd	Nakhon sawan	718
3rd	Pitsanulok	569

From the result of the Transportation Problem, the suitable site for construction of oil depot is Lampang, Nakhon Sawan and Pitsanulok where 90% of the oil stock has been distributed from those oil depots. Besides, these provinces are well connected to other provinces with the road network. Other provinces, i.e. Phetchabun, Kampheng Phet, and Chaing Rai are not a proper site for construction of oil depot because the oil throughput is low. Thus, the customer services for each province in the North will be as follows:

Lampang Oil Depot : Chiang Rai, Chiang Mai, Lampang, Lamphun and Phyao

Nakhon Sawan Oil Depot : Kamphang Phet, Nakhon Sawan, Phichit, Phetchabun, Uthai Thani, Tak, and Mae - Hongson

Pitsanulok Oil Depot : Pitsanulok, Sukhothai, Uttradit, Nan, and Phrae

4.1.6 Project Growth Rate Demand of Gasoline (ULG and ULR)and Diesel

Before the optimum tank size and size of pipeline for each terminal oil depot in the designated provinces, which are Lampang, Nakhon Sawan and Pitsanulok, is computed, the oil demand for the entire project life-term is needed (that is, the useful life of the pipeline of 30 years). Thus, the study and analysis is made to approximate the oil demand (ULG, ULR and HSD) in the Northern region between 1998-2032. (Note : project life is 30 years with construction of 2 year (2001-2002). The oil transport service begins in 2003, which is the first year of the project, and the thirtieth year of the project is 2032). The calculation involves four variables as follows (the entire analysis result is shown in Table 4.5).

1) Growth rate of ULG, ULR and HSD (unit : %)

This variable is growth or increase in oil consumption of the country in percentage. (source : from The National Petroleum Product Demand Projection of the enterprise plan of PTT as show in Appendix D).

2) Capture rate (unit : %)

Originally, the oil transport is made with the existing modes that are truck and train. It is not practical to have the whole customers change to transport oil products by the pipeline system. Therefore, the mode of transport will be gradually changed to the pipeline system depending on the capture rate that is assessed from experience of PTT and Thappline. Capture rate is assessed to be stable at 75% in year 6-12 of the project life because PTT and Thappline have set the maximum value of capture rate at 75%, because experiences show that some groups of customers still prefer the old mode of transport. In year 12 of the project, the pipeline is designed and assumed to have maximum flow of oil (this year the pipeline will be fully utilized at maximum flowing capacity).

In addition, the capture rate value may imply the oil throughput of the pipeline because the throughput is computed from capture rate and demand. The throughput data is also used to compute the size of the tank and the pipeline.

3) Demand (unit : million-litres)

Projection of each type of oil is separately made for each demand for ULG, ULR and HSD, and starts with the demand in 1998 for three selected terminal oil depots that are Lampang, Nakhon Sawan and Pitsanulok. The relationship of demand in those oil depots is prepared as follows (demand from the Demand Table 3.1-3.3 of the Ministry of Commerce).

$$\text{Demand} = \Sigma \text{ Demand in such provinces in the service area of such oil tank}$$

In addition, demand in the next year can be calculated from growth rate of the later year, the relation as follows:

$$\text{Demand in year "t"} = \text{Demand in year "t -1"} \times \text{Growth Rate in year "t"}$$

4) Throughput (unit : million-litres)

It is the amount of oil flowing through the pipeline, starting from the initial year of the project (2003) because it is the first service year of oil supply through the pipeline. Throughput may be computed from capture rate and demand under the following relation.

Throughput in year "t" = Total demand is such oil depot x Capture Rate in year "t"

In addition, throughput is the important factor in order to calculate not only the number and size of oil tank but also the size of pipeline.

