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Date 15th July 1992

Ext no 2494/2960

Metallurgical Industries Branch
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PO Box 300
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For the attention of Mr K Sato

Dear Sirs

Steelmaking for the Flat Products Project

We have pleasure in submitting our Final Report describing alternative ways of iron and steelmaking for the flat products project in Bang Saphan, Thailand. The Report has been prepared in accordance with the Terms of Reference issued by you in November 1991 but, because events have moved on in Thailand since the April 1991 seminar, the locational aspects of the work have required less emphasis than originally expected.

Our team have made two visits to Thailand. The first was in February of this year when the whole team collected information and visited the project site. After this we wrote our Draft Report. The Project Manager made the second visit to discuss this in Bangkok in June.

We were asked to include more information about tariffs and to include an executive summary. The political situation in Thailand during May delayed this second visit and hence the production of this report.

We have received considerable help from staff at the Ministry of Industry, Sahaviriya personnel, and others within the Thai steel industry and we should like to record our thanks to these people.

Yours faithfully
for and on behalf of
WS ATKINS INTERNATIONAL LIMITED

R A F Collins - Director

Atkins

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION

AND

THE GOVERNMENT OF THE KINGDOM OF THAILAND

STEELMAKING FOR THE FLAT PRODUCTS PROJECT

FINAL REPORT
DP/THA/87/021

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EXECUTIVE SUMMARY

Introduction

1. In 1989, the Thai Government issued a license to Sahaviriya Steel Industries (SSIC) to build a hot strip mill, cold mill and galvanising line. The present study examines alternative ways of integrating this project backwards to incorporate the production of iron and steel. The project is being developed at Bang Saphan, a coastal site situated about 400 km south of Bangkok. The strip mill and galvanising line are planned to come on stream at the end of 1993 and the cold mill should be commissioned at the end of 1997.

2. The original capacity of the strip mill was to be 1.8m tonnes per year and the cold mill 0.67m tonnes. As market growth in Thailand continues to be strong, these have now been revised to 2.5m tonnes and 1m tonnes repectively.

3. The forecasts for flat products consumption contained in the Master Plan Study have not been reviewed in detail but imports over the last three years confirm that the projected trends were broadly correct. Given those trends and the timing and size of the SSIC project, the report shows that, apart for a short period before the start up of the cold mill, there should be sufficient market opportunities to fill the larger capacities.

4. About 2.6m tonnes of slabs will be required to supply the hot strip mill at full production. The report has drawn up four proposals for meeting this demand for slabs but, in order to avoid underutilising two casting machines, each proposal is based on producing 2m tonnes of slabs only - on a single two-strand machine. The remaining slabs would be imported.

   The four options are as follows:

   - Electric arc steelmaking with all scrap charge;
   - Electric arc steelmaking with directly reduced iron;
   - Blast furnace ironmaking and BOF steelmaking;
   - Corex ironmaking and BOF steelmaking.

5. For each option, the report describes the technology that would be employed, the infrastructure requirements and their availability at Bang Saphan, the cost and economic performance and the impact on the environment.

6. The rates of return for each alternative have been calculated for a range of future slab prices. Currently the cif cost in Thailand would be about US$230. Because of the depressed market for steel and the overcapacity in the world market, this price is lower than that expected for the future. As a 'base case' it has been assumed that a long term trend price for slabs is about US$270.

Electric Arc Steelmaking with All Scrap Charge

7. This alternative would comprise two 175 tonne EAF's, operated with a 'hot heel', 2 scrap basket charges and foamy slag practice. Each furnace would have a ladle furnace to undertake refining and temperature control. Slabs would be cast on a single two strand casting machine.

8. Capital costs would be relatively low but large additional investments would be required to build a power station close to the site. It is estimated that this would need to have an installed capacity of about 1100 MW. This size is determined, not by energy requirements but by the strength needed within the overall electricity supply.

9. No additional investments would be required in the port as scrap would be handled over the berths currently planned for importing slabs. (If the power station was to be coal fired, then a bulk handling berth would need to be built.) This alternative would have only a minimal effect on the surrounding environment.

10. Importing large volumes of scrap would add to Thailand's dependence on this material at a time when trends in world steelmaking may make it more expensive. Currently there are also technical problems about producing some steel qualities from scrap although it is expected that these will be solved in the timescale envisaged for the works.

11. The rates of return generated by the project are low, ie about four percent in real terms at the US$270 slab price. This calculation excludes the cost of building the required power station.

Electric Arc Steelmaking with Directly Reduced Iron

12. The configuration for this option would be similar to the first one but would include in addition two Midrex 600 modules to make an annual quantity of 1.5m tonnes of DRI. The remaining feedstock would be provided by scrap arising within the works and small quantities of purchased scrap.

13. The requirements for a power station would be the same as above but in this case an extension to the port would also be needed.

14. The Midrex units would use gas as the reductant and so this alternative could only go ahead if a pipeline was routed northwards from Khanom.

15. With a gas price of US$3/MBTU, this alternative performs similarly to the scrap based option. That is, the real rate of return (excluding power and gas investments) is about three percent at the US$270 slab price.

Blast Furnace Ironmaking and BOF Steelmaking

16. This alternative comprises a single blast furnace, two basic oxygen furnaces, a sinter plant, coke ovens, and a casting machine. It is the most expensive option on the grounds of capital costs.

17. The port facilities would need to be expanded to provide a bulk handling berth capable of handling fully laden vessels of up to 150,000 dwt. A new power station would also be required but this would be considerably smaller than for the two previous options. It would have an installed capacity of about 350 MW.

18. The environmental impact of this alternative would be considerable. Coke ovens and sinter plants face ever more stringent regulations in industrialised countries but even so, there are still significant emissions to atmosphere.

19. The real rate of return at the US$270 slab price would be about six percent.

Corex Ironmaking and BOF Steelmaking

20. The Corex process was developed in the mid-1980's and the first commercial plant built at ISCOR, South Africa. It has operated well for a number of years. The process seperates the iron reduction and melting stages in two reactors and this allows a wide range of ordinary non-coking coals to be used.

21. The option consists of three 600,000 tonnes per year Corex units with two BOF's and a caster as in the previous option. This size of unit has not yet been commercially proven but will probably be available by the time it is considered for Bang Saphan.

22. It requires identical port and electricity facilities as in the blast furnace route but in this case the power station could be fed by gas generated as part of the Corex process. This gas could also be used by industry but a market must be found for it if the process economics are to be properly exploited.

23. As with the blast furnace option, the real rate of return is about six percent at the base case slab price. Because it requires neither sinter plant or coke ovens, however, it will be preferable on environmnetal grounds. It also has lower capital costs.

Bang Saphan

24. There is sufficient land already owned by SSIC to build any of the alternative steelmaking options.

25. Larger volumes of water will be required than currently being provided for the rolling mills. There are a number of options described in the report and the investments needed are not huge compared to cost of plant and equipment.

26. Road improvements are already planned for Highway 4 and these will assist the works in transporting products to markets. The majority of goods will however be transported by sea. There is an opportunity for the railways to carry cargoes as the line passes the SSIC site. In theory it should be able to provide a cheaper service than road if it can do so reliably.

27. Transport requirements specifically for steelmaking are small as both coal and ore will arrive by sea. A suitable local source of limestone, however, will be needed and an appropriate transportation method adopted.

28. SSIC have tentative plans for a second hot strip mill. This would require a strengthening of the grid before it could be built. This would almost certainly mean installing additional capacity in the region.

29. The Bang Saphan site may attract other users in time, particularly those who will be significant customers of the steel mill. It would be of benefit to Thailand if SSIC and the Industrial Estates Authority could work together to develop the area.

Conclusions

30. SSIC do not currently plan to make steel at Bang Saphan. They beieve it will be cheaper to import slabs for the foreseeable future. This decision would appear to be confirmed by the analysis presented in the report. In this case, the challenge for SSIC will be to obtain a reliable source of slabs at reasonable prices and with a good range of qualities.

31. In the longer term there is really no reason why Thailand should not be able to compete on cost grounds with other producers in South East Asia. Bang Sapahan has deep enough water to reap most of the economies of scale available in transporting raw materials. Only gas is available at significantly cheaper prices in nearby countries.

32. There are private companies building steelworks but it is still rare to find them contemplating projects of this size and scale. Usually Governments are more involved than the Government wishes to be in Thailand. It has to be said, however, that in many cases such steelworks have not made adequate financial returns.

33. It is also true that even if the Government paid for all infrastructure (ie the port expansion, gas pipeline, power station and water supply) this would probably not of itself make steelmaking profitable in private sector terms.

34. Bang Saphan is an isolated site, situated a long way from other significant industrial areas. This shows itself particularly in the weakness of the electricity system available. Moving the steelmaking operations to the Eastern Seaboard would not however yield cost reductions. The size of ships used for bringing in raw materials would be smaller and the slabs would still have to be transported by sea to Bang Saphan. It would only have been worth considering this option if electric steelmaking showed itself to be a lot more profitable than oxygen steelmaking but this has not been the case.

35. The current tariffs for flat products, particularly for cold rolled steel, need to be revised to bring them into line with other steel products. The report shows tariff levels in other Asian countries and elsewhere. Most countries apply a rate of duty of up to 10% on hot and cold rolled products. The tariff for Thailand may have to be higher than this in the early years of the SSIC project and decisions on the appropriate level of tariffs should be made as soon as possible so that all those affected, both consumers and SSIC, can plan accordingly.

36. The report lists a number of things that Government departments can do if they wish to assist SSIC to achieve its goals in the short term.

1. INTRODUCTION

Terms of Reference

1.1 A Master Plan Study for the iron and steel industry was commissioned by UNIDO and the Thai Ministry of Industry in 1989. Discussions were held concerning the plan at a special seminar held in Bangkok on 18th April 1991. Following these discussions, a further area of work was identified, namely a detailed techno-economic analysis of the technology, location and environmental impact of the integrated steel plant for producing flat products. In the event, the location of the plant is now fixed. The site at Bang Saphan is under active development and a hot strip mill is expected to be completed by the end of 1993. An electro-galvanising line will also be commissioned at this time and, at a later stage, a cold mill will be added.

1.2 This report describes some alternative ways of integrating backwards from the planned development in order to produce liquid steel for the continuous casting of slabs.

The Master Plan Study

1.3 The Study was undertaken during the period November 1989 to May 1990. At this time, the licence for the new flat products project had just been awarded. Thailand had tinning and galvanising lines but no rolling or steelmaking facilities for flat products. Overall consumption of this type of steel was about 2.3m tonnes, all of which was imported.

1.4 It was envisaged that the market for flat rolled strip would grow rapidly and would reach more than 5m tonnes by the year 2000. In response to this growth, it was recommended that the capacity of the hot strip mill should be increased from 1.8m tonnes to 3m tonnes. This would still leave excess requirements to be imported and further developments were suggested for implementation after the moratorium period of the licence was over.

1.5 The Study looked at a number of possible locations for the new project and it was felt that Map Ta Phut on the Eastern Seaboard was the most appropriate site. Since then the decision has been taken to build the plant at Bang Saphan on the western coast.

1.6 Based on prices and costs prevailing at that time, it was calculated that the full project (ie rolling and steelmaking) would earn a real rate of return of about 9% with no tariff protection. At the rate of import duties prevailing at the time, the return increased to about 12%.

The Market for Flat Steel

1.7 The Master Plan forecasts for consumption in the year 2000 were 2.7m tonnes of hot rolled flat products and 2.5m tonnes of cold rolled flat products. Table 1.1 sets out the forecast and actual consumptions. It can be seen that the consumption of cold rolled products is still closely in line with the forecast, but that there has been a faster than expected growth of hot-rolled imports.

TABLE 1.1. - MASTERPLAN FORECASTS AND ACTUAL CONSUMPTION

Product	1988 (actual)	1991 (actual)	1991 (forecast)	1995 (forecast)	2000 (forecast)
Hot rolled coil	1,262	1,900	1,631	2,147	2,712
Cold rolled coil	420	580	564	767	1,027
CR - coated	698	885	865	1,114	1,468
Total CR coil	1,118	1,465	1,429	1,881	2,495

Annual growth rates	Actual 1988 - actual 1991	Actual 1988 - forecast 2000(a)
Hot rolled coil	14.6%	6.6%
Cold rolled coil	11.5%	7.7%
Cold rolled coated products	8.2%	6.4%

(a) These forecasts contained higher growth rates in the earlier years than the later ones. The quoted rates are averaged out over the period

1.8 One emerging industry using hot rolled steel is that of making transport containers. Several new production lines have come on stream since the Master Plan Report. There is also considerable optimism concerning the market for welded fabricated beams and columns. A change in construction methods is expected - moving away from reinforced concrete construction in high rise buildings and towards structural steel. This is certainly the experience in other countries.

1.9 Not too much should be read into figures for just the three most recent years, but they do indicate that, so far, the forecasts do not need to be drastically revised although they are possibly on the low side for hot rolled products. Economic growth forecasts have been trimmed a little since 1989/90, but those used in the Study for the remainder of the century would still be considered reasonable by many economists in Thailand, at least until the events of May 1992.

1.10 If the forecasts for the year 2000 still remain valid, the implications for imports at that time are shown in Figure 1.1. Two assumptions are made concerning the eventual output of the flat products project; firstly that it produces according to the licensed capacities, and secondly that it is able to produce 2.5m tonnes of hot rolled steel and 1.0m tonnes of cold rolled, as currently proposed by its owners. In either case, considerable volumes of imports are anticipated. In the short term, however, until the cold mill is in production there will be excess hot rolling capacity. Figure 1.2 shows the importance of completing the cold mill on time.

Progress of the Flat Products Project

1.11 The project is being developed by Sahaviriya Steel Industries Co. (SSIC). This is a consortium of both Thai companies and banks and foreign investors. They are building the hot strip mill themselves and have entered into a joint-venture with the Japanese firm, NKK, to build the electro-galvanising line. Partners for the cold mill have not yet been selected but the licence agreement allows for more time before this part of the project is brought on stream.

1.12 The site at Bang Saphan has been prepared and piling has started for the hot strip mill. The equipment is on order from an Italian supplier and delivery is expected to start in the second half of this year. First production is due in November 1993, about three months before the date set out in the licence agreement.

1.13 For the electro-galvanising line, civil works on the site are under way and the equipment will be delivered in early 1993. It will be installed by October 1993 and the line will open at the end of that year.

1.14 There are three important infrastructure requirements that need to proceed in parallel with the installation of plant and equipment.

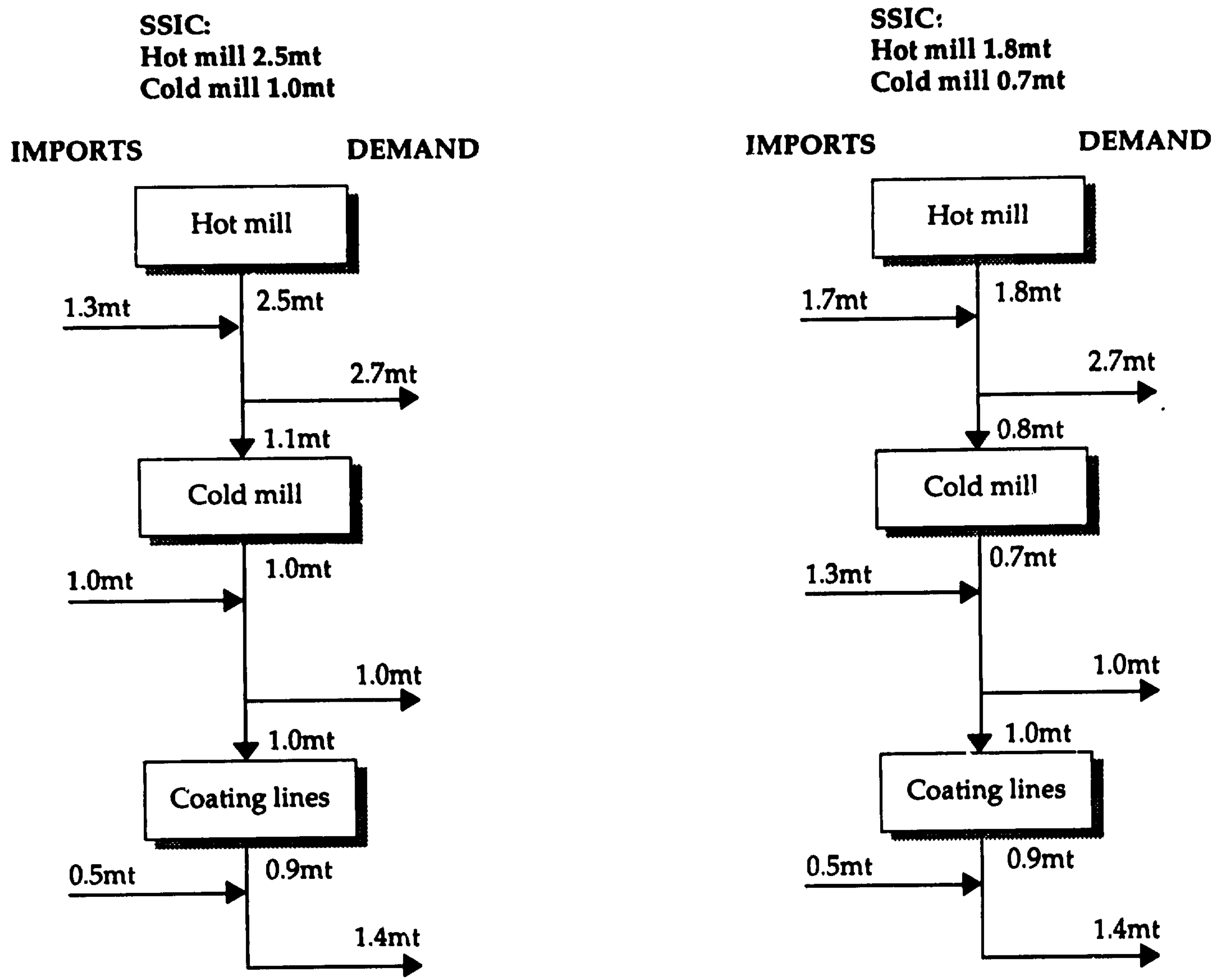

Figure 1.1 Thai production and imports in the year 2000 - according to masterplan forecasts

