SELECTION OF A PLANT LOCATION A CASE STUDY: UREA PRODUCTION USING CALUB GAS

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ABSTRACTS

The aim of choosing an appropriate plant location is to select the place which will enable a factory to process the material and deliver the product to its customers at a minimum cost. To meet this goal there are a number of criteria to be analyzed before taking any decision. The criteria are, amongst others, supply of raw materials and fuel, market proximity, water supply, waste removal etc. It is not easy to find a location that can satisfy all requirements simultaneously, hence it is necessary to recognize which are the most important parameters and choose the location accordingly.

The main purpose of this article is to illustrate in some detail how to tackle such a complex issue using the Ethiopian scenario. For this reason, a case study of location selection for a urea plant using Calub Gas is demonstrated. The selection of the appropriate location focuses on three problems:

1. *To set up critical factors for Ethiopian scenario*
2. *To select several specific areas which would be economically desirable*
3. *To make detailed cost analyses of these locations for selected critical factors and determine the most advantageous one.*

INTRODUCTION

One of the most important considerations in any project planning is the selection of plant location. The location of the plant can have a crucial effect on the profitability of a project, and the scope for future expansion. If a plant is not located in the most economically favorable position, the competitive advantages of the process, can be wiped out. Without careful thought on all the factors which must be considered for optimum plant location, the plant may even be inoperable. Location and site are often used synonymously but must be distinguished. The choice of location should be made from a fairly wide geographical area, within which several alternative sites can be considered. Within a recommended location one or more specific project sites should be identified and assessed in detail.

The choice of a suitable location requires an assessment of availability of raw materials, sales factors such as markets and transportation, power and fuel supply, water supply, labor and utilities, which would be reflected in the costs involved and the profitability.. The criteria assigned to evaluate these vary from industry to industry, and a chemical engineer will have to use his professional skill to identify those criteria which are relevant for each specific project [1-4].

The Calub Gas Field (CGF) is located in the southeastern part of Ethiopia, 1200 km from Addis Ababa. The discovery of the gas deposit was identified first by Tenneco in 1973 and additional exploration work was carried out by a Russian firm from 1981 to 1993. The gas reserve has been estimated at about 70 billion cubic meters and is found at depth of 2307 to 3219 m below sea level. The gas composition shows mainly natural gas (~85 Mol%) and the rest is Nitrogen, Liquid Petroleum Gas (LPG) and C_5^+ paraffins [5]. This huge amount of gas reserve can be used to solve the country's problem in the energy sector (electricity) and agricultural sector by helping to produce the necessary fertilizers such as urea. The gas reserve can also be utilized for synthetic fuels (gasoline).

The utilization of Calub Gas deposit for urea production were studied by foreign consultants like BEICIP FRANLAB (Petroleum Consultants)[6], International Fertilizer Development Center(IFDC) [7]. Recently, China National Complete Plant Import and Export Corporation Limited (COMPLANT) has come with a proposal to implement the project[8]. To this end, the Prime Minister Office of Ethiopia has established a technical sub-committee to review the technical proposal and to assess the flexibility and efficiehcy of the proposed technology by COMPLANT and to provide the necessary input. The author is requested by this committee to study and propose the location of the plant for urea production based on Calub Gas.

Urea from fossil raw materials

Urea is a nitrogenous fertilizer and is obtained using ammonia and carbon dioxide raw materials in the following reaction.

$$2NH_3 + CO_2 \rightarrow H_2N\text{-}CO\text{-}NH_2 + H_2O$$

The raw material ammonia is produced from the mixture of nitrogen and hydrogen in a catalyst-filled pressure reactor according to the reaction.

$$\tfrac{1}{2} N_2 + 3/2\, H_2 \rightarrow NH_3$$

N_2 is obtained from air by low temperature fractionation and Hydrogen is currently produced from fossil raw materials (Natural gas, Crude oil, and Coal) using the following reaction.

$$\text{Fossil raw material} + H_2O\ (\text{steam}) \rightarrow H_2 + CO$$

Carbon dioxide is obtained from carbon monoxide conversion which is a by product in the production of Hydrogen. Therefore, looking into the above reactions the main raw materials for the production of urea are fossil fuels (like natural gas) and water(~7000 cubic meter per hour for 760 ton per day urea production).