Table 4.5 The Projection Growth Rate Demand of Benzene and Diesel of Northern Region in 1998 - 2032 and Throughput

Project	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Calendar year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Growth rate (%)																		
- Gasoline		0.05	2.40	2.91	4.05	4.46	4.46	4.14	3.93	4.03	3.71	3.50	3.40	3.40	3.40	3.40	3.40	3.40
- HSD		2.29	3.84	4.43	4.25	3.95	4.35	4.13	3.87	3.94	3.62	3.41	3.31	3.31	3.31	3.31	3.31	3.31
Capture Rate (%)						50%	55%	60%	65%	70%	75%	75%	75%	75%	75%	75%	75%	71%
Demand (mml)																		
Lumpang																		
- ULG	271	271	278	286	298	311	325	338	351	365	379	392	405	419	433	448	463	478
- ULR	75	75	77	79	82	86	90	94	98	102	106	110	114	118	122	126	130	134
- HSD (Oth.)	630	644	669	699	729	758	791	824	856	890	922	953	985	1,018	1,052	1,087	1,123	1,160
Sub Total	976	990	1,024	1,064	1,109	1,155	1,206	1,256	1,305	1,357	1,407	1,455	1,504	1,555	1,607	1,661	1,716	1,772
Throughput (mml)						578	663	754	848	950	1,055	1,091	1,128	1,166	1205	1,246	1,287	1,287
Nakhon Sawan																		
- ULG	108	108	111	114	119	124	130	135	140	146	151	156	161	166	172	178	184	190
- ULR	78	78	80	82	85	89	93	97	101	105	109	113	117	121	125	129	133	138
- HSD	533	545	566	591	616	640	668	696	723	751	754	780	806	833	861	889	918	948
Sub Total	719	731	757	787	820	853	891	928	964	1,102	1,014	1,049	1,054	1,120	1,158	1,196	1,235	1,276
Throughput (mml)						427	490	557	627	701	761	787	813	840	869	897	926	926
Pittsanulok																		
- ULG	102	102	104	107	111	116	121	126	131	136	141	146	151	156	161	166	172	178
- ULR	69	69	71	73	76	79	83	86	89	93	96	99	102	105	109	113	117	121
- HSD (Oth.)	398	407	423	442	461	479	500	521	541	562	582	602	622	643	664	686	709	732
Sub Total	569	578	598	622	648	674	704	733	761	791	819	847	875	904	934	965	998	1,031
Throughput (mml)						337	387	440	495	554	614	635	656	678	701	724	749	749
Total Demand	**2,264**	**2,229**	**2,379**	**2,473**	**2,577**	**2,682**	**2,801**	**2,917**	**3,030**	**3,250**	**3,240**	**3,351**	**3,433**	**3,579**	**3,699**	**3,822**	**3,949**	**4,079**
Total Throughput						**1,342**	**1,540**	**1,751**	**1,970**	**2,205**	**2,430**	**2,513**	**2,597**	**2,684**	**2,775**	**2,867**	**2,962**	**2,962**

Table 4.5 The Projection Growth Rate Demand of Benzene and Diesel of Northern Region in 1998 – 2032 and Throughput (continue)