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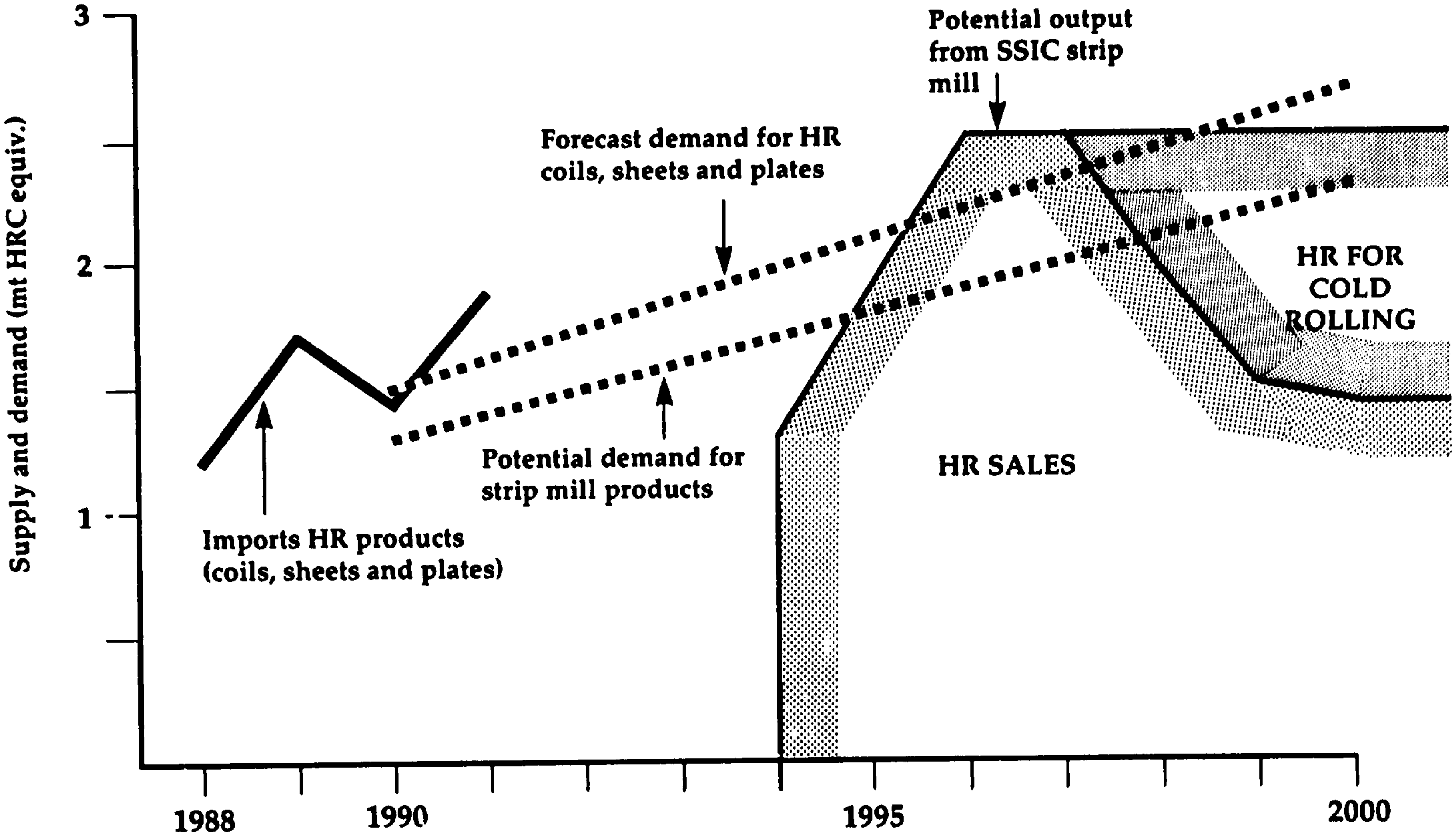

Notes: Demand forecast as in Master Plan
Supply assumes SSIC start up hot mill 1994, cold mill 1998

Figure 1.2 Supply and demand for hot rolled coil

1.15 Water is being obtained from a nearby weir on the Bang Saphan river. Sufficient water can be extracted from this river but its availability is seasonal. This has required the building of large reservoirs at the site accommodating sufficient storage for about six months consumption.

1.16 Electricity will be supplied by EGAT from its 230kV and 115kV transmission lines connecting Prachuap Kiri Khan and Surat Thani. There is concern within SSIC that their needs will be adequately met and they have invested in a synchronous voltage controller to minimise the detrimental effects of voltage fluctuations.

1.17 A port is being constructed to handle imported slabs and cold rolled coil and outgoing hot rolled coil and galvanised products. Hydraulic studies have been undertaken and tenders for port construction are currently being evaluated. It is hoped that an eighteen month construction period will be sufficient and that the port will be operational by the end of 1993. A temporary jetty will be constructed to bring in plant and equipment.

1.18 SSIC currently do not expect to integrate backwards into steelmaking at the Bang Saphan site. They believe that there will be environmental problems in doing so but, more importantly, they believe that it will be more economic for them to buy slabs from existing producers. Slab prices are very low at the moment and there is considerable excess capacity in the steel industry worldwide.

1.19 Space has been allocated at the site for the construction of a second hot strip mill. This does not yet have Government approval and in considering steelmaking options in this report, only the production of slabs for the first mill are taken into account. In Section 3, however, consideration is given to the infrastructure requirements of the second mill as well as those for making slabs for the first one.

2. OPTIONS FOR BACKWARD INTEGRATION OF THE SSIC FLAT PRODUCTS COMPLEX

2.1 The planned SSIC development comprises a hot strip mill (HSM) of 2.5M tpa rated capacity, with a current BOI licence for 1.8M tonnes production, and an electro-galvanising line (EGL), with a current BOI licence for 135,000 tonnes. Both these facilities are scheduled to commence production by February 1994.

2.2 The HSM will import mainly low carbon steel slabs of 1,000 to 1,550mm width x 200 to 250mm thickness and up to 30 tonnes weight, and roll them into coils of 650 to 1,550mm width x 1.2 to 12mm thickness, including about 1.2M tonnes of light gauge coils.

2.3 The EGL will import 15 tonne coils from Japan, and produce coils (average 3 tonnes weight) of electro-galvanised strip with both sides coated (average coating thickness 20gms/m^2).

2.4 In addition, SSIC has a BOI licence for a 700,000 tpa cold mill (CM) facility, but its product range has still to be fixed.

2.5 Ultimately, SSIC intend applying to extend their licences to allow the HSM to achieve its rated capacity of 2.5M tonnes, the EGL to increase production to 180,000 tonnes, and the CM to increase production to 1M tonnes. The site layout also has provision for the possible future installation of a second HSM.

2.6 To achieve its rated production of 2.5 million tonnes per annum of hot rolled coils, the SSIC hot strip mill will require a feedstock of 2.6 million tonnes of slabs, assuming a yield of 96 percent. Slabs will comprise 2.5m tonnes of low carbon steel grades and 100,000 tonnes of stainless steel grades.

2.7 Due to technical and economic restraints, it is not normal practice for steelshops producing low and medium carbon steel grades to also produce stainless steels. Consequently, any stainless steel slabs requirement are assumed to be imported.

2.8 Since Thailand does not currently have any indigenous sources of high grade iron ores, any iron oxide requirements for ironmaking would need to be imported.

2.9 For fuel and reductant requirements, Thailand possesses only natural gas and lignite. A gas pipeline to the southern seaboard is currently being planned, which would initially supply natural gas to Khanom, and subsequently may be routed northwards to Bang Saphan and beyond. The nearest lignite source is at Amphoe Khian Sa to the south of Surat Thani, but this lignite has very high sulphur levels which make it unsuitable for iron or steelmaking.

2.10 Coking and steam coals are not available indigenously, and would need to be imported.

Steelmaking Options

2.11 To provide the large annual steel requirements of the SSIC flat products complex, four commercially proven process options have been considered, these are:

(i) electrical arc furnace (EAF) steelmaking with all steel scrap charge.

(ii) gas based direct reduced iron (DRI) plant plus EAF steelmaking.

(iii) blast furnace (BF) plus basic oxygen furnace (BOF) steelmaking.

(iv) COREX plant plus BOF steelmaking.

2.12 Except for the last of these options (COREX), all the processes are commercially proven for the level of production needed for the SSIC complex. COREX has commercially proven its 300,000 tonnes per annum furnace at the ISCOR, Pretoria works, Republic of South Africa, but is still developing a 600,000 tpa unit, which would be a more suitable size for the planned SSIC production.

2.13 Other process options, including coal based rotary kilns for direct reduced iron production, COMBISMELT, energy optimisation furnace, plasma arc furnaces etc have not been considered. These either have limited production capacities, or are not commercially proven at the level of production planned for the SSIC complex.

Option 1 - EAF Steelmaking with All Scrap Charge

2.14 The annual requirement of slabs for the hot strip mill at maximum production is 2.6 million tonnes, including 100,000 tonnes of imported stainless steel slabs. If the 2.5 million tonnes of low carbon steel slabs were produced within the steelworks, it would require the installation of two - 2 strand slab casting machines. However, a better economic solution would be to install a single 2 strand slab casting machine, which would have a capacity of about 2 million tonnes, and to import the surplus requirement of slabs. This arrangement has been adopted in each alternative.

2.15 Steelmaking would be undertaken in two 175 tonnes capacity ultra high power EAF's equipped with 140 MVA transformers, and oxy-fuel burners to ensure rapid scrap meltdown. The EAF's would be operated with a 'hot heel', 2 scrap basket charges and foamy slag practice, which allows short tap-to-tap cycle times of about 70 minutes and enables low power and electrodes consumptions to be achieved.

2.16 Each EAF would have a ladle furnace equipped with a 30 MVA transformer, to undertake steel refining and casting temperature adjustment. The installation of ladle furnaces provides a buffer between the steelmaking and casting operations, and considerably assists in sequence casting, ensuring high levels of slab production are achieved.

2.17 A rotary kiln would calcine locally quarried limestone to provide the burnt lime requirements for steelmaking.

2.18 Figure 2.1 shows the materials balance for Option 1 - All Scrap Charge EAF Steelmaking.

2.19 It can be seen from this materials balance that the principal incoming supplies through the port are 2,065,000 tonnes of steel scrap and 600,000 tonnes of slabs, including 100,000 tonnes of stainless steel slabs.

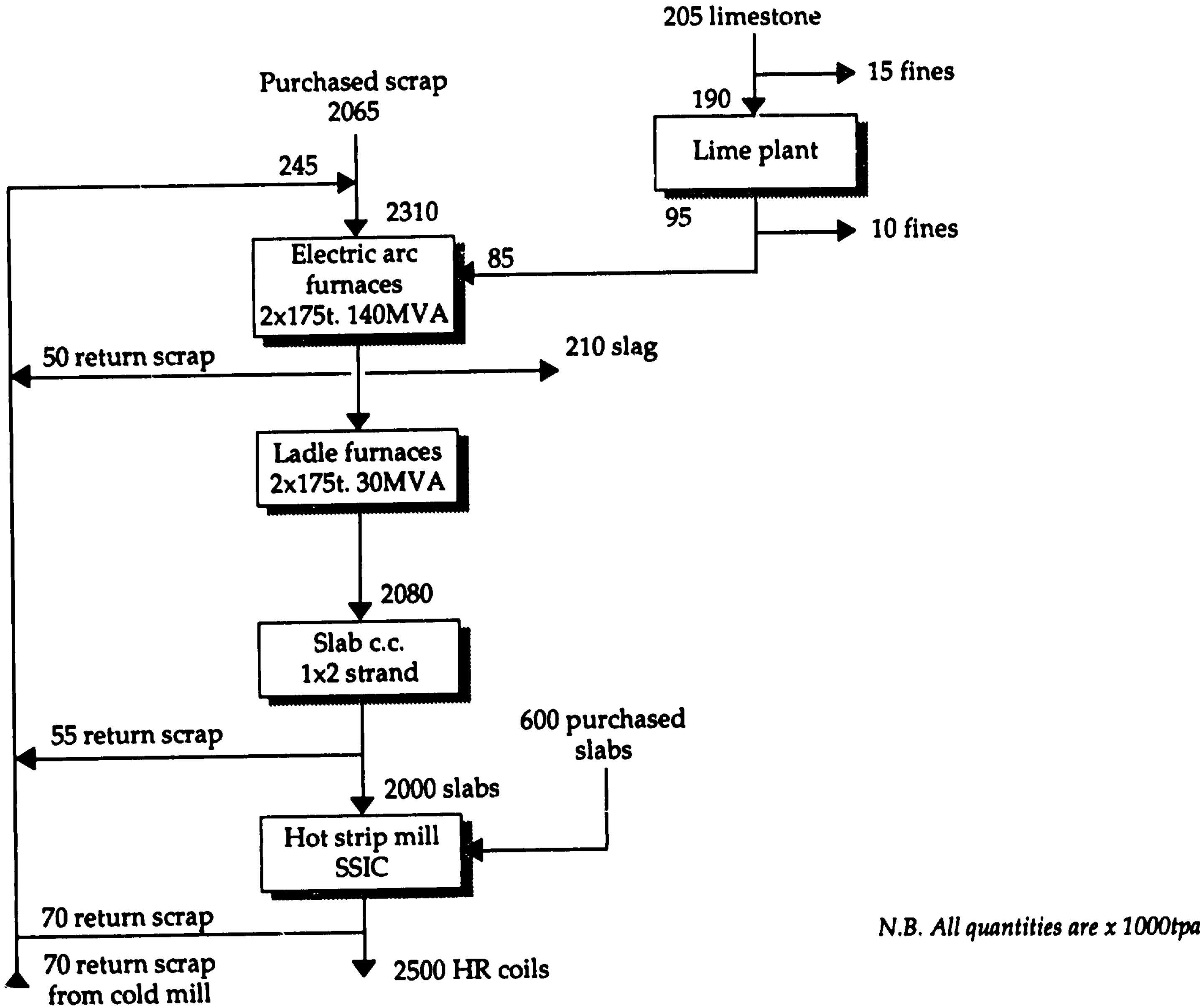

Figure 2.1 **Option 1 - All scrap charge EAF**

Option 2 - DRI plus EAF Steelmaking

2.20 The steelmaking and slab casting facilities would be similar to Option 1, and only the constituents of the EAF charges would be different.

2.21 When producing steel from DRI and steel scrap charges, the EAF's are operated with a 'hot heel' into which the steel scrap charge is melted, with the DRI subsequently fed continuously into the molten bath. This operating practice allows the EAF's to achieve short tap-to-tap cycle times of 60 to 70 minutes. A charge practice of 70 percent DRI and 30 percent steel scrap gives a production rate similar to all scrap melting operations.

2.22 If such a practice were adopted for the SSIC development, the steelmaking furnaces would require annually 600,000 tonnes of steel scrap and 1.8 million tonnes of DRI.

2.23 Using the proven Midrex 600 modules for DRI production, and operating them on a charge comprising 80 percent oxide pellets and 20 percent lump ore, both of 67 percent Fe and low gange content, an annual production of 750,000 tonnes per module has been achieved at many plants around the world. Thus, 3 modules would need to be installed to produce 1.8 million tonnes, but with each module only operating at 80 percent of its rated capacity. Alternatively, if all the modules are operated at their rated capacity, 450,000 tonnes of DRI surplus to the flat products complex requirements would have to be sold externally.

2.24 Option 2 is based on an economically preferred solution which involves installing 2-600 modules operating at their rated capacities, i.e. a total annual production of 1.5 million tonnes of DRI, and completing the steelmaking metallic charge requirement with works arising and purchased steel scrap. This will result in the EAF's being operated with a charge comprising 63 percent DRI and 37 percent steel scrap.

2.25 It is proposed that hot briquetted iron (HBI) is produced, since it is attractive to steelmakers being a low residual metallic raw material, and combines all the advantages of DRI plus the physical advantage of higher density, and is non-pyrophoric. These physical advantages give benefits to steelmaking operations, and make HBI suitable for merchant shipments, since it can be readily handled, shipped and stored in all types of weather.

2.26 Figure 2.2 shows the materials balance for Option 2 - DRI plus EAF Steelmaking.

2.27 It can be seen from this material balance that the principal supplies through the port are 460,000 tonnes of lump ore, 1.84 million tonnes of oxide pellets and 600,000 tonnes of slabs.

Option 3 - Blast Furnace plus Basic Oxygen Furnace Steelmaking

2.28 Slab casting facilities would be similar to the EAF steelmaking options, ie. a single 2 strand slab casting machine having a capacity of about 2 million tonnes, with surplus slab requirements being imported.

2.29 Steelmaking would be undertaken in two 210 tonnes capacity basic oxygen furnaces equipped with top and bottom oxygen blowing. Each BOF would have its own ladle furnace equipped with a 40MVA transformer for steel refining and casting temperature adjustment.

2.30 The BOF's would be charged with about 89 percent hot metal and 11 percent works arising scrap.

2.31 The annual requirement of hot metal would be produced in a 5,700 tonnes per day rated capacity blast furnace, having a hearth diameter of 12 metres and working volume of 2,600m^3. The BF would operate at high top pressure and be equipped with coal injection through the tuyeres to reduce the coke rate. Assumed fuel rate is 500 kgs/tonne hot metal, comprising a pulverised coal injection rate of 150 kgs and 350 kgs of charged coke. The BF has been assumed to operate on a charge comprising 90 percent sinter and 10 percent lump ore.

2.32 The annual sinter requirement of 3.4 million tonnes would be produced on a continuous strand sinter machine of 342m^2 effective grate area ie. 76 metres long x 4.5 metres wide strand, equipped with a circular pressure type cooler. The assumed grate production rate is 30 tonnes/m^2 of grate/day. The sinter plant has been assumed to be operated with imported 62 percent Fe oxide fines and 50kgs of coke breeze per tonne sinter.