Critical factors for selection of a plant location

The selection of suitable location depend on critical factors such as,

- Raw-material supply
- Proximity to the market
- Availability of reliable and abundant water
- Infrastructural conditions
- Environmental aspects
- Socio-economic conditions
- Availability and quality of land
- Climatic conditions
- Equity of regional development

Critical factors for selection of a plant location in Ethiopian scenario

From the above listed important factors for consideration, environmental aspects, socio-economic conditions, availability and quality of land, and climatic conditions apply equally to all parts of Ethiopia, hence can not be used as a critical factors for the Ethiopian scenario. Equity of regional development should be considered separately by relevant decision makers and is disregarded from the set of critical factors. Therefore, the following factors are taken as critical for the selection of plant location in Ethiopia.

- Raw material supply (raw material transport)
- Proximity to the market (product transport)
- Availability of reliable and abundant water
- Infrastructural condition

SELECTION OF A PLANT LOCATION FOR THE PRODUCTION OF UREA

To decide on the location of the most appropriate site for the urea plant, specific regions are selected widely spaced about the country from Calub Gas Field. The distance from the Gas Field to the respective areas are taken following the existing all-weather road. Figure 1 shows specific regions pipline routing from the Gas Field. The suitability of these locations is analyzed based on the set of critical factors preselected in the proceeding section. The analysis is presented in Table 1. Availability of reliable and abundant water is one of the foremost critical factors, which helps in deciding on any considered location by a simple yes/no solution. It is simply a prerequisite for location consideration before any other comparison of the other variables is made.

From the above proposed locations Jigiga, Dire Dawa, Addis Ababa, Mekele and Nekemte are automatically rejected for lack of sufficient water. Jimma, Gambella, Bahir Dar and Kombolcha, though they have sufficient water, are dropped due to prohibitively long distance from the source of the raw material. Therefore, the following three locations remain for consideration:

1. Gode
2. Asasa
3. Metahara

Figure 1 Specific regions pipline routing from Gas Field, (.) All weather road, (———) Pipeline route

Table 1: Pre-selection of urea production plant location from specific Regions

Location	Distance from Calub (in Km)	Raw Material Transportation	Product Transportation	Water Availability	Infrastructure
Gode	120	G	P	Wabe Shebele	P
Jijiga	459	P	P	P	P
Dire Dawa	695	P	S	P	G
Asasa	700	P	L	Melka Wakena	S
Metahara	950	P	G	Awash	S
Addis Ababa	1200	P	G	P	G
Jimma	1161	P*	L	Gibe	G
Gambela	1586	P*	L	Baro	P
Bahir Dar	1650	P*	L	Tana	G
Mekele	1575	P*	L	P	G
Kombolcha	1373	P*	L	Borkena	S
Nekemte	1344	P*	L	P	S

Key: G = Good P = Poor S = Satisfactory
L = Locally limited P* = Poor & Very far from raw material location

RAW MATERIAL TRANSPORTATION AS CRITICAL FACTOR FOR UREA PLANT LOCATION

The main raw material for urea production is Calub Gas and is transported to the plant area by pipelines. Transporting gas by pipe is mainly a function of distance from the gas field, the diameter and thickness of the pipe. Gas pressure at the gas well head may not be the same as the plant and may require compression. Hence, raw material transportation by pipe involves the following costs:

- Pipeline investment cost
- Expansion cost
- Miscellaneous costs

a) Pipeline Investment Cost

All the pipeline would follow as much as possible the existing all weather road for two main reasons: easy access to construction and easy access to maintenance, control and security. The cost of a pipeline is a function of distance from the gas well head to the plant and it depends on the type of construction material, pipe line diameter, and wall thickness. To be accurate with the latest international cost, BEICIP-FRANLAB, pipeline investment costs for eight inch diameter have been taken for the three vicinities:

Gode ~ 120 Km.............................15,000,000 USD
Asasa ~ 700 Km .... 100,000,000 USD
Metahara ~ 950 Km .... 135,000,000 USD

b) Expansion Cost

The whole plant complex might not be installed at once. Due to various reasons expansion might be considered progressively which require the calculation of expansion costs. For example, for 100% capacity increase, one of the following alternative must be considered:

i) Either to install higher diameter pipeline which handles future expansion, or

ii) To install lower diameter pipeline with higher wall thickness which allows installation of booster stations during expansion in the later stage.