Project	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Calendar year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Growth rate (%)																	
- Gasoline	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40
- HSD	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31
Capture Rate (%)	67%	63%	60%	57%	54%	51%	48%	45%	43%	40%	38%	36%	34%	32%	30%	29%	27%
Demand (mml)																	
Lumpang																	
- ULG	494	511	528	546	564	583	603	624	645	667	690	713	737	762	788	815	843
- ULR	139	144	149	154	159	164	170	176	182	188	194	201	208	215	222	230	238
- HSD (Oth.)	1,198	1,238	1,279	1,321	1,365	1,410	1,457	1,505	1,555	1,606	1,659	1,714	1,771	1,830	1,891	1,954	2,019
Sub Total	1,831	1,893	1,956	2,021	2,088	2,157	2,230	2,305	2,382	2,461	2,543	2,628	2,716	2,807	2,901	2,999	3,100
Throughput (mml)	1,287	1,287	1,287	1,287	1,287	1,287	1,2,87	1,287	1,287	1,287	1,287	1,287	1,287	1,287	1,287	1,287	1,287
Nakhon Sawan																	
- ULG	196	203	210	217	224	232	240	248	256	265	274	283	293	303	313	324	335
- ULR	143	148	153	158	163	189	175	181	187	193	200	207	214	221	229	237	245
- HSD	979	1,011	1,044	1,079	1,115	1,152	1,190	1,229	1,270	1,312	1,355	1,400	1,446	1,494	1,543	1,594	1,645
Sub Total	1,318	1,362	1,407	1,454	1,502	1,553	1,605	1,658	1,713	1,770	1,829	1,890	1,953	2,018	2,085	2,155	2,225
Throughput (mml)	926	926	926	926	926	926	926	926	926	926	926	926	926	926	926	926	926
Pittsanulok																	
- ULG	184	190	196	203	210	217	224	232	240	248	256	265	274	283	293	303	313
- ULR	125	129	133	138	143	148	153	158	164	170	176	182	188	194	201	208	215
- HSD (Oth.)	756	781	807	834	862	891	920	950	981	1,013	1,047	1,082	1,118	1,155	1,193	1,232	1,273
Sub Total	1,065	1,100	1,136	1,175	1,215	1,256	1,297	1,340	1,385	1,431	1,479	1,529	1,580	1,632	1,687	1,743	1,801
Throughput (mml)	749	749	749	749	749	749	749	749	749	749	749	749	749	749	749	749	749
Total Demand	4,214	4,355	4,499	4,650	4,805	4,966	5,132	5,303	5,480	5,662	5,851	6,047	6,249	6,457	6,673	6,897	7,126
Total Throughput	2,962	2,962	2,962	2,962	2,962	2,962	2,962	2,962	2,962	2,962	2,962	2,962	2,962	2,962	2,962	2,962	2,962

4.1.7 Size of Oil Tank

Prior to the calculation of the number and the size of oil tanks, Demand, Throughput and Need for the minimum oil tank needed in such province are required to be computed first. Demand and throughput will be from Projection Table 4.5 by using the value in year 12 (the reason will be indicated in next paragraph). The need for the minimum oil tank needed is assumed from the agreement in Clause 4.1.2 (no. 6 and 7). The throughput is computed in million of litres per year. The relation is translated into the following equation:

	Min tank size	=	B + D
Where;	Min tank size	=	The minimum tank size
	B	=	The Batch size at 5 days of throughput
	D	=	Dead stock of 15% of total throughput

For example; Min tank size of ULG at Lampang oil depot equals:

= [(347 / 365) x 5] + {[(347 / 365) x 5] x 15%}

= 4.75 + 0.713

= 5.46 ≅ 5.5

Then, the calculation will be made to figure out the number and the size of oil tanks to be constructed with reference to the agreement, Clause 4.1.2 and the concept of oil tank construction that one tank is used to take the oil into the stock storage of oil depot and another thank is used to distribute the oil through the pipeline. Therefore, two oil tanks for each oil product are needed. The relation is concluded as follows:

Tank Size = Minimum tanks needed / 2

For example; Tank Size of ULG at Lampang = 5.5 / 2

= 2.75 ≅ 3.0

Generally, the tank size should start from 0.5, 1.0, 1.5, 2.0, 3.0, 4.0, 5.0 and so on. For example, if the number is over 0.65, the result is held as 1.0. In addition, the aggregate containing capacity of the tank to be constructed shall exceed the minimum tank needed to ensure safety and stock retention.

Computation of the size of oil tank may be made from the volume of oil throughput in the pipeline system to the terminal tank. The figure employed in the calculation is set at the maximum throughput, which is 75% of the demand in 2014 that is the twelfth year of the project (with reference to PTT experience, the project period should be about 10-12 years. If the investment period is over twelve years, there will be an over investment problem during the initial period). Therefore, the size of the oil tank is as follows :

1) Lampang Oil Depot

Demand in 2014 is at 1,716 million-litres and the throughput is about 1,287 million-litres (detailed as Table 4.5). Thus, the number of oil tank, and its size necessary to meet the minimum demand are as follows :

Unit : million-litres.