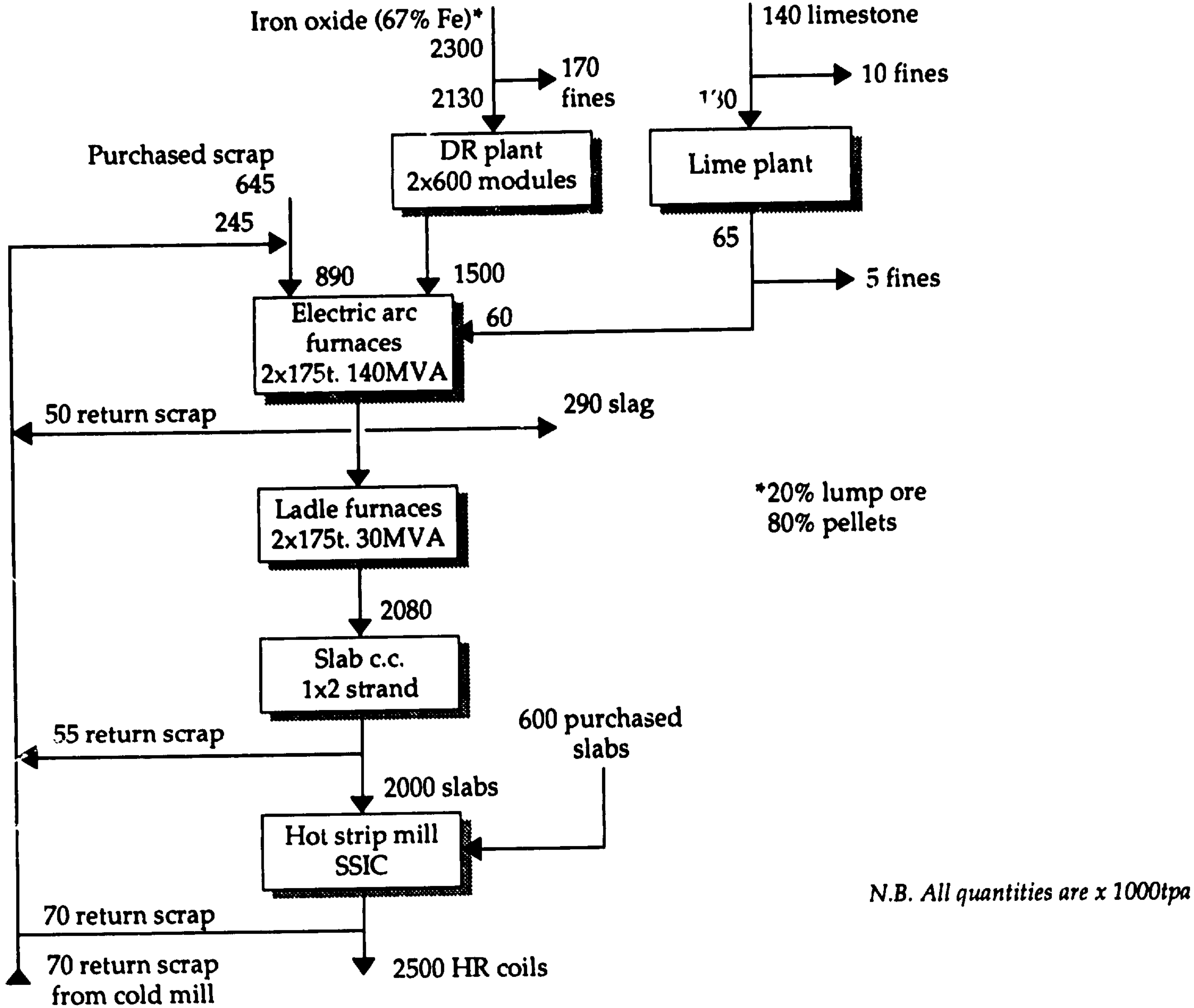

Figure 2.2 **Option 2 - DRI and EAF steelmaking**

2.33 Three batteries of 29 coke ovens of 6.25 metres height would be used to carbonise the imported coking coal to produce 700,000 tonnes of sized coke for the blast furnace, and 210,000 tonnes of coke breeze for the sinter plant and external sales. The coke ovens would be fired by a mixture of coke oven gas and blast furnace gas.

2.34 A by-product plant would be used to remove tar, ammonia, benzole and naphthalene from the coke oven gas before its re-use within the works.

2.35 Figure 2.3 shows the materials balance for Option 3 - Blast Furnace plus BOF Steelmaking.

2.36 It can be seen from this material balance that the principal supplies through the port are 3 million tonnes of oxide fines, 350,000 tonnes of lump ore, 1.3 million tonnes of coking coal and 600,000 tonnes of slabs.

Option 4 - COREX plus Basic Oxygen Furnace Steelmaking

2.37 During the mid 1980's the COREX process was introduced by the West German firm of Korf, in association with Deutsche Voest Alpine (DVA), to compete with the traditional blast furnace in the production of hot metal.

2.38 The first commercial COREX plant with a rated capacity of 300,000 tonnes per annum was installed at the ISCOR, Pretoria works in the Republic of South Africa. This plant has been in operation for over 4 years, and has exceeded its rated capacity with daily production of over 1000 tonnes. ISCOR have achieved production rates of up to 47 tph when operating with lump ore of over 62 percent Fe, and 53 tph with 67 percent Fe oxide pellets.

2.39 The COREX process separates the iron ore reduction and melting stages into two reactors. Generation of reducing gas and the liberation of the energy from coal for melting occur in a melter gasifier, and reduction of the iron ore in a shaft furnace. Because of this separation, a wide variety of untreated coals (ie. non-coking quality) can be used.

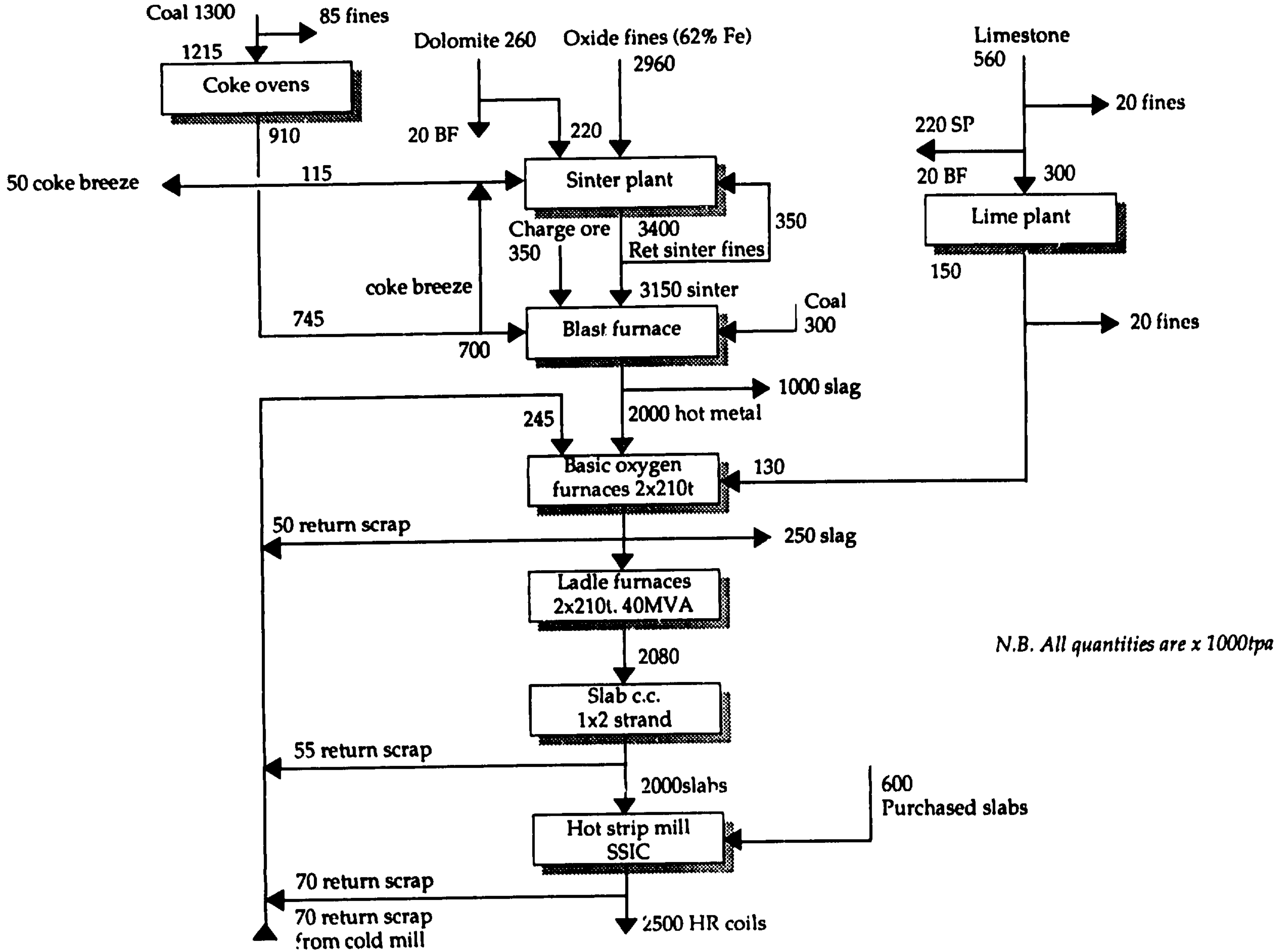

Figure 2.3 **Option 3 - Blast furnace and BOF steelmaking**

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2.40 The most important property of the coal used in the process is its volatile content, which determines the gasification temperature. Low-volatile coals generate a high temperature when gasified with oxygen, releasing energy for melting the sponge iron. High-volatile coals, such as lignite, result in a low temperature, since the volatile hydrocarbons must be cracked before gasification can occur. Therefore, if they are to be utilised, such coals must be mixed with anthracite, low-volatile bituminous coal, charcoal or coke breeze.

2.41 The COREX plant at ISCOR uses a shaft furnace based on the Midrex 400 module design, which produces over 400,000 tonnes per annum of DRI of over 92 percent metallisation, and charges it directly through the melter gasifier roof located immediately beneath it. Coal and limestone are also charged separately into the top of the melter gasifier.

2.42 Reducing gas is generated in a fluidised bed by partial oxidation of the coal. After leaving the melter gasifier, the hot raw gas is mixed with cooling gas, cleaned in hot cyclones and either fed to the shaft furnace as reducing gas, or delivered as export gas to other consumers.

2.43 Coal consumption depends on coal quality and is in the range of 0.5 to 0.7 tonne C fixed per tonne of hot metal.

2.44 Depending on the coal composition and quality, the specific oxygen consumption is 500 to 600 Nm^3/tonne of hot metal, and the energy requirement for this oxygen production is about one third of the excess process gas produced.

2.45 When a high volatile bituminous coal is used, an export gas production of about 1,800 Nm^3/tonne hot metal, with a nett calorific value of about 7,300kJ/Nm^3 is produced.

2.46 This surplus gas can be used for:

- heating the HSM furnaces
- power generation (including the oxygen plant power requirements for the COREX process)

2.47 Deutsche Voest Alpine are currently developing a 600,000 tpa rated capacity plant, which would utilise a Midrex 600 module shaft furnace. This size of plant would be more suitable for the proposed steelmaking development, since it would only require several units to produce the hot metal requirements.

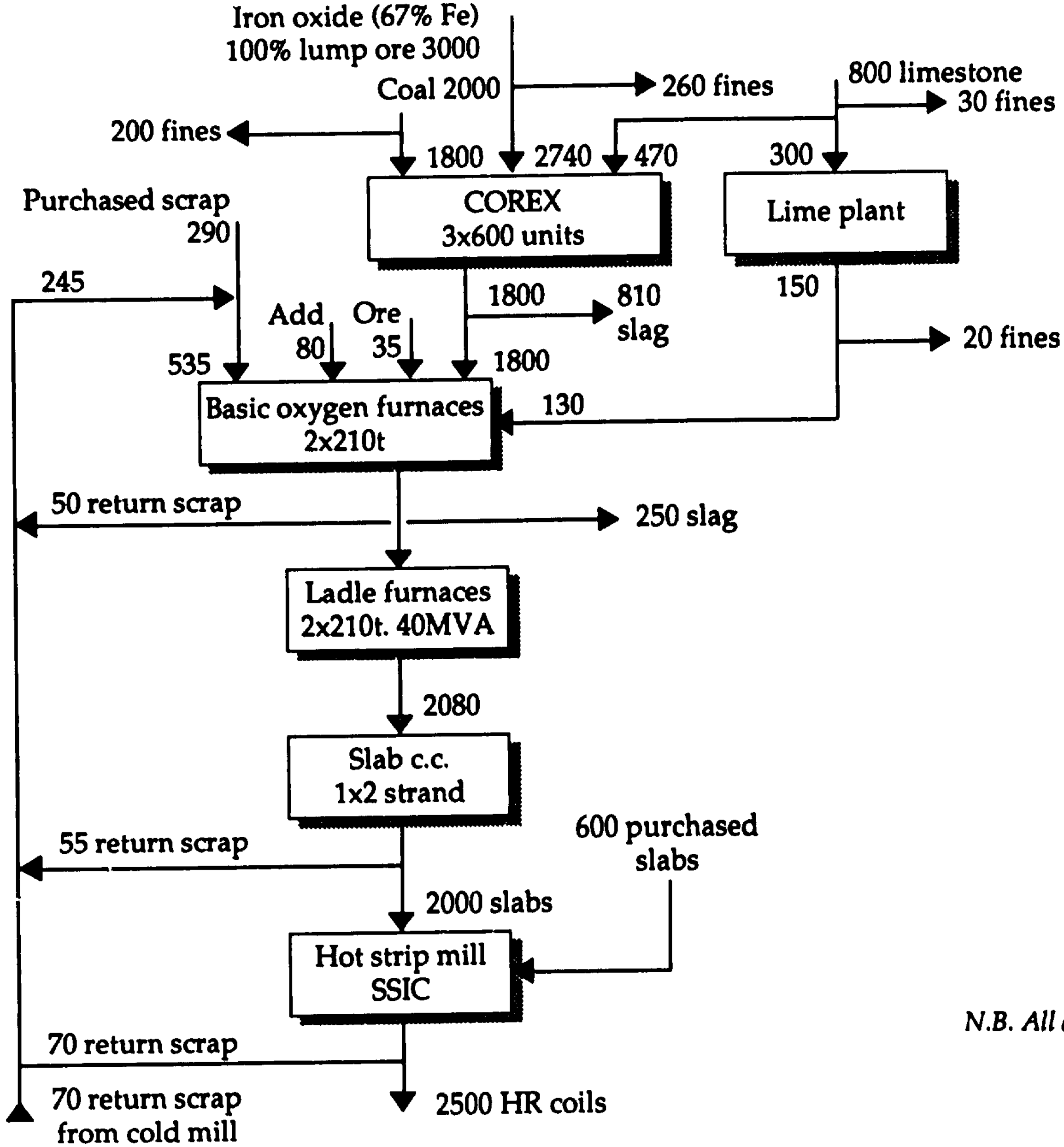
2.48 Option 4 is based on installing three - 600,000 tpa COREX furnaces to produce an annual hot metal production of 1.8 million tonnes, and completing the steelmaking metallic charge requirement with works arising and purchased steel scrap. This will result in the BOF's being operated with a charge comprising 77 percent hot metal and 23 percent steel scrap.

2.49 The steelmaking and slab casting facilities would be similar to Option 3.

2.50 Figure 2.4 shows the materials balance for Option 4 - COREX plus BOF steelmaking.

2.51 It can be seen from this materials balance that the principal supplies through the port are 3 million tonnes of lump ore, 2 million tonnes of bituminous coal and 600,000 tonnes of slabs.

2.52 Each of these alternative process routes for making slabs are evaluated in Section 5 and 6.



N.B. All quantities are x 1000tpa

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Figure 2.4 Option 4 - COREX and BOF steelmaking

3. INFRASTRUCTURE FOR STEELMAKING

3.1 This section describes the way infrastructure could be provided at Bang Saphan. Comments are made in terms of SSIC's current development, its proposed second strip mill, and the steelmaking alternatives set out in section 2. figure 3.0 shows a map of the area around the project.

Land

3.2 Suitable land for steel industry development is located at Bang Saphan in the 2-3km wide coastal strip between the shore and the single track railway to Chumpon. The area is at present generally occupied by coconut plantations, paddy fields and fishmeal processing factories, with some low-lying swampy areas which are not cultivated.

3.3 The ESTS Feasibility Study (1982 & 1984) identified Bang Saphan as a good site for an integrated steelworks. The Sahaviriya Group (SSIC), has purchased land in this area and is constructing a hot strip mill, cold mill and electro-galvanising line. SSIC's long term plan includes a second hot strip mill situated parallel to the first unit though this has yet to be approved by Government. They do not at present have any plans for producing their own steel, and the hot strip mill layout has not been arranged to suit direct rolling of slabs made at an adjacent steelmaking plant.

3.4 The complex is 5km north west of Laem Mae Ramphung and occupies an overall area of about 1500 rai (240 hectares). A 4km long road and service corridor will connect the steel plant to the port. This will require some 300 rai (4000m x 120m) and land will also be needed in the port area, say another 700 rai - a total requirement of 2500 rai (400 ha).

3.5 The Consultants were informed that SSIC currently owns 6000 - 7000 rai and is buying up small adjoining plots from local farmers and other landowners.