If the second option is considered, the number of boosters installed might not be different vary for Asasa and Metahara and the cost is estimated for three booster stations to be about 18,000,000 USD and for Gode one booster station costs 6,000,000 USD is used.

c) Miscellaneous Costs

Miscellaneous costs vary with distance and depend on the specific features of a project like cost of trouble shooting along the pipeline, safety supervision costs and pipeline operating cost, etc.. Again, these costs are taken from BEICIP and calculated for 20 years of project life. Table 2 shows the value of miscellaneous costs.

The final raw material transportation costs are summerized in Table 3. The raw material transport costs do not include compensations associated with the damages to farmers holdings and construction of new road during pipe laying . These costs definitely will escalate with distance.

Table 2: Miscellaneous costs

Location	Troubleshooting and safety on pipeline per project life ('000 USD)	Pipeline operating cost ('000 USD)	Total ('000 USD)
Gode	2000	650USD/yr *20 yrs = 13000	15,000
Asasa	10000	2900USD/yr *20 yrs=58000	68,000
Metahara	10000	3700USD/yr *20 yrs=74000	84,000

Table 3 Raw material transportation costs

Location	Pipeline Investment Cost in'000 USD	Expansion Cost in'000 USD	Miscellaneous Cost in'000 USD	Total in '000 USD
Gode	15,000	6,000	15,000	36,000
Asasa	100,000	18,000	68,000	186,000
Metahara	135,000	18,000	84,000	237,000

PRODUCT TRANSPORTATION AS A CRITICAL FACTOR FOR UREA PLANT LOCATION

The advantages of locating a plant near the market are obvious. However, availability of large amount of water, method of transporting raw materials, equity development etc., will have to be explored before any decision is taken to consider product transportation as a critical factor for plant location selection .

The main product in the process is solid urea. Most likely this product can be transported by truck. The 1998/1999 urea demand for the distribution center in three regions(which is 80 % of the total urea demand in the country) is taken as a basis (Table 4,5 and 6). The total urea demand in these three regions were 87,000 tons. Then the amounts of urea distribution to each center based on plant capacity of 250,000 ton per year is calculated:

$$\dot{Q}_{based\ on,250,000} = \frac{Demand}{87,000} \times 250,000$$

The ton- km of each distribution center is obtained by multiplying Q by the distance of each center.

Table 4: Fertilizer demand for the year 1998/99 by Zones and special Woredas and their ton - km from the three proposed plant location - **Amhara Region**

Market Center	Demand [ton]	$Q_{based\ on}$ 250,000 [ton]	Gode		Asasa		Metahara	
			Distance (km)	ton-km '000	Distance (km)	ton-km '000	Distance (km)	ton-km '000
Bahir Dar	5381	15,500	1469	22770	738	11439	786	12183
Debre Markos	9230	27,500	1205	33138	474	13035	522	14355
Gonder	2620	7,500	1644	12330	913	6848	961	7208
Debre Tabor	3029	8,750	1572	13755	841	7359	887	7761
Weldiya	1083	3,000	1427	4281	696	2088	744	2232
Dessie	3146	9,000	1307	11765	576	5184	624	5616
Debre Birhan	6930	20,000	1036	20720	305	6100	353	7060
Koso Ber	934	2,500	1366	3415	635	1588	683	1708
Kemise	89	250	1231	308	500	125	548	137
Others	3244	9,320			-	-	-	-
TOTAL	**35,686**	**103,250**		**122,480**		**53,766**		**58,260**

Table 5: Fertilizer demand for the year 1998/99 by Zones and special Woredas and their ton -km from the three proposed plant location - **Oromiya Region**