Products	**Demand**	**Throughput**	**Minimum Demand of Tank**	**Number and Size of tank**
ULG	463	347	5.5	2 x 3.0
ULR	130	98	1.5	2 x 1.0
HSD	1,123	842	13.3	2 x 7.0
Interface			1.0	2 x 0.5
Total	1,716	1,287	21.3	23.0

2) Nakhon Sawan Oil Depot

Demand in 2014 is at 1,235 million-litres and the throughput is about 926 million-litres (detailed as Table 4.5). Thus, the number of oil tank, and its size necessary to meet the minimum demand are as follows :

Unit : million-litres.

Products	**Demand**	**Throughput**	**Minimum Demand of Tank**	**Number and Size of tank**
ULG	184	138	2.2	2 x 1.5
ULR	133	100	1.6	2 x 1.0
HSD	918	688	10.8	2 x 6.0
Interface			1.0	2 x 0.5
Total	1,235	926	15.6	18

3) Pitsanulok Oil Depot

Demand in 2014 is at 998 million-litres and the throughput is about 749 million-litres (detailed as Table 4.5). Thus, the number of oil tank, and its size necessary to meet the minimum demand are as follows:

Unit : million-litres.

Products	**Demand**	**Throughput**	**Minimum Demand of Tank**	**Number and Size of tank**
ULG	172	129	2.0	2 x 1.0
ULR	117	88	1.4	2 x 1.0
HSD	709	532	8.4	2 x 5.0
Interface			1.0	2 x 0.5
Total	998	749	12.8	15.0

4.1.8 Facilities at the Oil Depot

To ensure efficient and safe distribution of petroleum products at the oil depots, the following facilities should be equipped at the oil depots.

1) *Terminal Automation System or TAS* that consists of Depot Computer, Truck Loading Bay Controllers, Automatic Tank Gauging, and Emergency Shutdown.
2) *Distribution System* includes Loading Bay, Pump, Metering, and Additive Injection System.
3) *Safety System* that composes of Water Supply & Storage, Foam, Dry Chemical Powder, Fire Pump, Fire Alarm, Emergency Generator, Uninterruptible Power Supply (UPS), and Lightning Protection.
4) *Communication System* includes Public Address, Radio, Telephone, Fibre Optics, and Computer.
5) *Utilities System* that consists of Hydrant Water (Tap water), Electricity, Drainage System, API Separator, and Vapor Recovery System.
6) *Building* includes Office Building, Warehouse, Truck Entrance and Exit Inspection.

4.2 Pipeline System

4.2.1 **Factors related to the Decision on the Pipeline Installation**

The factors involved with the decision on the pipeline construction and installation are *the technical, environmental, and economic feasibility*.

4.2.2 **Initial Criteria in analysis the pipeline system**

The initial assumptions employed in the analysis as following:

1) The pipeline will be laid from Saraburi oil depot of Thappline to the oil tank to be constructed by PTT, Shell and Esso in Lampang, Nakhon Sawan and Pitsanulok.
2) The maximum throughput is at 75% of the regional demand at Lampang, Nakhon Sawan and Pitasanulok in the twelfth year of the project, which is 2014. Each company has employed various delivery systems, particularly, the small companies prefer to directly transport their oil from the oil depot in the central to their customers rather than retention of oil products in the terminal oil depot.
3) The length of the pipeline is approximated from the map with scale of 1:50,000.
4) The High-Voltage power line is from the Electricity Generating Authority of Thailand (EGAT). The highway route is in the map of the Highway Department.

4.2.3 **The Suitable Route for Laying Pipeline**

High-Voltage power line of the Electricity Generating Authority of Thailand (EGAT).