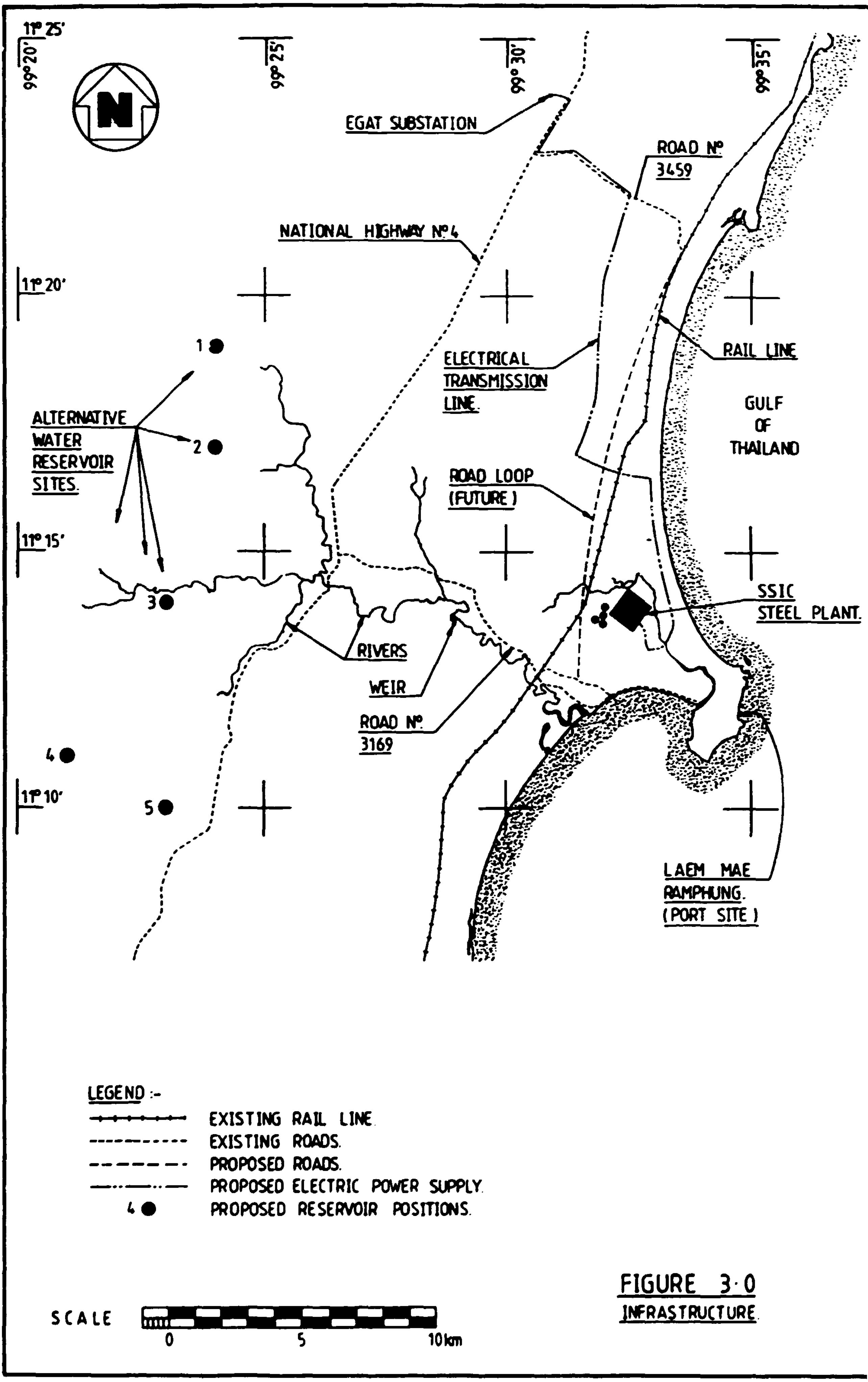


FIGURE 3·0
INFRASTRUCTURE

Future development

3.6 Land which is suitable for steel works expansion is located mainly to the north of the SSIC development, but there is also land available to the south west. Land adjoining the first phase development is swampy and not utilised but further north the land is occupied by coconut plantations. The level of the low-lying land will need to be raised 2-3m by placing fill material, as has already been done for the hot strip mill. A total area of 10,000 rai (1600 ha) could in principle be used for the steel industry. This would involve some land acquisition, clearance of a few coconut plantations and resettlement of a small number of persons.

3.7 The blast furnace option would require the most land but even in this case the total requirement would be about 4000 rai. There is, therefore, sufficient land at Bang Saphan for any of the options.

Electricity

First phase SSIC works development

3.8 The works at Bang Saphan will currently be supplied by a single 115 kV transmission line, capable of supplying the required load for the first development phase, ie. electrolytic galvanising line, hot strip mill and cold rolling mill. The maximum/peak demand being about 160 MVA.

3.9 The works supply will be from the (Bang Saphan) main grid substation located 27 km north-west of the steelworks site. This substation is under construction but will no be completed before commissioning of the works first production units, and consequently a temporary arrangement will be in operation during the start-up phase.

3.10 This grid substation will switch twin 230 kV and twin 115kV transmission lines running North - South and connecting Bangkok with Surat Thani, each line being 400 MVA capacity. The substation will be able to interconnect the lines to ensure adequate security and power availability to the steelworks initially and in the future, subject to sufficient generating capacity being available for connection.

3.11 For a modern steelworks the connected supply must be a strong and stable one, to minimise voltage disturbances caused by the peaky nature of the steelworks electrical load. This is reflected as a high short circuit fault level of the system and is a complex function of the amount of generation capacity connected and the length of the transmission line to the works.

3.12 With the above mentioned temporary supply arrangement it is reported that the short circuit fault level will be particularly low initially (411MVA), which may cause operating difficulties with the hot strip mill. To limit voltage drop, caused by peak loading on the supply, it may be necessary for production to be limited to one slab at a time in the mill. The fault level will increase (886 MVA) when the Bang Saphan substation is available in March 1994 which will improve the situation. However it is understood that 1200 MVA is the desired fault level and this may be attained from increased strength for the system as generating capacity becomes available for connection in the future. The strip mill is arranged with a SVC (synchronous voltage compensator) which will assist voltage stability by counteracting a measure of reactive power swing caused by the mill, but it's actual performance remains to be established.

Second phase development - hot strip mill No. 2

3.13 If a second hot strip mill development were to be considered, instead of the steelmaking integration, the necessary strength of the supply would be determined in the light of operating experience of the first mill. With a suitable SVC operation it may be possible to operate both mills at about the 1200 MVA fault levels. However about 2000 MVA should be considered a desirable minimum supported, with a local power station.

Full development - integrated steelworks

3.14 The four process options described in Section 2 each have a different electrical load characteristic. These are summarised in the table below and totalised with the phase 1 load of 500Gwh, 160 MW, to show the overall supply requirement.

TABLE 3.1 - ELECTRICITY DEMAND

Option	Plant	Energy Gwh/year	Max 15 min demand MWe	Total Gwh/year	Phase 1 and 2 MWe
1	Scrap/EAF	1,490	215	1,990	320
2	DRI/EAF	1,740	250	2,240	350
3	BF + BOF	700	90	1,200	215
4	COREX + BOF	1,410	180	1,910	290

3.15 Options 1 and 2 include electric arc furnaces which impose severe reactive power demand fluctuations on the supply system and cause the supply voltage to vary in a random low frequency manner know as flicker, because it has this effect on low voltage incandescent lamps. It is most unacceptable to the electricity supply authority which usually imposes strict limits on the voltage disturbance caused by the furnaces, about 1.6% at 230kV.

3.16 The short circuit fault level of the 230 kV grid supply to the arc furnaces is a critical factor in this context as it is a measure of the strength of the system, the higher the strength of the system the lower is the disturbance caused by a given furnace arrangement. Unfortunately the low fault level of the supply to Bang Saphan means that the furnaces will cause disturbance vastly in excess of the limit normally imposed.

3.17 Synchronous voltage compensators (SVC) can be used to reduce disturbances to about a third or quarter and are expensive, but even with these, disturbance will still be several times the allowable level. Thus the only solution to enable arc furnaces to be employed will be to strengthen the supply to a short circuit level of about 5000 MVA, compared to 866 MVA projected at present.

3.18 As mentioned above, the short circuit fault level is a function of generation capacity connected to the grid and the length of transmission line to the load furnace, long lines rapidly attenuate the strength of the system. Hence the most effective means of strengthening in this context is to install a power station as close as possible to the load, preferably within about 10 km. A very preliminary estimate indicates a connected capacity of about 830 MW would be required, which implies that a base load power station of about 1100 MW installed capacity needs to be built. If it were coal fired, further port investment would be needed. This power station would provide much more power than will be consumed in the area at least in the short term. Excess power would need to be transported long distances either north or south.

3.19 Options 3 and 4, although still imposing high electrical demands on the system, are fairly constant types of load which do no have the rapid fluctuation of reactive power caused by one or two single units of plant, such as electrical arc furnaces. They can therefore operate on a weaker supply without causing disturbance, unacceptable to other consumers. Even so the projected fault level of 866 MVA is low for a supply to a steelworks for this size (particulary option

3) and a short circuit fault level of about 2000 MVA would be considered a desirable minimum.

3.20 A locally situated power station to support such a large industrial development is therefore still an implied necessity, but in this case requiring a connected capacity of about 225 MW, say 350 MW installed. This is of the order of capacity which could be fuelled with by-product gas obtained with option 4.

3.21 It is likely that the second phase development of the works would require a second transmission line at 230 kV from the main grid substation for security, and flexibility which in the case of the electric arc furnaces would allow segregation of the supply into 'dirty' and 'clean' lines.

Gas

3.22 PTT have plans to bring gas ashore to Khanom though the timing of the project and the size of the line are still not firmly decided. There are then tentative plans to build a line right up to Bangkok. This would almost certainly pass within a mile of two of the Bang Saphan site.

3.23 SSIC are hoping very much that this line will be built. They would then use gas in their re-heat furnaces instead of oil. They would also consider building a combined cycle power station. The only steelmaking option that would use large quantities of gas, however is the DRI/EAF option.

Water

3.24 Water for the Bang Saphan region is provided by the Bang Saphan River (Khlong Bang Saphan) which flows in a west-east direction to its river mouth south of the flat products complex. The total annual average river flow is 145 million m^3 (average flow rate $4.6 m^3/sec$) but the monthly run-off varies considerably, ranging from a mean value of $6.4 m^3/sec$ in the wet season from June to November to an extreme recorded low value of $0.5 m^3/sec$ in some dry months.

3.25 Water presently extracted from the river is mainly used for agricultural and domestic purposes. There are no storage reservoirs at present on the river and the only control structure is a weir located 2km downstream of the confluence of Khlong Khanan, Khlong Yang Khuano and Khlong Thong, the three main tributaries of the Bang Saphan River. Two irrigation canals on the left and right banks of the river take water for paddy cultivation; their intakes are at the abutments of the weir. Domestic water supply for Bang Saphan township is provided by the Bang Saphan waterworks located 10km downstream of the weir. The present demand is low but, allowing for increases in population, greater consumption per head and irrigation requirements, the projected total for the end of the century is:

Irrigation	0.33 m^3/sec(28,500 m^3/day)
Domestic	0.05 m^3/sec(4,300 m^3/day)
	0.38 m^3/sec

3.26 In very dry weather the river flow of 0.5 m^3/sec will therefore be only just sufficient for this requirement.

First phase steel industry development

3.27 The SSIC flat products complex will take its water supply at an intake upstream of the weir. In view of the seasonal fluctuation, with river flow being much reduced in the dry months, a large water storage capacity is being provided at the site. Four polyethylene lined storage ponds (each 240m diameter x 10m water depth) are being constructed to provide a total of 1.8 million m^3 effective storage capacity, sufficient for about 5-6 months supply at a consumption rate of 300,000 - 330,000 m^3/month (0.13 m^3/sec) for the first hot strip mill, cold mill and electro-galvanising line. This storage is intended to cover the dry season requirement, when water extraction from the river may not be possible.

3.28 The reservoirs will be supplied by a 500mm diameter steel pipeline, 14km long, extending from the weir to the SSIC plant site with a design discharge rate of 0.4m^3/sec. The proposed pump station at the intake will have one - 900 HP and two - 200 HP electrically driven pumps. A 22kV transmission line to be installed by the PEA will supply power to a substation near the intake.

3.29 The water storage capacity being provided for the first phase development could theoretically meet 5-6 months demand without any extraction from the river, providing the reservoirs are full at the start of the dry season. However, any leakage losses and evaporation (possibly accelerated by the use of black polyethylene lining in a fairly shallow reservoir) will require to be monitored during the first few years of operation to establish their total effective dry season storage capacity.

Second phase development - hot strip mill No. 2

3.30 Installation of a second hot strip mill will increase the total monthly requirement to 500,000 m^3/per month. This can be met by one of the following alternatives:

- additional storage ponds at site (two of similar size to first phase ponds);
- a dam and storage reservoir at suitable location, with connecting pipeline to the site.

3.31 Provision of additional storage ponds is the cheaper option and is likely to be adopted, providing monitoring during the first phase has confirmed this method is reliable.

Full development - integrated steelworks

3.32 The total water demand for the various integrated steelworks options, and the phase 1 rolling mills, ranges from 10 million m^3/year to 14 million m^3/year (0.45 m^3/sec). This large demand cannot be met by direct intake from the Bang Saphan river and must either be met by a supply pipeline from an existing reservoir with surplus capacity or by construction of new reservoirs at any suitable nearby sites.

3.33 The nearest large storage reservoir to Bang Saphan is the Pranburi reservoir which is located 120km due north of Pang Saphan. This reservoir has 445 million m^3 total storage but it serves the fast growing Hua Hin region and is unlikely to have spare capacity to supply other areas; furthermore, powerful pumps and a long pipeline to Bang Saphan would be required. The Yang Chuan reservoir, also to the north, is nearer to Bang Saphan - about 105km - but its storage capacity is only 32 million m^3. Water supply from existing reservoirs is not likely to be the preferred option.

3.34 If new storage reservoirs are constructed to supply water to the integrated steelworks, service industry and housing, the alternatives are:

- construction of two or more small reservoirs at suitable sites within 25-30km of the steelworks;

- construction of a single larger reservoir at a location further from the site, thus requiring a longer pipeline.

3.35 The potential of various reservoir sites was investigated in earlier studies in 1982 and 1984. These studies are the source of the data which is used below.

Small reservoirs

3.36 Potential reservoirs near the Bang Saphan steelworks (location 11°14'N, 99°33'E) include the following, all located in the hilly country to the west of National Highway No. 4:

No.	Location N	Location E	Source (river)	Catchment (km^2)	Av. Annual Inflow (million m^3)
1	11°19'	99°24'	Khlong Thong	53	17.4
2	11°17'	99°24'	Khlong Loi	39	13.3
3	11°14'	99°23'	Khlong Khanan	39	13.3
4	11°11'	99°21'	Huai Yang Kwang	36	12.7
5	11°10'	99°23'	Huai Lam Ching	45	13.3
6	11°03'	99°20'	Huai Yang	45	17.0

3.37 Although the potential storage volume at any site - which depends mainly on site topography and assumed water elevation - can be increased theoretically by building a higher dam, none of the potential sites has a catchment and annual inflow which is large enough to store sufficient water in a single reservoir to supply the steelworks in an unusually dry year. Two or more reservoirs would be required, linked to a main supply pipeline to the steelworks. A suitable combination would be reservoirs 1, 2 and 4 (reservoir 3 would be close to National Highway No. 4 and developing it may not be feasible).

Larger reservoirs

3.38 Potential larger reservoirs, which would be further distant from Bang Saphan than those described above, include:

No.	Location NE	Source (River)	Catchment (km^2)	Av. Annual Inflow (million m^3)
7	10°55' 99°13'	Khlong Tha Sae	353	182
8	10°45' 99°05'	Khlong Rub Roh	330	407

3.39 The Rub Roh project (about 100km from Bang Saphan) is a major development which was studied in 1982 for hydroelectric power generation by the National Energy Agency. It is understood that it is not likely to be implemented for hydropower but has been transferred to the Royal Irrigation Department for evaluation of its water supply potential. At present there are no definite plans for implementation. If it were to proceed, it would be for general water supply for Chumpon province but it could also supply the steelworks.

3.40 A potential reservoir on Khlong Tha Sae (No. 7) would have sufficient capacity to meet the needs of the steelwork and other users. A 70km long pipeline and suitable pumps would be required to bring water to Bang Saphan.

3.41 Construction of Reservoir 7 is a suitable option if a single large reservoir is to be built to serve the steelworks, other industrial developments and also provide for general growth in the region.

Conclusions - water supply

3.42 The conclusions for the three development phases are summarised below, together with outline cost estimates for phases 2 and 3:

- First phase (SSIC's current project).

3.43 The water supply proposals are satisfactory but leakage and evaporation losses should be monitored in the first few years of operation to confirm that adequate storage capacity exists for unusually dry years:

- Second phase (second hot strip mill).

3.44 Two additional storage ponds at site will be required. Estimated cost (storage ponds and ancillary work) = US$4 million.

- Third phase (integrated steelworks).

3.45 Water supply from new storage reservoirs will be necessary.

3.46 For steel making options 1 and 2, development of reservoir sites 1 (Khlong Loi) and 2 (Khlong Thong) will be required. Estimated cost (dams, reservoirs, pipelines etc) = US$21 million.

3.47 For steel making options 3 and 4, development of reservoir sites 1, 2 and 4 (Huai Yang Kwang) will be required. Total estimated cost = US$39 million.

3.48 The above development proposals and costs are based on the assumption that water is provided solely for steelworks. General improvement of water supplies in the province might also meet the requirements of the steelworks and make these proposals unnecessary.

Land Transport

3.49 The majority of SSIC's products will be transported to the Bangkok area, at least in the early years. The approximate costs are as follows:

- by sea 165 baht/tonne
- by rail 200 baht/tonne
- by road 500 baht/tonne

3.50 For planning purposes it has been assumed that 80% of products are shipped by sea, 10% are shipped by rail and 10% are shipped by road.

3.51 While road is much more expensive than rail, rail transport is generally not favoured in Thailand. SRT have a poor reputation for service. Sea transport has the additional advantage that many consumers are used to importing and have good access to the Chao Phraya River.

Roads

3.52 National Highway No. 4, which runs from the Bangkok region to the south, is the main road link for Bang Saphan. Bang Saphan town is situated about 9km east of Highway 4 and is connected to it by Provincial Road No. 3169 which runs from the main highway to the coast. The turn-off from Highway 4 to Bang Saphan is near the 400km marker and the total distance by road from Bangkok to Bang Saphan is about 410km.

3.53 Highway 4 is designed for heavy vehicular traffic and is a four-lane divided highway up to a point (185km marker) between Petchaburi and Cha-am. Beyond this, it is a two-lane undivided road - single lane each way - which is being progressively improved southwards to provide two lanes in each direction for the heavy traffic which uses it.

3.54 Road No. 3169 is a narrow road with thin asphalt surfacing, suitable for light and medium traffic only. The road suffered some traffic damage during the early stages of the earthmoving operations for construction of the SSIC steel plant (until the contractor opened up another route for his vehicles) and the surfacing has crumbled in many places.

Road improvement programme

3.55 The Department of Highways has a programme for improving Highway 4 to the southern seaboard development area and eventually the four-lane divided highway will be extended to Surat Thani and Khanom. Likely dates for the proposed improvement are:

Section	Completion
Cha-am to Pranburi	end 1994
Pranburi to Kuiburi	end 1995
Kuiburi to Prachuap KK	end 1996
Prachuap KK to Bang Saphan	end 1997

3.56 Concurrently improvements will be carried out northwards from Chumpon to Bang Saphan and by end 1997 the entire length from Bangkok to Chumpon should be a four-lane highway.