Market Center	Demand [ton]	Q based on 250,000 [ton]	Gode		Asasa		Metahara	
			Distance (km)	ton-km '000	Distance (km)	ton- km '000	Distance (km)	ton- km '000
Assela	2690	7750	-	-	-	-	202	1566
Goba-Robe	370	1075	491	528	266	286	468	503
Negelle	270	775	743	576	553	429	671	520
Harar	3340	9500	671	6375	505	4798	303	2879
Asbe Teferi	890	2500	871	2178	305	763	103	258
Metu	730	2100	1305	2741	725	1523	773	1623
Jimma	3000	8500	1051	8934	521	4429	569	4837
Nazareth	8400	24000	808	19392	77	1848	125	3000
Fitche	4010	11500	1022	11753	291	3347	339	3899
Ambo	7810	22500	1007	22658	300	6750	348	7830
Nekemte	3890	11250	1234	13883	503	5659	551	6199
Gimbi	1780	5000	1347	6735	616	3080	664	3320
TOTAL	**37,180**	**106,200**				**32,912**		**36,434**

Table 6: Fertilizer demand for the year 1998/99 by Zones and special Woredas and their ton - km from the three proposed plant location - **Southern Nations Nationalities and Peoples Region(SNNPR)**

Market Center	Demand [ton]	Q based on 250,000 [ton]	Gode		Asasa		Metahara	
			Distance (km)	ton- km '000	Distance (km)	ton- km '000	Distance (km)	ton- km '000
Hosaena	3266	9500	778	7391	339	3221	455	4323
Durame	3060	8750	743	6501	288	2520	490	4288
Welkite	3394	9750	905	8824	332	3237	380	3705
Sodo	3039	8750	801	7009	346	3028	460	4025
Awassa	967	2750	691	1900	236	649	350	963
Dila	122	350	777	272	322	113	436	153
Bonga	26	73	1151	84	1073	78	672	49
Mizan Teferi	44	128	1242	159	736	94	784	100
Jinka	49	140	1169	164	712	100	825	116
Sokoru	60	173	1134	196	441	76	489	85
Konso	20	58	1013	58	558	32	672	39
Kele	37	105	860	90	405	43	519	55
Soyema	27	78	912	71	457	36	571	45
TOTAL	**14,110**	**40,605**		**32,720**		**13,227**		**17,946**

From Table 4,5 and 6, the sum of the ton- km for Gode, Asasa and Matahara amounts 256,618 x 10^3, 99,905 x 10^3 and 112,640 x 10^3 ton- km respectively. The cost of product transportation from each plant location to the distribution center taking transportation cost at 0.46 Birr per ton - kilometer for 20 years of project life is calculated using the following rate and the result is summarized in &able 7.

$$\frac{1\$ \times 0.46 \mathrm{Birr}}{8 \mathrm{Birr.Ton.km.yr}} \times \mathrm{Ton.km} \times 20\mathrm{yr}$$

Table 7: Product transportation cost to the distribution center

Location	Product transportation cost in '000 USD
Gode	295,111
Asasa	114, 891
Metahara	129, 536

INFRASTRUCTURAL CONDITIONS AS A CRITICAL FACTOR FOR UREA PLANT LOCATION

Infrastructure is another factor in selecting the location of the plant. The most important considerations in evaluating infrastructural conditions are electricity, transportation, communication, living conditions, educational facilities and recreational facilities. These apply equally to all the three locations and therfore can not be considered as critical factors. However, the ammonia/urea plant involves heavy pieces of equipment (e.g. the ammonia /urea reactors weigh about 100 to 200 tons and length of 30 to 50 m). Figure 2 illustrates as an example stripper in urea process.

which is difficult to fulfil at the present Ethiopian situation.

- *Transporting the reactors by plane*: Large cargo carriers like Antonove or Hercules can be considered but requires an international standard airport near by the plant location which involve heavy investment.