With regard to the preliminary technical and environmental examination, it is apparent that the suitable pipeline route installation should be along the High-voltage power line of the Electricity Generating Authority of Thailand (EGAT) due to the reasons as follow:

- The Right-Of-Way (ROW) of the power line is good enough for construction and installation of the pipeline. When regarding to other route such as

Highway route (Phaholyothin road route), the roads covers the entire ROW area, so it is not suitable for the pipeline laying.

- From analysis of environmental feasibility, the power line is predominantly passed through fields, besides it was found that the successful pipeline routing should not lay through sections with densely populated communities. So, the power line is appropriate for installation in environmental and public aspects.

- In the opinion of PTT and Thappline (which laid the Sriracha-Saraburi pipeline), the power line of EGAT should be used for pipeline laying because this route would not pay the charge rent for the land.

In addition, if compare with the route along the State Railway of Thailand (SRT) Rail Line, route along the rail line should not be used for pipe laying because the State Railway of Thailand would charge rent at a very high rate. That is, the rent to be charged was 156 baht per sq.m. (about 290 million baht a year, compared with compensation for land at about 113 million baht for a period of 30 years). The rent rate would be increased each year at the rate 5-7% depending on inflation rate. (If the inflation rate is below 5%, it will be raised by 5%. If the rate is 5-7%, the increase is to be made in accordance with actual inflation rate. If the inflation rate is above 7%, the increase is 7% only). SRT would agree to make a contract for the term of 3 years at a time and SRT reserves the right to terminate the contract at all times. This has accounted for Thappline's facing a problem in finding a low interest loan from financial institutions abroad. So, the rail line is not a suitable route for pipeline.

However, EGAT has no ownership in the land, only the right to construct the high-voltage power line. If the pipeline construction is needed in the area, the project owner is required to negotiate process. However, there is a possibility of success. With consideration on the experience of Thappline and PTT for installation of the oil pipeline in this area, there will be a problem on Cathodic Protection, but the problem could be overcome technically.

Thus, the analysis indicates that the suitable route for laying of pipeline should be along the High-voltage power line of EGAT because it is convenient and has least environmental and public impacts, compared to other alternatives that are the highway route and the railroad track.

4.2.4 Pipeline Description

1) Size of the Pipeline

The North pipeline is divided into three sections that are Saraburi to Nakhon Sawan, Nakhon Sawan to Pitsanulok, and Pitsanulok to Lampang. From the calculation of optimum pipe size can be summarised as follow: (detail of the calculation is shown in Appendix G)

The pipeline is referred to API 5L GR.B SCH. 40 (seamless) or ASTM A106 GR.B as shown in Appendix E. In addition, Carbon Steel pipe is used in this pipeline project. The section between Saraburi and Nakhon Sawan will be Norminal Pipe Size (NPS) 14 inch (355.6 mm) diameter pipe. The next section from Nakhon Sawan to Pitsanulok reduces to NPS 12 inch (323.8 mm) diameter pipe, and the pipe size is reduced to NPS 10 inch (273 mm) diameter pipe in the last section between Pitsanulok and Lampang.