3.57 The Department of Highways' programme also includes improvements to the provincial roads in the vicinity of Bang Saphan but these will not be completed until 1997 or 1998. The programme includes:

- reconstruction of road 3169;

- improvement of road 3459 which runs east from highway 4 (380km marker) to the coast;

- linking of roads 3169 and 3459 by a coastal road so that there is road loop comprising highway 4, road 3459, the coastal road and road 3169. (The land for this road link, which is owned by the Accelerated Road Development Programme Department and Public Works Department is to be transferred to the Department of Highways).

Steel industry requirements

3.58 Road transport for the steel industry is likely to be used for:

- delivery of raw materials such as limestone, dolomite etc. used in the steel production process. Total quantities range from 140,000/year (Option 2) to 840,000 tonnes/year (Option 3). Transport of 840,000 tonnes/year would require about 140 truck journeys (round-trips) per day. Although an improved road could be designed for this volume of heavy traffic, there would be much noise and nuisance to residents of Bang Saphan;

- export of 10% of the products of the steel plant;

- passenger and goods traffic to service industry and other downstream industrial developments, housing and educational areas.

3.59 The Department of Highways proposed development programme will eventually improve road infrastructure in Bang Saphan. However, if the steel industry develops, road improvements should be expedited. There is an urgent need to reconstruct and upgrade road number 3169 for heavy vehicular traffic for the SSIC plant's incoming materials and outgoing products.

3.60 If the full development of an integrated steel works proceeds and other downstream industry is implemented, road 3169 will require widening and upgrading to four lanes

Rail

3.61 Bang Saphan is served by SRT's rail service between Bangkok and the Malaysian border. Between Prachuap Khiri Khan and Chumpon the single track railway line runs close to the coast, less than a kilometre west of the SSIC site. The nearest railway station is Na Pak Kuang station close to Bang

Saphan town. Road 3169 crosses the rail track at a level crossing just south of the station.

3.62 The rail service is much used by passengers and the trains are very congested, particularly in the Bangkok area. Passengers are SRT's first priority. Each day there is a total of 30 trains to and from the south (15 trains in each direction) of which 20 are passenger trains and 10 are for freight.

3.63 Rolling stock currently in use and the existing track are suitable for trains of 1280 tonne (gross) weight and a maximum axle load of 15t. Freight wagons with 2 or 4 axles are available.

Development programme

3.64 Approval has been granted for implementation of the Bangkok to Nakhon Pathom double-line project. This will provide 56km of dual track near Bangkok. Although this will mainly benefit commuter services, it will provide potential for improving train frequency generally, since congestion mainly occurs close to Bangkok. The project is expected to start in 1994.

3.65 SRT has no plans at present for extending the double track beyond Nakhon Pathom but said it would consider doing so if the volume of traffic justifies an increase.

3.66 SRT consider that rail capacity could be increased with the existing infrastructure, if improved rolling stock were purchased.

Steel industry requirements

3.67 SRT has stated that it could transport 750t per freight train of steel products with existing rolling stock. SRT's usual practice for rail sidings for industrial developments is that SRT executes its own work on land owned by the railway. Sidings on the developer's land are built by the developer but he may subcontract the work to SRT.

3.68 SSIC and SRT have discussed the feasibility of transporting up to 20% of the total output of the hot strip mill by rail. With a total output of 2.5 million tonnes/year, up to 500,000 tonnes/year might be transported by rail - that is 670 train loads per year or 2 trains per day.

3.69 This volume of traffic would not warrant doubling of the track or other infrastructure improvements. New rail sidings near the hot strip mill would however be required.

3.70 If an integrated steelworks were to be developed, the following factors would determine whether the rail infrastructure requires improvement:

- total capacity of plant and the process used;

- proportion of total product despatched by rail;

- source of raw materials (eg limestone) and volumes likely to be transported by rail.

3.71 Sea, and to a lesser extent road, transport are likely to be the chosen options and on present information, improved rolling stock for the railway is all that is likely to be required.

3.72 Development of the steel industry in Bang Saphan presents a good commercial opportunity to SRT (the existing mainline track is remarkably close to the site) providing it can offer a reliable and safe service.

Sea Transport

3.73 At present there is no major port at or near Bang Saphan but Laem Mae Ramphung, the cape to the east of Bang Saphan, has been identified in earlier studies as a good location for a deep sea port. The seabed near the western shore of the Gulf of Thailand is shallow and the 20m depth contour is generally 5-10km from the coastline. However at Laem Mae Ramphung the headland juts out into the sea and depth contours are also generally closer to land, so the distance of the 20m contour from the shore at the port site is only 1.6km. There is a clear sea approach to Laem Mae Ramphung and only a short dredged channel would be necessary for the large bulk carriers used for the transportation of iron ore and coal.

3.74 This coastline is exposed to offshore winds and waves during the NE monsoon and to low amplitude, long period, swell from the South China Sea (direction SE and E), and there are no offshore islands to shield the coast from wave action. Ships berthed at an open sea berth would be subject to excessive weather "down-time" and a new port would require breakwater protection to permit efficient cargo handling operations.

3.75 The topography of the coastal land at Laem Mae Ramphung is suitable for port construction. Two rocky headlands are connected by an 1800m length of straight and generally flat coastline. The land between the headlands has a foreshore of boulders and gravel, suitable as foundation strata for the breakwaters which will extend out from shore, and also for port storage areas. The seabed soils near the shore consist of loose fine to medium silty sands overlying denser sand. Further offshore, cohesive soils (soft silty clay overlying stiffer clay) and dense sands are found.

3.76 The Thai coastline in this region generally experiences longshore sediment transport with net littoral drift southwards, but not to an extent that might significantly affect the proposed port development or cause excessive siltation which cannot be controlled by normal maintenance dredging.

First phase development - SSIC port project

3.77 SSIC proposes to develop a port for incoming steel slabs, fuel oil and other materials for the hot strip mill, and for shipment of products to the Bangkok region. Incoming and outgoing volumes for the first stage development (2.5 million tonnes/year hot strip mill, cold mill and electrogalvanising line) are:

	Volume(mtpa)
Incoming	
Steel Slabs	2.6
CR Coils	0.18
Outgoing	
Steel products*	2.0
Scrap	0.14

* 80% of total production assumed to be shipped by sea

3.78 The SSIC port will be named Prachuap Port and will provide facilities for vessels up to 40,000 dwt (220m overall length, 11.2m loaded draught) for incoming steel slabs and for smaller vessels for the shipment of products. The main elements of the port comprise:

- a rock mound breakwater, L-shaped in plan, of overall length about 1400m;

- a 250m wide approach channel and berthing area dredged to -14.0m below mean sea level (MSL) which provides 12.3m water depth at extreme low water;

- 450m of quay with a dredged level of -14.0m MSL alongside, to provide two berths for 40,000 dwt vessels;

- 300m of quay with seabed level varying from -6.0m MSL (shore end) to -11.0m MSL (seaward end), to provide three berths for coastal vessels in the range 1000 - 5000 dwt.

3.79 The proposed port layout is shown in Figure 3.1.

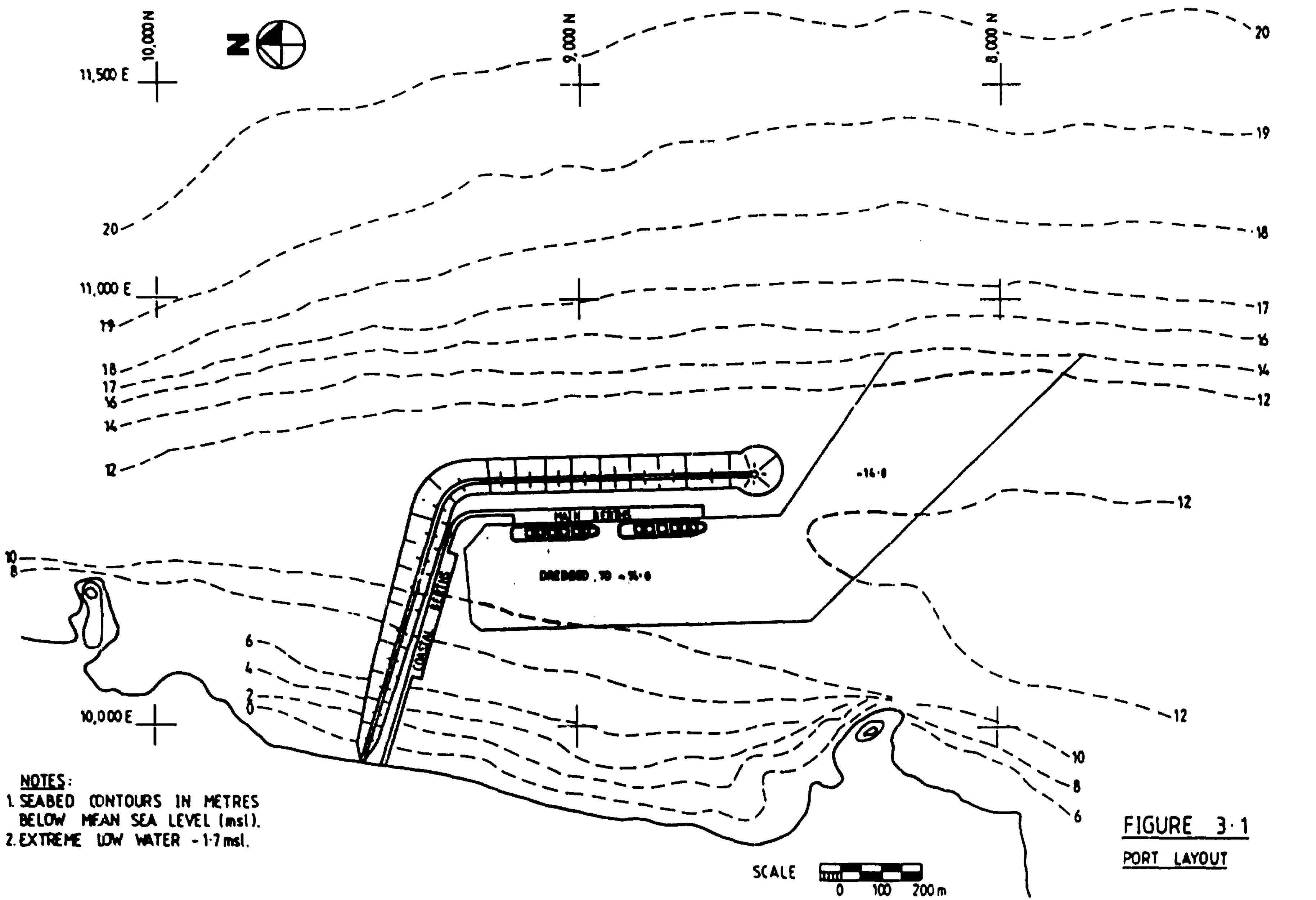
3.80 If it is assumed for the first stage development that steel slabs are received in 30,000t shipments (average size), the total number of vessels to be unloaded per year will be 87. For average vessel turn-around time of 3 days, the berth occupancy with two berths will be 0.36, which is satisfactory. If the second stage development is implemented the estimated berth occupancy increases to 0.72 which is too high, and would result in queuing and excessive waiting times for shipping (assuming random arrivals). To keep berth occupancy below 0.6, some improvement will be necessary. This could either be by:

- deepening the berth to accept larger vessels up to 50,000 dwt; and/or

- increasing craneage to reduce vessel turn-around time; or

- building an extra berth.

3.81 The proposed three berths for coastal vessels are adequate for shipment of 2.0 million tonnes/year of products, assuming 3000t shipments and 24 hour turn-around (berthing, loading and deberthing). The estimated berth occupancy is 0.61 which is acceptable for a 3-berth facility. For the second stage development it will be necessary to build additional berths and/or increase average shipment size.



NOTES:
1. SEABED CONTOURS IN METRES BELOW MEAN SEA LEVEL (msl).
2. EXTREME LOW WATER -1·7 msl.

FIGURE 3·1
PORT LAYOUT

3.82 SSIC's proposed port facilities appear satisfactory in principle but at the time of the Consultants visit to Thailand in February 1992 it was understood a formal application to the Harbour Department for a construction permit had not yet been submitted, nor had an Environmental Impact Assessment been completed. Other detailed matters to be progressed in the next few months include availability of harbour tugs for berthing operations (purchase or lease), cargo handling equipment, navigation aids, etc.

3.83 It seems likely that timely completion of the port will be a critical element of the project. It is understood that SSIC have a contingency plan for transhipment of steel slabs and coils, via the Ko Si Chang anchorage, to a temporary construction jetty if the port is not ready in time for start-up of the hot strip mill.

Full development - integrated steelworks

3.84 Construction of the proposed port described above has been preceded by thorough site investigations and hydraulic model testing and the design has been prepared by experienced consultants. The completed port should in principle satisfy the needs of the hot strip mill complex. In the initial years following completion operational performance data will be available, e.g. percentage of weather down-time (the port is protected by a single breakwater, so there will be some wave action within the harbour due to SE and SSE waves), sedimentation in dredged areas and annual maintenance dredging volumes and costs etc. This data will be useful for port expansion planning.

3.85 Port expansion will be necessary if the steel industry develops. Import of iron ore and coal will require berthing and unloading facilities for vessels up to 150,000 dwt. The first stage development is suitable, with a small increase in dredged depth, for vessels up to 50,000 dwt. SSIC have suggested that the port could be further deepened for larger vessels but, in our opinion, this would not be a satisfactory option.

3.86 The proposed SSIC Scheme has inadequate manoeuvring room for large bulk carriers and their attendant tugs during berthing operations. It also lacks a turning circle of sufficient depth within the harbour, where large vessels can be controlled and turned in sheltered water. The expanded port will require additional berths, a vessel turning circle and a sheltered approach channel.

Port planning criteria

3.87 Annual cargo tonnages for the integrated steelwork options are tabulated below:

Cargo	Option (mtpa)			
	1	2	3	4
<u>Incoming</u>				
iron ore/oxide fines		2.3	3.3	3.0
coal			1.6	2.0
steel scrap	2.1	0.7		0.3
steel slabs	0.6	0.6	0.6	0.6
<u>Outgoing</u>				
steel products *	2.0	2.0	2.0	2.0

* 80% of total production assumed to be shipped by sea

3.88 Of the incoming cargoes, iron ore and coal is often shipped in large bulk carriers up to 250,000 dwt to minimise transportation costs, providing the annual throughput is sufficiently large. Vessels between 120,000 to 150,000 dwt would be suitable for the relatively small tonnages tabulated above. Total bulk imports range from 2.3 million tonnes/year to 5 million tonnes/year. Assuming an average shipment of 135,000t per vessel, the number of vessels to be unloaded per year would be 17 (option 2), 36 (option 3), or 37 (option 4). A single berth would suffice for any of these options. Berth occupancy, assuming an average turn-around period of four days, would be 0.41 for option 4 (satisfactory) and less for the others. The single berth would be designed for 150,000 dwt vessels with typical dimensions 300m length, 45m beam and 16m loaded draught. A dredged level of -19m MSL (17.3m water depth at extreme low water) would be required.

3.89 Incoming steel slabs and scrap, would be transported in smaller vessels in the 30,000 - 40,000 dwt range. The two berths built in the current SSIC development would have adequate capacity for any of the options. Assuming average vessel turn-around of 3 days and 30,000t shipments, estimated berth occupancy varies up to 0.37 (option 1) which is satisfactory for a port facility with 2 berths.

3.90 Berth requirements for outgoing products, which will not change, were described earlier in section 3.4.2.

Conceptual development plan

3.91 A conceptual layout for port expansion to provide for the unloading of bulk ore and coal carriers is shown in Figure 3.2. It includes a berth for 150,000 dwt vessels, a sheltered channel in which these large ships can reduce speed and be brought under the control of harbour tugs before berthing with tug assistance at the unloading berth, and a turning circle for ships leaving the port. A second bulk unloading berth could be added later. For possible long-term needs arising from other developments in the region, there is space available for other cargo facilities. The main features of the scheme are:-

- main breakwater extension 1650m long ; 700m from the first stage breakwater to the 18m depth contour and a further 950m along this contour to the port entrance;

- new secondary breakwater 1050m long to provide protection from SE and SSE seas and swell;

- 250m wide navigational channel from the port entrance to the bulk unloading berth, dredged to -18m MSL;

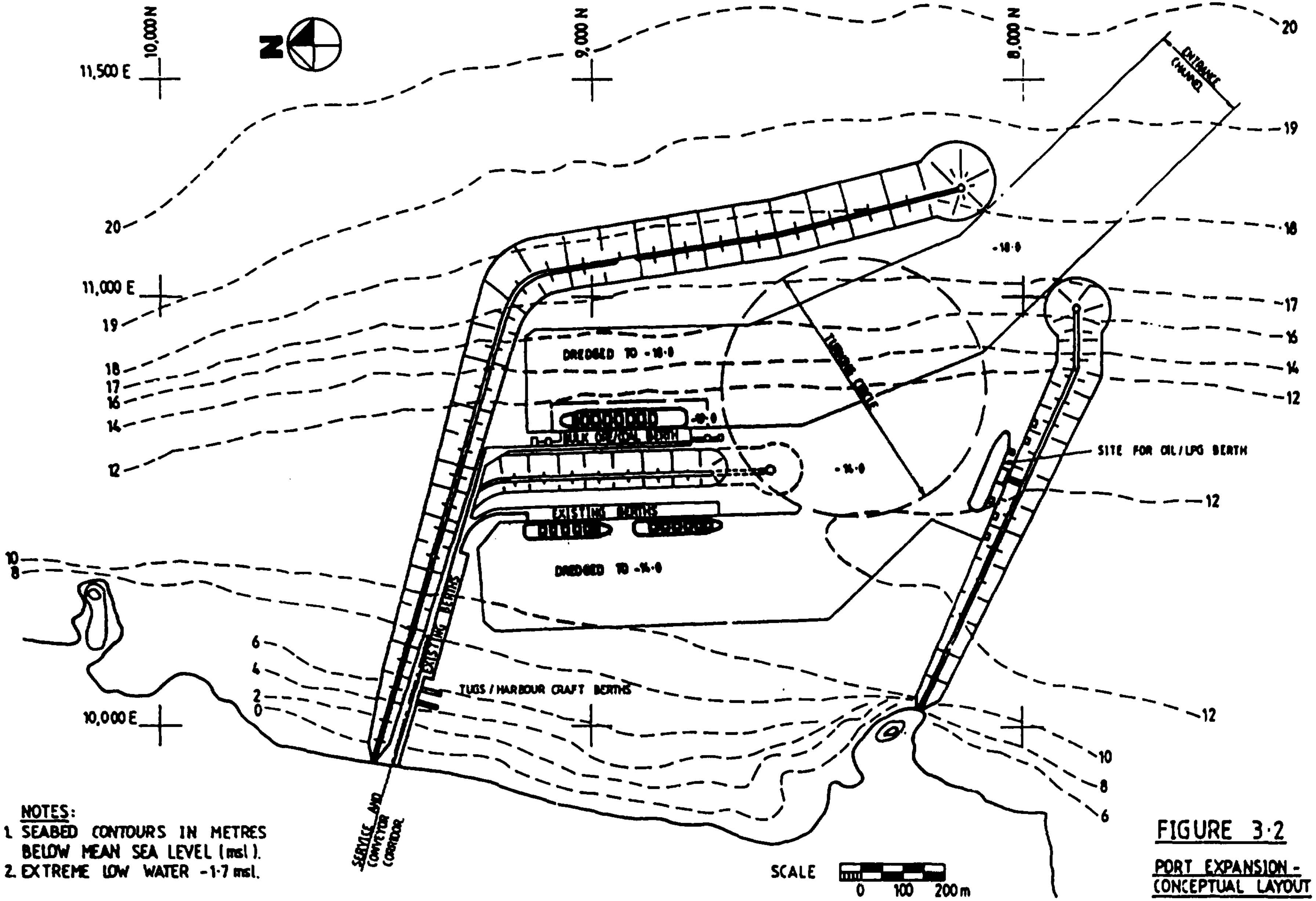
- 600m diameter vessel turning circle dredged to -14m MSL, for turning 150,000 dwt unloaded ships (reduced draft) when they leave the port and for turning smaller ships on arrival or departure without restriction;

- unloading berth and mooring dolphins for fully loaded 150,000 dwt vessels (300m long, 45m wide and 16.0m loaded draft) with dredged level at the berth of - 19m MSL which provides 17.3m minimum water depth at extreme low water. The berth would also accept part-loaded vessels up to 200,000 dwt;

- ship unloaders and bulk conveyors for coal and ore handling;

- berths for harbour craft (tugs, pilot launch and mooring launches);

- electrical and piped services, navigation aids, roads and paved areas, operational and administration buildings.