- *Transporting the reactors by road*: It is an approprate alternative to Ethiopian conditions. Transporting such type of equipment require very long vehicles to distribute the axel load. To this end, there will be costs associated with river diversions, bridge reinforcement, sharp and turn-modifications and cost of specialized services to be deployed for the transportation of equipment from the port. The cost is expressed nsing the following relationship:

Figure 2 Stripper in urea process [9]

Bringing such type of equipment to the desired location in the country is a function of distance and involves heavy investment. There are a numbers of options which can tackle this problem :

- *Replacing one reactor by two reactors in parallel*: The result is feasible but would increase the cost of reactor and maintenance.

- *Delivering the reactors in two (or more) pieces and to reassemble them at site*: Such action requires an important bulk of material and equipment be transported at site to reassemble the reactors, proceed with welding operations which involve relatively sophisticated technique, stress relieving heat treatment, X-ray and other inspection action,

$$P = C_b \sum L_b + n_c C_c + G_x$$

where P = Total cost
C_b = Cost of bridge for meter length (~7000 USD)
L_b = Span of bridges
n_C = Number of culvert
C_C = Cost of one culvert(~7000 USD)
Gx = Costs of special services (e.g. management supervision service etc.) amounts to 1 MMUSD for each location.

Again, here one has to consider the difficulties which arise from lack of actual information from Ethiopian Road Authority (ERA).

Taking Djibouti as port of entry and assuming:

- Djibouti - Gode road has 250 span of bridges(L_b) and 100 culverts
- Djibouti - Asasa road has 2000 bridges (L_b) and 400 culverts
- Djibouti - Metahara road has 1200 bridges (L_b) and 300 culverts

Using the above relation, the equipment transportation costs can be determined which are summarized in Table 8.

Table 8: Equipment transportation cost

Location	Equipment transportation cost in '000 USD
Gode	2,925
Asasa	17,800
Metahara	11,850

CONCLUSIONS AND RECOMMENDATION

The costs of the critical factors which are considered in the selection of the appropriate plant location are summarized in Table 9.

The Dollar value analysis of the three locations favors Gode. However, it should be clear that the cost of product transportation is calculated only for the sake of showing the cost incurred due to establishing the factory in the particular area. The cost is not related directly to the cost of production. Product transport costs are borne by consumers. Since fertilizers are imported from abroad, transport costs from port to distribution centers are born by the farmers. Therefore, the competitiveness of local production will not be affected by this factor. Equipment transportation costs for such magnitude as mentioned earlier are a one time affair. It should be part of the costs involved due to the location of the factory. Hence, in reality the anticipated cost summary for the urea plant is illustrated in Table 10. Here, the Dollar value analysis of the three location is conclusively for Gode. This demonstrates transport cost of gas (pipeline installation cost) to alternative location is a dominant cost and put a significant impact on the choise of location. It implies, for the urea production using gas, the plant should be located near the source of the raw material like Gode.

Table 9: Cost summary involved due to urea plant location

Location	Raw material Transport Cost in '000 USD	Product Transport Cost in '000 USD	Equipment Transport Cost in '000 USD	Total Cost in '000 USD
Gode ~ 120 Km	36,000	295,111	2,925	334,036
Asasa ~700 Km	186,000	114,891	17,800	318,691
Metahara ~ 950 km	237,000	129,536	11,850	378,386

Table 10: Summary of anticipated cost involved due to urea plant location

Location	Raw material Transport Cost in '000 USD	Equipment Transport Cost in '000 USD	Total Cost in '000 USD
Gode ~ 120 Km	36,000	2,925	38,925
Asasa ~ 700 Km	186,000	17,800	203,800
Metahara ~ 950 km	237,000	11,830	248;830

To conclude, current supply of fertilizers is a dominant bottle neck in food self sufficiency. At the current rate of growth in fertilizer demand, Ethiopia will be affected by port and road infra structural congestion, if the import surpasses the million tons per year mark. This will hamper import and export activities of the nation. Therefore, establishing a local fertilizer plant from local raw material will alleviate both food security problems and enhance infra structural development of the nation. Generally, establishing a fertilizer plant in Ethiopia should not consider in terms of profitability only, rather the country should look it as a future strategy.

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