2) Length of the Pipeline

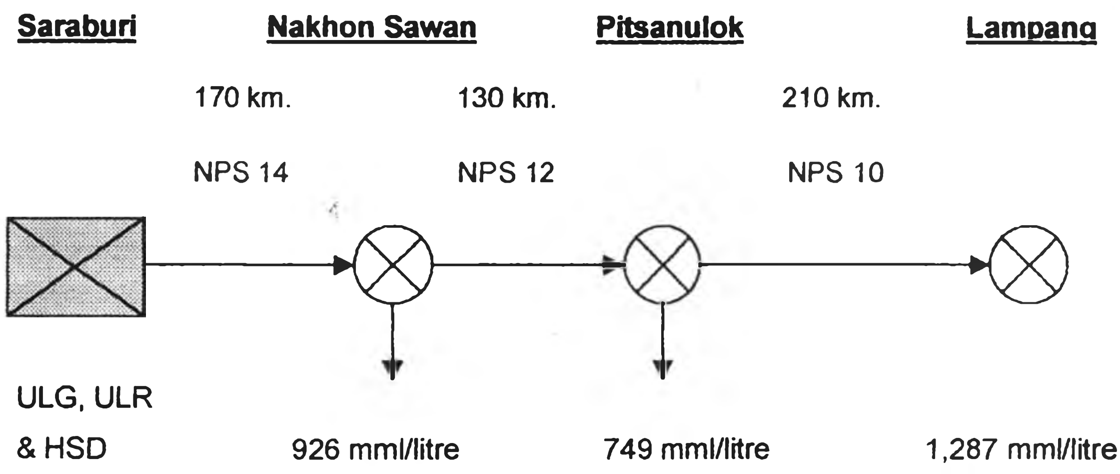
From Saraburi to Lampang, the total length of this pipeline is 510 km. The approach for this leg of the pipeline is to divides its construction into three major spreads:

<u>Saraburi to Nakhon Sawan</u> (kp 0 to kp 170) : Starting from the Thappline depot in Saraburi, the pipeline corridor traverses a northwest direction for 170 km along the EGAT High-Voltage power line. This section of the pipeline is on the central plain.

<u>Nakhon Sawan to Pitsanulok</u> (kp 170 to kp 300) : The pipeline is still part of the central plain and runs for 130 km along the EGAT HV power line.

<u>Pitsanulok to Lampang</u> (kp 300 to kp 510) : The total length of this section is 210 km along the EGAT HV power line. In some region of this section is characterised by small hills and mountains.

Pipeline schematic for the North line is depicted in drawing as following:



4.2.5 Facilities of the Pipeline

To ensure efficient and safe distribution of petroleum products of the pipeline, the following facilities should be equipped at the pipeline.

1) Pump Station will be installed at each depot at least one.
2) Pigging Facilities consist of Pig Luncher and Pig Receiver.
3) Metering System include Inlet and Outlet Meter.
4) Supervisory Control and Data Acquisition (SCADA) will supply whole information of pipeline system to a central control facility from which the operation of the pipeline, pump stations and delivery control valves will be monitored, controlled and activated.
5) Densitometer for defining groups of petroleum products by measuring the different density.
6) Colorimeter. Type of petroleum products will be classified by the different colour.
7) Block Valve will be installed at each 15 km to obstruct in cases of oil leak or pipeline maintenance process.
8) Cathodic Protection System for protection and minimisation of corrosion of pipeline system.

4.3 Summary of Technical Analysis

From the result of the technical analysis can be summarised as follows:

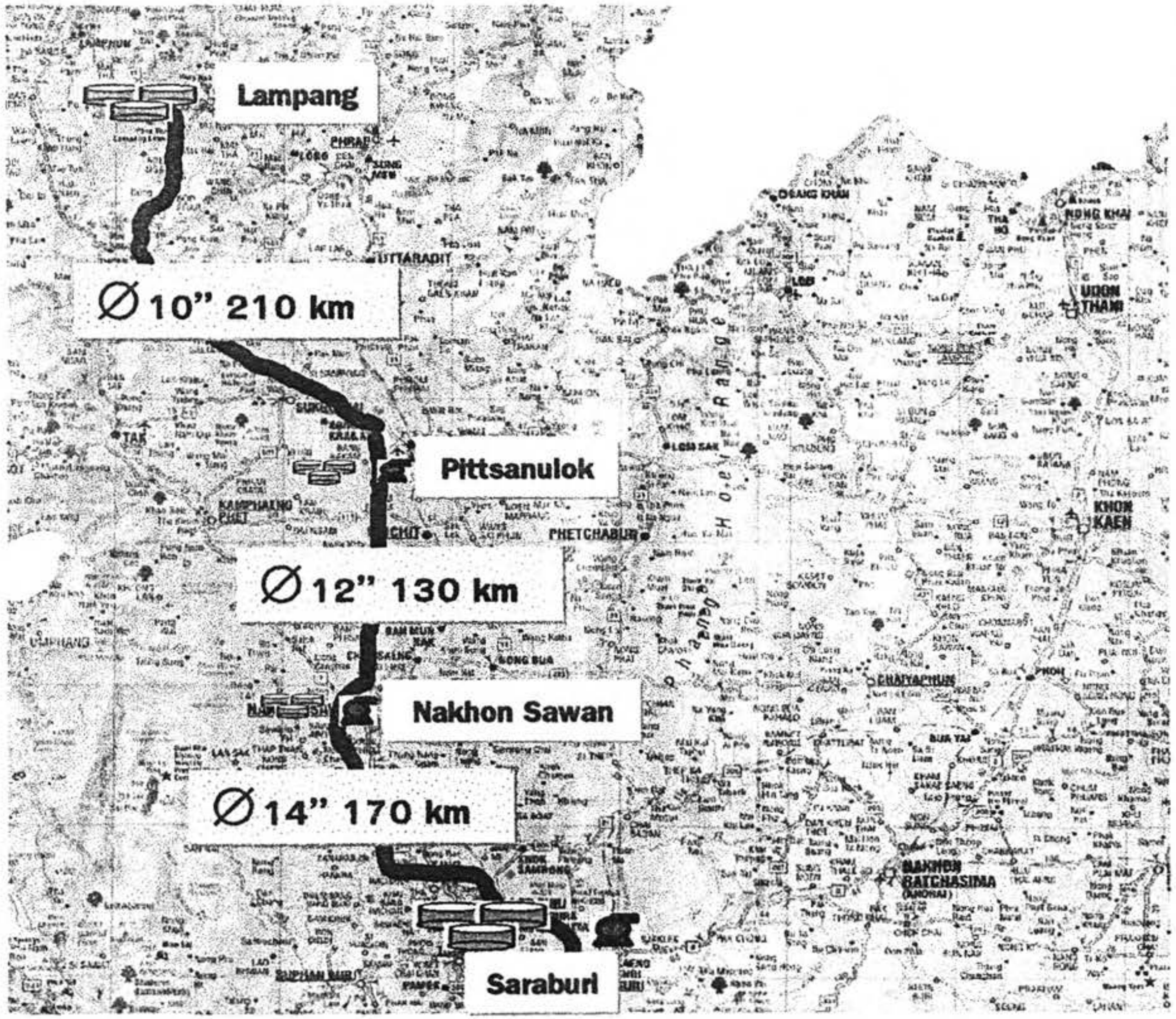
1) The suitable location:

According to Transportation problem technique by using the lowest expenditure, Nakhon Sawan, Pitsanulok and Lampang provinces are appropriate locations for construction terminal oil depots.

2) Lampang oil depot has 8 oil storage tanks with capacity of 18 million-litres, Pitsanulok consists of 8 oil tanks with 15 million-litres of capacity, and Lampang is the last terminal oil depot with capacity of 23 million-litres has 8 oil tanks also.
3) The suitable route of pipeline laying is the EGAT High-Voltage power line.
4) Pipeline Description:

   The North pipeline has approximately an overall length of 510 km from Saraburi oil depot to Lampang oil depot. The section form Saraburi to Nakhon Sawan will be 170 km of NPS 14 (355.6 mm) diameter pipe, and this reduces to NPS 12 (323.8 mm) diameter pipe for the next 130 km of the pipeline through to the Pitsanulok. And the pipe size is reduced to NPS 10 (273 mm) diameter pipe in the last section between Pitsanulok and Lampang terminal oil depot.

Figure 4.2 Northern Refined Petroleum Products Pipeline Project



The Northern

Total Distance 510 Km.

Capacity 2,962 mll/yr.