NOTES:
1. SEABED CONTOURS IN METRES BELOW MEAN SEA LEVEL (msl).
2. EXTREME LOW WATER -1·7 msl.

FIGURE 3·2

PORT EXPANSION - CONCEPTUAL LAYOUT

3.92 The existing berths of the first stage development would continue to operate for slab imports, steel scrap imports and outward shipment of products.

3.93 The two 40,000 dwt slab import berths of the first stage development will have spare capacity for other cargoes since iron ore import will substitute for slabs. There will also be opportunities to cheaply build additional berths on the southern breakwater. The figure shows, for example, a possible berth for inflammable cargoes. Preliminary enquiries by the Consultants to the Harbour Department and UNESCAP in Bangkok indicate, however, that demand for other cargoes in the near future is likely to be small. The economic case for port expansion needs to be based almost wholly on steel production.

3.94 The expansion scheme outlined above is suitable for steelmaking options 3 and 4. If option 2 were adopted, the proposed development would be similar in principle but would cater for a maximum vessel size of 100,000 dwt (270m long, 14.0m loaded draft) instead of 150,000 dwt.

Cost estimates

3.95 For steelmaking options 3 and 4 the total estimated cost of the expansion (dredging, breakwaters, berth structures and bulk handling equipment, harbour craft, services, navigation aids etc.) is **US$92 million**. About half the total estimate is for breakwater construction.

3.96 For option 2, where the principal dimensions, dredged depths etc. are appropriate for a 100,000 dwt vessel only, the above figure is reduced by US$12 million, i.e. estimated cost **US$80 million**.

4. ENVIRONMENTAL ISSUES

4.1 Whatever type of iron and steelworks were to be installed at Bang Saphan it would have a considerable environmental impact on the area.

4.2 The nature of iron and steelmaking processes involves the application of thermal and chemical reactions to melt or convert oxide materials or steel scrap into hot metal or liquid steel. These reactions generate large volumes of dirty gases and fumes which can cause atmosphere pollution, and their cleaning systems produce large quantities of liquid effluents and waste materials.

4.3 To reduce their environmental impact to acceptable standards, most new steelworks are equipped with sophisticated anti-pollution and water treatment plants. The capital costs for the various options reflect the provision of this equipment within process plants and the general works services.

4.4 However, to achieve the necessary performance from the anti-pollution equipment requires regular monitoring of air emissions and effluents by trained personnel. All too often this does not occur, due to works management concentrating on production rather than non-profit making activities, such as limiting the levels of particulates emitted into the atmosphere, or quality of effluents discharged into local rivers.

4.5 Much of the pollution that occurs in a steelworks is due to poor operational and maintenance procedures. Examples of this being the large volumes of red fume escaping from steelshops into the atmosphere due to breakdown of the gas cleaning systems, and large emissions of noxious fumes from coke oven doors due to poor cleaning of the frames.

4.6 Of the three options that include ironmaking plant, the direct reduction plant (Option 2) has the least environmental impact, since its direct reduced iron is in solid form, and consequently does not experience the pollution problems of hot metal and slag associated with the blast furnace and COREX options.

4.7 The two options both produce hot metal and slag from similar oxide raw materials, and consequently they will have similar levels of pollutions from ironmaking operations. However, the blast furnace (Option 3) also includes coke ovens plant, coke oven gas by-products plants and sinter plant which produce additional high volumes of gases, water effluents and waste products. Consequently, the blast furnace option has the worst environmental impact for ironmaking.

4.8 Electric steelmaking generates less fumes than basic oxygen steelmaking. Also, it uses a dry system for gas cleaning and produces dry dusts for disposal. This is environmentally cleaner than oxygen steelmaking which uses wet gas cleaning systems and produces water effluents.

4.9 Thus, Option 1 with scrap based electric arc furnace steelmaking has the least environmental impact and only causes minor levels of emissions of particulates into the atmosphere. Option 2 which adds a direct reduction plant has nominally higher atmosphere emissions, together with discharges of treated water effluents. The installation of either of these options should not have a profound effect on the neighbouring environment.

4.10 The remaining two options which include ironmaking facilities would have a much greater environmental impact, especially the blast furnace facility (Option 3) with its highly pollutant coke ovens and by-products plant.

4.11 The effluents and waste products produced in the various plants associated with the options are described in the following sections:

Blast Furnace Ironmaking

4.12 Blast furnace operations produce wastes in the gaseous, liquid, and solid states. Air pollutants are produced by three different stages of the operation: blast furnace gas, cast house emissions, and slag handling and processing.

4.13 Blast furnace gas is a relatively pollution-free fuel when stripped of its dust burden. Large production units are frequently connected to combined power and furnace blowing units. For certain other uses, the calorific value of this gas is increased by mixing it with coke oven gas. The gas must be cleaned of dust to a high degree before being used as a fuel. Cleaning or scrubbing is done by a wet process, producing a liquid waste which may contain toxic substances. Under normal operations, air pollution from blast furnace gas production is not considered significant.

4.14 Molten metal and slag are discharged from the furnace and cause fume emissions as the result of exposure to air and oxidation. Further emission arise from vaporization of alkaline oxides from slag. Emission of sulphur dioxide from molten slag may also be a problem.

4.15 Coarse aggregate is produced by pouring the molten slag into a slag pit in layers, either adjacent to, or at a distance from the furnace. Water spraying is frequently used to accelerate the cooling process, and this can result in a hydrogen sulphide odour.

4.16 Blast furnace wastewaters originate primarily from top gas cleaning. The wastewaters contain large quantities of particulate matter and quantities of cyanide, phenol, and ammonia. Other pollutants include heavy metals and certain organics originating in the raw materials or formed during the combustion process.

4.17 Solid wastes include blast furnace slag, dry dust, and moist filter cake, cast house fumes, refractory wastes and ladle skulls (the metal shell which solidifies on the sides and bottoms of the ladle). The slag is processed and used as a building material, raw material for blast furnace cement, and other similar purposes. Cast house dusts are collected on filter extraction systems and fed to the sinter plant. Used refractory material and ladle skulls are generally dumped on site.

4.18 To enable blast furnace gas to be recycled and reused, it undergoes a very high degree of cleaning. The cleaning process frequently involves up to three stages - dry collection in a "dust catcher", high energy scrubbing and wet electrostatic precipitation. Excessive emissions from the cast house operations can be avoided by maintaining sufficient ventilation. In the slag handling procedure, the mixing of molten slag with water is in itself effective in controlling much of the air pollution discharged.

4.19 Treatment of blast furnace wastewaters is concerned mainly with the removal of suspended solids. Other constituents, such as cyanides, phenols, oils and greases, metals are also of concern. These wastes originate mostly from the cleaning of gases resulting from combustion of the raw materials in the furnace. They are removed through the top of the furnace (and frequently referred to as "top" gases) for subsequent cleaning and use elsewhere in the plant.

4.20 Water treatment in most cases consists of thickener/clarifiers for removing the suspended solids. Sludge is removed continuously from the bottom of the thickener and pumped to vacuum filters, for dewatering. The filtrate is returned to the thickener influent. Various flocculating agents such as polymers, are often used to enhance solids removal. The clarified effluent can be used for cooling purposes. Solids removal, by itself, has only a minor effect on the chemical composition of the wastewater. Chlorination can be useful as a means of destroying cyanides and phenols. Bio-oxidation systems have also been successful in destroying cyanides.

4.21 Both organic and inorganic toxic pollutants have been found in blast furnace effluents, and hence should receive attention. Depending upon the individual or combination of pollutants involved, varying degrees of removal can be achieved by the application of filtration (as part of the suspended solids removal procedure), activated carbon, and carbon absorption

4.22 Disposal of solids, filter cake, sludges, and other similar materials which cannot by recycled is to controlled landfill. Slurries from the gas scrubbers frequently contain significant amounts of lead, zinc, and alkalis and hence cannot be recycled without receiving additional treatment.

Cokemaking and By-Products

4.23 A cokemaking plant not only produces high-quality coke, but also valuable by-products from the distillation reaction. Crude coal tars, crude light oils, ammonium sulphate, and naphthalenes are the principal by-products recovered. Other products, such as creosote oils, phosphates, creosote and elemental sulphur, are also recovered in some cases.

4.24 A by-product recovery coke plant consists of batteries of ovens in which blends of high, medium, and low volatile bituminous grades of selected coals are heated. The heating occurs out of contact with air in order to drive off volatile components without burning them. The volatiles are drawn off and recovered, while the residue remaining after about 16 hours of heating constitutes the coke product.

4.25 When ready, the coke is pushed from the oven and wet quenched (or cooled) before transfer into storage.

4.26 Utilization of the by-products keeps them out of the waste streams and hence significantly reduces the waste load which might otherwise be discharged from a coke plant. There are, however, several other potential sources of gaseous, particulate, and aqueous emissions which are not removed as part of the recovery process and can have an adverse effect on the environment.

4.27 Gravity charging of ovens can result in emissions of toxic and flammable gases, as well as fumes and dusts.

4.28 Major liquid wastes usually include excess ammonia liquor, final cooler wastewater, light oil recovery wastes from the benzol plant, barometric condenser wastes from the ammonia sulphate crystalizer, desulphurizer wastes, and contaminated waters from air emission scrubbers at charging, crushing, quenching, preheating, or screening stations.

4.29 By-product coke making also produces a number of toxic pollutants, both organic and inorganic. Some 30 organic substances are considered of major significance, including acrylonitrile, ethylbenzene, naphthalene, arsenic, cyanides, selenium, silver, and zinc.

4.30 Coke making may result in the discharge of gaseous ammonia, hydrogen sulphide, and hydrogen cyanide to the atmosphere if collectors, ductwork, and piping are not carefully monitored and controlled. Particulates may also escape to the atmosphere. With effective controls, little or none of these substances should be discharged.

4.31 Gases and dusts which are not otherwise recovered as useful by-products are effectively removed by dust collecting devices, sprays, or a combination of the two. Disposal is either to recycling or to landfills.

4.32 Burning of coke oven gas can produce significant emissions of sulphur gas, unless the sulphur component is removed before burning.

4.33 Following application of various by-product recovery measures, there still remains a residual discharge of contaminated wastewater which must be treated before release. The three most frequently applied methods are physical/chemical, biological, and incineration/evaporation technologies. Flow minimisation should be a first step in all cases.

4.34 The use of lime to raise pH levels prior to ammonia stripping produces large quantities of sludge in the form of unreacted hydroxide, along with precipitated calcium carbonates and sulphates. Disposal can be to landfill but care must be taken to prevent the sludges from redissolving and reaching streams as runoff. Lesser amounts of sludge form when caustic soda is used as the alkali, but this will cause an increase in the dissolved solid levels. Other sludges will contain coal or coke fines, and these can be readily recycled back to the process.

4.35 All sludges should be recycled to the process insofar as possible. Controlled landfill is the disposal method of choice for all solid wastes that cannot be recycled to the system, including those by-products which are not of suitable quality for marketing purposes.

Sintering

4.36 Sintering produces a useful agglomerate from oxide fines and a wide variety of wastes, such as coke breeze, mill scale, flue dust, limestone, and dolomite fines. The process has great flexibility in the agglomeration of raw materials having different physical properties and mineralogical composition.

4.37 Although sintering plants are generally fitted with high chimneys to assure adequate dispersion of waste gases, the use of high-sulphur raw materials can cause problems from sulphur dioxide combining with other contributions from nearby sources. Dusts or particulate matter can also be major problems.

4.38 Gas and dusts are effectively removed from exhaust streams by means of wet scrubbers or by dry methods, such as electrostatic precipitation. The removed solids are either recycled to the sintering process or transferred to a waste recovery operation elsewhere.

4.39 Wastewaters result mainly from the wet scrubbing and cooling of gases, dusts, and other materials involved in the sintering process. While treatment facilities are concerned mainly with solids removal, a side effect is to remove other pollutants as well. Thickeners and clarifiers or settling lagoons are used for suspended solids removal. Skimmers are effective for oil and grease removal.

4.40 Whilst suspended solids removal will also remove some of the toxic pollutants, higher degrees of treatment are usually required for this purpose. Advanced treatment technologies known to be effective for both organic and inorganic toxic pollutants include alkaline chlorination, sulphide precipitation, filtration, and activated carbon treatment.

Direct Reduction Plants

4.41 Dusts contained in the off-gases from direct reduction plants are usually removed by wet scrubbing. Cleaned gases are either used to provide heat for gas reforming or, in some instances, to preheat the feed material. The resulting slurry is filtered, pressed, and recycled. The clarified effluent can be used for cooling.

4.42 Since the DRI plant produces a solid product, it does not experience the environmental problems of fumes and slag associated with the molten hot metal production of blast furnaces and COREX plants.

COREX Plants

4.43 The COREX plant and the blast furnace are similar with respect to raw materials and hot metal and slag products. Also, they both use lock hoppers to ensure gases do not escape during materials charging, and enclosed processing and off-gas cleaning. Consequently, their generated emissions and effluents are similar. However, the COREX is a single process with no significant direct air emissions, ie. its by-product gas is used as a medium calorific value export gas. Thus, it is environmentally better than conventional ironmaking which comprises coke ovens, coke oven gas treatment and blast furnace, all of which have separate air emissions and water effluents.

4.44 COREX claim that particulate emissions rates from their plants are 30 to 40 percent less than from a conventional coke plant/blast furnace.

Electric Arc Furnace Steelmaking

4.45 Waste products discharged from the electric arc furnace process include smoke, slag, carbon dioxide and carbon monoxide gases, and oxides of iron emitted as submicron fumes. Other contaminants, such as zinc oxides from galvanised scrap, will also be discharged depending upon the type and quality of scrap used. Scrap containing large quantities of oil will yield heavy reddish-black smoke as the oils are burned off at the start of the meltdown cycle.

4.46 Dry gas cleaning systems are normally installed, being either bag filters or electrostatic precipitators. The dry dusts collected are transferred to a landfill site for disposal.

4.47 EAF steelmaking slag is cooled, then crushed to reclaim any entrained Fe, with the residue disposed of to landfill.

4.48 During scrap meltdown, a high level of noise occurs due to the electrodes arcing across the solid scrap. EAF's are now increasingly being installed within noise-proof enclosures to ensure a satisfactory working environment for the steelshop operators.

Basic Oxygen Furnace Steelmaking

4.49 The waste products from the basic oxygen steelmaking process include heat, airborne fluxes, carbon monoxide and dioxide gases, and oxides of iron emitted as micron dusts. Also, when the hot iron is poured into ladles or the furnace, submicron iron oxide fumes are released and some of the carbon is precipitated out as graphite. Fumes and smoke are also released when steel is poured into holding ladles from the furnace. Basic oxygen furnaces are equipped with some type of air pollution gas cleaning system for containing, cooling and cleaning the large volumes of hot gases and submicron fumes that are released.

4.50 Wastewaters from wet gas cleaning system are first subjected to primary treatment in a clarifier to separate the solids. It then flows to a thickener, to which a coagulant has been added. Thickener sludge goes to the vacuum filters, from which the cake goes to landfill disposal and the filtrate is returned to the thickener. Some 95 percent of the thickener overflow is recycled to the process. The remaining 5 percent undergoes further clarification. The sludge from this unit goes to the vacuum filters, while the effluent is acid neutralized and discharged.

4.51 Disposal of sludges, filter cakes, and other solids may be to landfill or to process recycling via the sintering plant. For landfill disposal the sludge is often dried to a higher solids content to reduce the volume.

4.52 BOF steelmaking slag is processed similarly to EAF slag.

Rolling and Finishing

4.53 The main sources of air pollutants in flat products rolling and finishing operations are the slab reheating furnaces, acid recovery plants and electro-galvanising lines. Current control practices provide sufficient extraction so that these sources are not considered significant.

4.54 Wastewaters from hot and cold rolling contain scale, oils and greases. Wastewater sources include cooling of the work rolls, strip cooling and pickled strip rinsing and fume scrubbing. These wastewaters undergo primary sedimentation in a scale pit equipped with oil skimming, followed by flocculation and secondary sedimentation in a thickener. The overflow is filtered prior to discharge or recycling.

4.55 The principal solid waste products from the rolling and finishing facilities are steel scrap, millscale, scarfing residues, and used oils and greases. Most of these are recovered and recycled back into the steelmaking process.

5. EVALUATION OF ALTERNATIVES

5.1 In this section is presented the data and results of a financial appraisal of each steelmaking option described in Section 2. The alternatives are compared against a "do-nothing" case where slabs are purchased from abroad. This is the current preferred option of SSIC and provides a benchmark against which the attractiveness or otherwise of steelmaking can be estimated.

5.2 The appraisal is based on a cash flow analysis which takes into account the capital and operating costs of the steelmaking projects as well as the requirements for working capital, but not financing and taxation. Cash flows are projected for a period of 25 years, after which the residual value of the investments is assumed to be 10% of their initial cost. An exchange rate of 25 baht/US$ is assumed throughout and all prices are expressed in 1992 values.

5.3 The internal rates of return for each alternative and for each slab price are quoted in real terms, that is they exclude inflation. On this basis we would expect SSIC to require a rate of return of at least 10%. This would assume a funding structure as follows:

- 30% equity with a real rate of return of 20%;
- 40% suppliers credit with a real interest rate of 3-5%;
- 30% other credit with a real interest rate of 6-8%.

5.4 Costs related to the expansion of the port and water supply have been included in the capital cost estimates. Electricity and gas investments are not included and are assumed to be paid for by EGAT and PTT respectively.

5.5 As explained in Section 2, in order to save capital expenditure on under-utilised equipment, each of the schemes has been sized so that it will make use of a single two-strand slab casting machine producing 2m tonnes of slabs per year. Any additional slabs needed to meet the hot strip mill's production will still be imported.

The Cost of Slabs

5.6 The "do-nothing" case requires an estimate of the landed cost of slabs at Bang Saphan. At today's prices, the fob cost of slabs around the world is about US$190-200 per tonne. To this must be added the shipping costs and handling charges at Bang Saphan. These would represent a further US$35 per tonne, making a total of about US$230 per tonne delivered to the site. Due to the current excess capacity in steelmaking worldwide, prices are low and sellers are not covering the total cost of their operations.

5.7 Even if a decision was taken immediately to proceed with steelmaking at Bang Saphan, it would not be until 1996/97 that production would commence. In practice, SSIC has no desire to make an early decision as both capital and management effort is taken up with the building of the rolling facilities. This means that it is likely to be the year 2000 before steelmaking would come on stream.

5.8 By this time it is expected that worldwide supply and demand for steel will be more in balance than it is today. If this is the case then steelmakers will want a better price for their intermediate products. It is estimated that currently an fob price of about US$240 would be required for costs to be fully covered, even in the more competitive locations. This would imply a long term landed price of about US$270 per tonne at Bang Saphan. The analysis has therefore been carried out for a range of (landed) slab prices from US$230 to US$290. Sensitivity tests on other vanables use the US$270 price.

5.9 As and when steel prices generally become firmer, the price of ferrous inputs (ie ore and scrap) will also increase. In the analysis, therefore, these prices are assumed to rise in direct proportion to the slab price.

Capital Costs

5.10 The capital costs of each alternative are shown in Table 5.1. They range from US$565m for scrap-based arc furnace steelmaking to US$1460m for the blast furnace and basic furnace steelmaking. When port and water supply costs are added the gap widens, as an extension to the port will be required for all options which require iron ore or coal to be imported. For the scrap based option, however, the present slab berths would provide sufficient handling facilities.

TABLE 5.1 - CAPITAL COST ESTIMATES (US $MILLIONS)

Item	EAF with 100% scrap	EAF & gas based DRI	Blast furnace & BOF	Corex & BOF
Port expansion	0	80	92	92
Additional water supply	21	21	39	39
Coke Ovens			180	
Sinter Plant (a)			140	
Blast furnace (b)			390	
Corex Units (c)				540
DR Plant (a)		240		
BOF			310	310
EAF	290	290		
Slab Caster	180	180	180	180
General Works Services	95	140	260	205
Pre-operating Expenses	40	40	40	40
Total	626	991	1,631	1,406

(a) Including raw materials handling
(b) Including blowers
(c) Including oxygen plant and raw materials handling

5.11 Capital costs have been estimated from the Consultants knowledge of prices currently being quoted by suppliers. For the DR plant, the arc furnaces, and the slab casting machine, the figures are reliable and based on several similar installations. For the blast furnace and coke ovens the estimates are less precise as there have been few installations of this type installed around the world in the last decade. For the Corex units, the Consultants have received an indicative quotation from the suppliers Deutsch Voest Alpine but, in the event have used a higher figure based on a comparison with known prices of DRI plants. As mentioned in Section 2, Corex have not yet built modules of the size assumed here and so an allowance for additional costs is prudent.

5.12 In each case it is assumed that the projects take three years to build and that capital is disbursed in the following way (year 0 represents the first year of production):

Year -3	40%
Year -2	25%
Year -1	25%
Year 0	10%

5.13 Pre-operating costs have been calculated by taking the following components:

- Six months of labour costs for training and commissioning;

- One month of variable costs (at full output) for trials and commissioning;
- The cost of providing expatriate workers for a two year period.

5.14 All units are assumed to operate at 60% of achievable capacity in their first year, 85% in their second year, and 100% from then onwards.

Operating Costs

5.15 Table 5.2 shows the costs assumed for ferrous inputs and how these are related to the slab price. Table 5.3 shows the prices assumed for other inputs.

TABLE 5.2 - COST ASSUMPTIONS - FERROUS MATERIALS (US$/TONNE)

Item	Landed Slab Price			
	230	250	270	290
Lump Ore	32	35	38	40
Pellets	40	43	47	50
Ore Fines	28	30	33	35
Scrap	130	141	153	164

All prices expressed as delivered Bang Saphan

TABLE 5.3 - COST ASSUMPTIONS - OTHER MATERIALS

Item	Units	Cost
Coking coal	US$/tonne	65
Steam coal	US$/tonne	40
Ferro-alloys	US$/tonne	600
Limestone	baht/tonne	300
Electrodes	US$/tonne	2,400
Electricity	baht/kWh	2
Nat.gas/fuel oil	US$/MBTU	3
Water	baht/m3	5
Manpower	baht/year	100,000

5.16 For each of the four options, tables 5.4 to 5.7 show the main yields and consumptions used in the evaluations, together with "other" costs required at each process centre. This latter item covers the cost of consumables and other small items not elsewhere mentioned as well as an allowance for maintenance materials and spares. All estimates assume that the plant is well managed and good working practices are adopted throughout.

TABLE 5.4 - YIELDS AND CONSUMPTIONS - EAF WITH 100% SCRAP CHARGE

Process	Item	Units	Amount
Raw Materials Stockyard	Electricity	kWh/t	6
	Water	m3/t	0.2
	Spares/cons/misc.	US$/t	2
Lime Plant	Limestone	kg/t	2,200
	Electricity	kWh/t	28
	Gas/Fuel oil	Mbtu/t	3.6
	Water	m3/t	1.2
	Spares/cons/misc.	US$/t	5
Oxygen Plant	Electricity	kWh/t	0.8
	Spares/cons/misc.	US$/t	0.02
Electric Arc Furnace	Scrap	kg/t	1,111
	Burnt lime	kg/t	40
	Electricity	kWh/t	500
	Water	m3/t	1.0
	Oxygen	m3/t	22
	Ferro-alloys	kg/t	10
	Electrodes	kg/t	5
	Spares/cons/misc	US$/t	15
Continuous Caster	Liquid steel	kg/t	1,040
	Electricity	kWh/t	19
	Gas/Fuel oil	Mbtu/t	0.1
	Water	m3/t	0.5
	Oxygen	m3/t	3
	Spares/cons/misc.	US$/t	10

TABLE 5.5 - YIELDS AND CONSUMPTIONS - EAF & DR OPTION

Process	Item	Units	Amount
Raw Materials Stockyard	Electricity	kWh/t	6
	Water	m3/t	0.2
	Spares/cons/misc.	US$/t	2
Lime Plant	Limestone	kg/t	2,200
	Electricity	kWh/t	28
	Gas/Fuel oil	Mbtu/t	3.6
	Water	m3/t	1.2
	Spares/cons/misc.	US$/t	5
Oxygen Plant	Electricity	kWh/t	0.8
	Spares/cons/misc.	US$/t	0.02
DR Plant	Pellets	kg/t	1,227
	Lump ore	kg/t	307
	Gas/Fuel oil	Mbtu/t	10.3
	Electricity	kWh/t	130
	Water	m3/t	1.5
	Spares/cons/misc.(a)	US$/t	11
Electric Arc Furnace	DR Iron	kg/t	721
	Scrap	kg/t	428
	Burnt lime	kg/t	30
	Electricity	kWh/t	625
	Water	m3/t	1.0
	Oxygen	m3/t	22
	Ferro-alloys	kg/t	10
	Electrodes	kg/t	5
	Spares/cons/misc.	US$/t	15
Continuous Caster	Liquid steel	kg/t	1,040
	Electricity	kWh/t	19
	Gas/Fuel oil	Mbtu/t	0.1
	Water	m3/t	0.5
	Oxygen	m3/t	3
	Spares/cons/misc.	US$/t	10

(a) Including licence fee

TABLE 5.6 - YIELDS AND CONSUMPTIONS - BLAST FURNACE OPTION

Process	Item	Units	Amount
Raw Materials Stockyard	Electricity	kWh/t	6
	Water	m3/t	0.20
	Spares/cons/misc.	US$/t	2
Lime Plant	Limestone	kg/t	2,300
	Electricity	kWh/t	28
	Gas/Fuel oil (a)	Mbtu/t	3.6
	Water	m3/t	1.2
	Spares/cons/misc.	US$/t	5
Oxygen Plant	Electricity	kWh/t	0.8
	Spares/cons/misc.	US$/t	0.02
Coke Ovens	Coal (b)	kg/t	1,850
	Electricity	kWh/t	50
	Water	m3/t	1.5
	Spares/cons/misc.	US$/t	13
	By-product Credit	US$/t	2.5
Sinter Plant	Ore Fines	kg/t	941
	Limestone/Dolomite	kg/t	140
	Electricity	kWh/t	30
	Water	m3/t	0.2
	Spares/cons/misc.	US$/t	4
Blast Furnace	Lump Ore	kg/t	175
	Sinter	kg/t	1,574
	Coke	kg/t	350
	Coal	kg/t	150
	Electricity	kWh/t	140
	Water	m3/t	1.1
	Oxygen	m3/t	0.4
	Spares/cons/misc. (c)	US$/t	13.5
BOF	Hot metal	kg/t	962
	Scrap	kg/t	118
	Lump Ore	kg/t	17
	Burnt Lime	kg/t	63
	Additions	kg/t	38
	Electricity	kWh/t	30
	Water	m3/t	0.4
	Oxygen	m3/t	55
	Ferro-alloys	kg/t	10
	Spares/cons/misc.	US$/t	15
Continuous Caster	Liquid steel	kg/t	1,040
	Electricity	kWh/t	19
	Gas/Fuel oil (a)	Mbtu/t	0.1
	Water	m3/t	0.5
	Oxygen	m3/t	3
	Spares/cons/misc.	US$/t	10

(a) Provided by by-product gases
(b) Includes fines to sinter plant and for sale
(c) Includes provision for reline

TABLE 5.7 - YIELDS AND CONSUMPTIONS - COREX OPTION

Process	Item	Units	Amount
Raw Materials Stockyard	Electricity	kWh/t	6
	Water	m3/t	0.20
	Spares/cons/misc.	US$/t	2
Lime Plant	Limestone	kg/t	2,300
	Electricity	kWh/t	28
	Gas/Fuel oil (a)	Mbtu/t	3.6
	Water	m3/t	1.2
	Spares/cons/misc.	US$/t	5
Oxygen Plant	Electricity	kWh/t	0.8
	Spares/cons/misc	US$/t	0.02
Corex Units	Lump Ore	kg/t	1,667
	Coal	kg/t	1,111
	Limestone	kg/t	260
	Additions	kg/t	100
	Electricity	kWh/t	60
	Water	m3/t	1.5
	Oxygen	m3/t	545
	Spares/cons/misc. (b)	US$/t	16
BOF	Hot metal	kg/t	865
	Scrap	kg/t	257
	Lump Ore	kg/t	17
	Burnt lime	kg/t	63
	Additions	kg/t	38
	Electricity	kWh/t	30
	Water	m3/t	0.4
	Oxygen	m3/t	55
	Ferro-alloys	kg/t	10
	Spares/cons/misc.	US$/t	15
Continuous Caster	Liquid steel	kg/t	1,040
	Electricity	kWh/t	19
	Gas/Fuel oil (a)	Mbtu/t	0.1
	Water	m3/t	0.5
	Oxygen	m3/t	3
	Spares/cons/misc.	US$/t	10

(a) Provided by Corex gas
(b) Including licence fee

5.17 Table 5.8 shows the manpower requirements of each option. The levels chosen are higher than in many steelworks in developed countries but are deemed appropriate for Thailand. An average cost of employment over all grades of 100,000 baht/year has been assumed. This results in labour costs that are low compared to many countries, both developed and less-developed. The results are not sensitive to changes in labour costs.

TABLE 5.8 - MANPOWER REQUIREMENTS

Item	EAF with 100% scrap	EAF & gas based DRI	Blast furnace & BOF	Corex & BOF
Coke Ovens			250	
Sinter Plant			300	
Blast furnace			350	
Corex Units				425
DR Plant		250		
BOF			325	325
EAF	325	325		
Slab caster	125	125	125	125
Gen. Works Services (a)	180	250	450	550
Total	630	950	1,800	1,425

(a) Includes raw materials handling at port and plant

By Products

5.18 The Corex and blast furnace options will produce gases which can be consumed in downstream processes or other industries, displacing fuel oil or natural gas. These gases have been valued taking into account their calorific value and the alternative cost of fuel.

5.19 The Corex plant will generate a net output of about 11 MBTU's per tonne of hot metal. After deducting the requirements of the lime plant, BOF and caster, the figure becomes about 10.5 MBTU's. If 10% of this amount is wasted due to the fluctuating nature of the supply, the value of the gas is about US$28 /tonne hot metal. This excess gas is sufficient to supply the hot strip mill and cold mill as well as a power station producing about 175 MW average output.

5.20 Gases from the coke ovens and blast furnace are less significant. When consumption in other steel-making units has been allowed for, the net output is about 1 MBTU/tonne of hot metal. Allowing for the low CV of this gas, it has a value of about US$2 / tonne of hot metal. The amount is likely to be sufficient to supply the requirements of the cold mill only.

5.21 Apart from gases, a number of other by-products will be produced. For example, small quantities of lime fines can be put straight on the land as a fertiliser, blast furnace slag can be used in cement production, etc. Bang Saphan, however, is not well placed to sell these very profitably. While they will undoubtedly have a value, in nearly all cases the transport costs will make their ultimate contribution small. A credit has only been taken into account for coke breeze which has been valued at US$2.5 per tonne of coke charged to the blast furnace.

Working Capital

5.22 Stocks of raw materials, purchased slabs and produced slabs have been accounted for in the analysis. These are to some extent offset by delays in payment, ie creditors. The values used are shown in Table 5.9. It should be noted that the stock and creditor figures have also been applied to the "do-nothing" option creating a modest additional benefit for the projects. Stocks of slabs can be lower if produced on site than if purchased from abroad.

TABLE 5.9 - WORKING CAPITAL REQUIREMENTS

Item	Rule
Creditors	45 days of non-manpower costs
Stocks	60 days of materials costs and purchased slabs 20 days of produced slabs

Production Costs

5.23 Using the above data, it is possible to calculate a cost per tonne of slabs, for each alternative. Table 5.10 shows the results, using ferrous prices appropriate to a US$270 slab price. As would be expected, the options which use ore and coal directly have lower operating costs than those which make use of purchased scrap since more of the processing is being carried on at the plant. When depreciation and interest charges on the capital costs are included, however, the picture changes and the overall unit cost is almost the same for each option.

TABLE 5.10 - UNIT PRODUCTION COSTS (US$/TONNE SLABS)

Item	EAF with 100% scrap	EAF & gas based DRI	Blast furnace & BOF	Corex & BOF
Ferrous Materials	166	109	64	68
Other Materials	47	57	68	73
Energy (incl. coal)	34	72	63	46
Manpower	1	2	4	3
Operating Costs	248	240	199	210
Depreciation (a)	15	22	38	32
Interest (b)	21	31	52	45
Total Cost	284	293	289	287

(a) 5% of capital costs, excl port and water
(b) 7% of capital costs, excl port and water

5.24 None of the alternatives can produce slabs to compete with the US$270 import price assumed for the long term, unless significant tariffs were introduced.

Return on Capital

5.25 This section shows the incremental rate of return for each option when compared to the "do-nothing" case. The results are summarised in Figure 4.1.

Scrap-based EAF Steelmaking

5.26 Even at the upper end of expected slab prices, this option only generates a real rate of return of 4 to 6%. This excludes consideration of the investments required for power station developments in the Bang Saphan area. The estimated returns for each price level are as follows:

Slab price (US$/t)	Internal rate of return
230	-3.8%
250	+0.5%
270	+3.7%
290	+6.4%

5.27 Scrap prices are the most important element of costs. With a US$270 slab price, scrap costs are estimated at US$153. A decrease in the scrap cost of 5% would increase the rate of return from 3.7% to 6.7%. An increase of the same amount would reduce it to 0.2%.

Gas-based DRI Production and EAF

5.28 This option performs a little worse than the scrap-based option though the gap is narrowing with the higher slab and oxide feedstock prices. The results exclude the investments associated with bringing a natural gas pipeline from Khanom to Bang Saphan. The returns are estimated as follows:

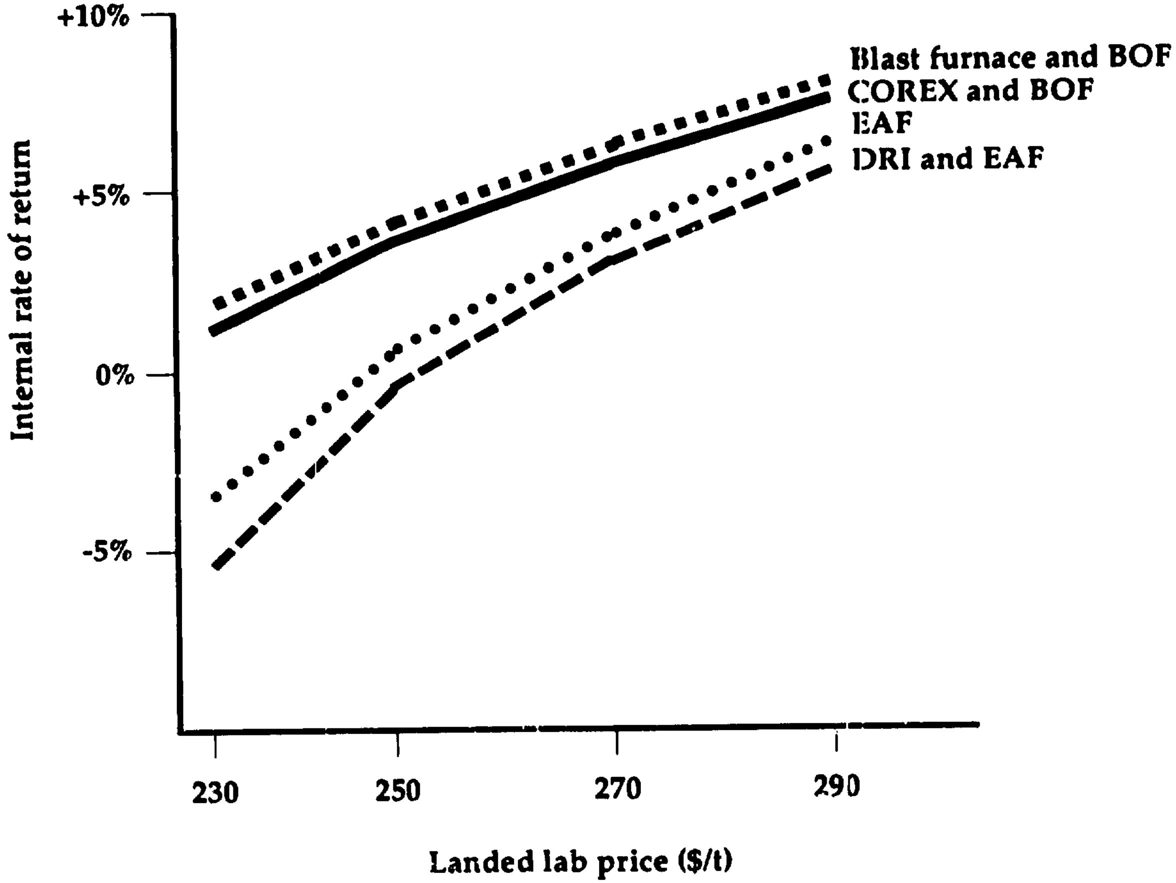


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Figure 5.1 Internal rates of return for each option

Slab price (US$/t)	Internal rate of return
230	-5.4%
250	-0.5%
270	+3.0%
290	+5.7%

5.29 A gas price of US$3/MBTU has been used in the analysis. If this was reduced to US$2.8, ie the same price as paid by EGAT, the return would rise from 3.0% to 3.4% given a US$270 slab price. If on the other hand, the price rose to that charged to other industrial consumers (US$4), the return would drop to 0.8%.

Blast Furnace Ironmaking and BOF Steelmaking

5.30 This option has the highest capital costs and for this reason changes in the slab price have less impact on the rate of return. The estimated rates of return are:

Slab price (US$/t)	Internal rate of return
230	+1.6%
250	+4.0%
270	+6.1%
290	+7.9%

5.31 As few plants of this type are being built at the moment, the major uncertainty with this option is the capital cost. If total expenditure increased by 10%, this would reduce the rate of return from 6.1% to 5.2% at the US$270 slab price. A decrease of the same magnitude would result in a rise to 7.0%.

Corex Ironmaking and BOF Steelmaking

5.32 In this case there is a considerable quantity of excess gas available. The IRR's assume that there will be purchasers near to the site. The quantity is sufficient to fire a medium sized power plant, catering for most of the electricity requirements of the complex, or for other heavy industrial uses, eg cement manufacture, steel fabrication, etc. Without such gas sales the option would perform very poorly as this excess gas production is an integral part of the process economics.

5.33 The rates of return are:

Slab price (US$/t)	Internal rate of return
230	+1.2%
250	+3.7%
270	+5.8%
290	+7.7%

5.34 The main risk in this case is the fact that modules of the size being costed have not yet been built. A sensitivity of 10% of the capital costs at the US$270 slab price yields a range from 5.0% to 6.8%.

5.35 While this option has one of the highest rates of return, they are still considerably lower than our 10% target level. To attain this, either the slab price must increase to US$300 and the capital costs come down by 12%, or the slab price must be US$290 and the capital costs 20% lower.

5.36 The results show that none of the rates of return are likely to be attractive to a private investor in Thailand. The EAF options perform slightly less well than the blast furnace and Corex options. This conforms with the general steel industry view that electric steelmaking is only competitive up to production levels of about 1m tonnes per year. The exceptions to this are in areas with low energy costs such as Saudi Arabia, Venezuela and Mexico. Although few blast furnaces have been built recently this is more connected to overcapacity than to the technology being outdated.

6. DISCUSSION OF THE OPTIONS

6.1 As already mentioned, SSIC do not currently expect to make steel at Bang Saphan. With present market conditions this would seem to be the right decision. Certainly for some years it will be cheaper to import slabs than it will be to make them.

6.2 The main reason why steel prices are currently very low is that, even after a decade of closures in Europe and America, there is still excess capacity worldwide. One of the sources of this surplus capacity is Eastern Europe. In 1991 alone, production in these countries fell by 30 million tonnes. What will happen to these plants is still unclear. Many will close but others will be desperately seeking export contracts.

6.3 Low prices are an obvious result of overcapacity. Companies are having to accept prices that cover marginal costs and make a small contribution to overheads. Another reason for low prices, however, is that in some countries inputs are still not charged at market rates. Electricity in Poland, for example, is half the normal international price. Adjustments are taking place fast and so product prices will also rise, even in the next 2-3 years.

6.4 Few forecasters will attempt to predict the supply and demand balance for semi-finished products except in the very short term. It will depend very much on the decisions taken by investors like SSIC as they build new projects. For example, a recent study estimated that in the Pacific region there was a need for an extra 30 million tonnes of finished products capacity by the year 2000, over and above announced projects. If only rolling mills are built, and people take the same view as SSIC about purchasing semis, the supply and demand imbalance may disappear quite quickly. If, on the other hand, they all build integrated works, then it will persist for longer.

6.5 The three main inputs for steelmaking are ferrous materials, energy and capital. Thailand has no clear advantages in any of these, but in the long term there should be no reason why it cannot compete in steelmaking, at least for producing its own requirements where it will have a "freight cost protection" of about US$35/tonne. The following comments apply to the main areas of costs:

- Scrap costs in Thailand are high because of the lack of material generated within the country and within the SE Asian region as a whole. Currently most scrap comes from North America. As more mini mills are built in developed countries there will be a trend towards using scrap closer to where it is generated, rather than exported it;

- Other ferrous costs need not be higher than average. An extended port at Bang Saphan could take 150,000 dwt bulk carriers which is an economic size in world terms and especially so if ore was to come from Australia;

- Electricity costs in Thailand are equivalent to about US$0.06 per kWh which is similar to the price in most developed countries. In some Eastern European countries steelmakers pay less, but this is likely to change when market prices prevail;

- Coking coal would need to come from North America, Australia or South Africa and so would not be cheap in Thailand. However, as with ore, the provision of facilities to unload 150,000 dwt vessels would minimise the disadvantage. Steam coal for the Corex option could also come from Australia and the same comments apply;

- Gas is expensive in Thailand compared to many places where DRI plants have been installed. Even the well-head cost of 2.1 US$/MBTU is well above what customers pay in oil producing countries.

6.6 Energy and ferrous costs need not, therefore, be substantially higher in Thailand than in many other countries. There is no reason why the cost of capital should be more either but there is a critical difference in this case. The options are being evaluated from the point of view of a private company, not a state-owned enterprise. A private developer will expect a greater return from his investment than will the state. In the past public sector companies have often had other motives in mind when investing in steel, for example self sufficiency, employment generation, etc. It has not been an industry which has made large profits and it is uncommon at present to find private sector companies investing in steelmaking except in fairly special circumstances.

6.7 There will be two challenges for SSIC if they choose to rely on purchased slabs. Firstly quality will need to be carefully monitored, especially if slabs come from various suppliers. In Eastern Europe, for example, it is still common to find slabs produced from ingots rather than a continuous caster. Secondly the supply and procurement mechanism will need to be efficient to ensure continuous production and at the same time reasonably low stock levels of coils or slabs.

Bang Saphan as a Location for Steelmaking

6.8 Table 5.1 summarises some measures of performance for each steelmaking option. As has already been explained, none of them yield high rates of return, except with slab prices considerably higher than at present. If this situation changes or if SSIC find it impossible to adequately control quality and quantity, then one of the steelmaking options may be introduced. The main issues associated with each are described below.

TABLE 5.1 - MAIN FEATURES OF ALTERNATIVE SCHEMES

Item	Purchase Slabs	EAF with 100% scrap	EAF & gas based DRI	Blast furnace & BOF	Corex & BOF
Cost of slabs	US$270	US$284	US$293	US$289	US$287
Capital Cost	none	low	low	high	high
Project rate of return (a)	n/a	3.7%	3.0%	6.1%	5.8%
Need for port expansion	no	no	yes	yes	yes
Need for new power plant	no	yes	yes	yes	yes
Need for gas connection	no	no	yes	no	no
Environmental impact	none	small	small	large	medium

(a) Port and water investments included in capital costs, slab price US$270

Scrap-based steelmaking

6.9 The principal advantage of this option is its relatively low capital cost. This, however, is offset by the need to build a large power station close to the site in order to provide an electricity supply of sufficient strength. The size of this station would need to be much larger than the actual energy requirements of the plant so electricity would need to be transmitted long distances to other consumers. The port would be adequate as scrap could be handled on the berths to be built for importing slabs.

6.10 Importing about two million tonnes of scrap per year would add to Thailand's dependence on scrap. The long products plants will also be seeking considerable quantities of scrap. Currently it is difficult to use scrap for making high quality, deep drawing steels but the Consultants believe that this restriction will eventually be removed.

Electric arc furnaces with DRI as the main feedstock

6.11 As with scrap-based steelmaking, this option would require a very large investment in the electricity supply. It would also depend upon PTT building a pipeline from Khanom to the north and the port would require expansion. The technology, however, is proven and there will be no problems obtaining feedstock.

6.12 The rates of return are not attractive even without the investments needed to supply sufficient electricity and gas. At the highest slab price considered, it is still only 5-6%.

Blast furnace and BOF steelmaking

6.13 This option has very high capital costs but rates of return a little higher than those under the DRI alternative. It would not require the same level of infrastructure investment, as the power requirements are smoother and there is no need to supply gas. A significant disadvantage of this option is that it has a large environmental impact. If coke ovens and a blast furnace were built at Bang Saphan, the nature of the region would be changed dramatically.

6.14 This option might become more financially attractive if a larger size of operation was envisaged, ie feeding the second strip mill. It is the only one where there are still economies of scale to be reaped beyond the 2 million tonne level. These effects are unlikely to affect the results much, however.

Corex Ironmaking and BOF Steelmaking

6.15 This is a less proven option than the others, but has a number of interesting features. It does not require large investments in gas and electricity and so is attractive for an isolated site like Bang Saphan. It has less environmental impact than the blast furnace route and similar rates of return. These depend, however, on the area having other industries or for a power plant to be built in order to provide customers for the excess gas produced as part of the Corex process.

6.16 SSIC are monitoring the technical progress of Corex as it develops over time.

Other Possible Uses of Bang Saphan

6.17 SSIC plan to expand the activities they carry out at Bang Saphan. In particular they wish to build a second hot strip mill to double their output of hot rolled coil. They also wish to attract other industries to the site. Some people in Thailand are sceptical about whether they will be successful in this but at some stage new industrial areas will be needed as and when the Eastern Seaboard becomes "full".

6.18 Its principal advantage is that it has deep water at a close distance from the shore. In Thailand this is unusual and presents a real benefit. What it does not have at the present time is a strong electricity supply nor gas. It could not yet, therefore, host the proposed DRI plant to provide an alternative feedstock to the long products mini-mills.

6.19 For the second strip mill it is estimated that a power station will need to built near the site. The present supply has sufficient energy but insufficient strength to cater for processes that require large surges of demand over short periods. The port will also require more berths.

6.20 Other industries could be developed without major investments. They could be large users of hot rolled coil making such things as structural steelwork, containers, railway wagons, small ships, etc. These items could be shipped by sea or transported overland and do not require a local market in the same way as consumer orientated products. They could be users of galvanised steel or cold rolled products, making office furniture, household appliances, etc. If Thailand becomes a good country from which to export products made of steel then Bang Saphan may find itself in a good position to capture industries of this nature.

Steelmaking at Other Locations

6.21 The advantage of Bang Saphan as a site for making slabs is the proximity of relatively deep water near to the coastline. The disadvantage is that, for any type of steelmaking, a power station will need to be built. For electric steelmaking it would need to be a very big power station producing much more electricity than would be required for the plant.

6.22 If steelmaking were carried out at Map Ta Phut and the slabs transported to Bang Saphan, a strong power supply would probably be available and so all of the options might be feasible.

6.23 There are, however, several cost disadvantages to this type of arrangement. Firstly ship sizes will be much smaller. Even if Map Ta Phut is dredged to take 60,000 dwt vessels for the proposed DRI plant, ore and coal would cost about US$2 to 3 per tonne more, than at Bang Saphan. Then slabs would need to be transported, adding a further US$6 to 7 per tonne.

6.24 If electric steelmaking (and particularly scrap based steelmaking) was showing a much higher rate of return than the other options there might be a case for considering Map Ta Phut. This, however, is not the case and it would not seem to be an attractive option now that the location of the rolling mills is fixed.

7. THE IMPLICATIONS FOR GOVERNMENT

7.1 The steel industry has been given a high priority in the 7th National Plan. The aim is to broaden the range of products made in Thailand and to substitute imports with domestic production, within an overall framework of private sector involvement. Government might participate in "multi-user" projects, such as the proposed DRI plant where the aim is to diversify the feedstock available to the long products melters but it does not intend to make other major investments within the sector.

7.2 This report has shown that, under existing market conditions it is unlikely that steelmaking will be an attractive venture for a private sector investor like SSIC. It is doubtful whether any practical assistance from Government could change this conclusion.

7.3 An approximate estimate of the foreign exchange savings resulting from a steelmaking project is a net present value (at a 10% discount rate) of about 15 billion baht over the 25 year period. This and an employment generation of about 1,400 direct workers represent small benefits to the country; insufficient for the Government to want to intervene in an active way. There are, however, issues that are important for the future of the flat products industry and for the project at Bang Saphan.

7.4 The market forecasts would suggest that the SSIC project is unlikely to satisfy all the demand for flat products in the future. The situation is complicated by the granting of an exclusive licence to SSIC for a ten year period starting in 1989. A way needs to be found of stimulating further investment without threatening the huge investments already made or committed by SSIC.

7.5 There are three areas where Government policies will impinge on the future production of flat products, namely:

- the licensing of new projects;
- the setting of tariffs;

- acting as a facilitator to ensure that developments are carried out as effectively and speedily as possible.

The Licencing of New Projects

7.6 There are companies which wish to produce flat products but are barred from doing so under the terms of the licence agreed with SSIC. This is a difficult area for Consultants to comment upon but two general points can be made. Firstly, with regard to hot rolled coil, it must be in the best interests of the Thai economy that:

- SSIC be allowed to "expand" their capacity from the 1.8m tonnes in the licence to the 2.5m tonnes currently sought. This extra capacity is already built into the present strip mill design and will make it a more economic project.

- Other companies be allowed to apply for licences to build plants as soon as legally possible. It may be that a second hot strip mill at Bang Saphan will prove to be the best option but we would expect that the new technology of thin slab casting would be able to compete well with it, even using largely imported scrap.

7.7 Secondly, with regard to cold rolled products, the Government should encourage SSIC to make their plans known as soon as possible regarding the design of the cold mill. Knowledge of its intended product range will allow an assessment to be made of what other projects will one day be needed. Here again, it will make for a more economic project if the capacity of the plant is increased to the 1m tonnes currently spoken of. At the same time further projects should be approved as the licence agreements allow.

The Setting of Tariffs

7.8 It is the intention of the Government that, in general, tariff protection will be lowered as industries become more ab[illegible] with foreign suppliers. The Asean negotiations will only encour[illegible]ess. The long term aim for tariffs is broadly as follows:

Raw materials	0%
Intermediate products	10%

Finished products	20%

The Thai Industry Federation (TIF) have proposed a five-part breakdown as follows:

Basic raw materials	0%
Other raw materials	1-5%
Intermediate raw mats	5-10%
Intermediate products	10-15%
Finished products	20-30%

7.9 The problem with both of these classifications is the definition of intermediate and finished products. Within the steel industry, hot and cold rolled coil are finished products, and ones which have required considerable processing. Within the economy as a whole, however, they are still intermediate goods.

7.10 With respect to setting the tariffs on flat products there are two counter-balancing arguments to be born in mind. Firstly steel is often sold on the export market at prices lower than the full cost of production. Some protection is therefore justified and is common in many countries. This takes the form of customs duties, quotas or "voluntary" agreements. Such protection is presumably even more valid when an industry is still in an early stage of development. Even the most efficient producer would find it difficult to justify a new steelworks based only on international prices. Against this is the fact that there are several important industries within Thailand which rely on steel as their prime raw material. It would be wrong to harm some industries simply in order to help others, especially when one is a monopoly producer.

7.11 Table 7.1 shows the import duties charged on hot and cold rolled coil in a variety of different countries. It can be seen that in South East Asia generally, duties on these products are generally in the region of 0% to 10%, that is of the same order as "intermediate raw materials" in the TIF list. It is only the less developed countries such as India and Pakistan where duty rates are much higher than these levels. Currently Thai rates are 12% (or less in some sub-categories) for hot rolled coil; and 400 baht (ie about 3%) for cold rolled coil.

TABLE 7.1 - IMPORT DUTIES IN SELECTED COUNTRIES

Country	Import Duty (hot/cold rolled coil)
India (a)	45%
Pakistan(a)	50%
Philippines	10%
Malaysia	2%
Indonesia (b)	5%
Taiwan	8%
S.Korea	10%
Singapore	0%
Australia	5-10%
New Zealand	10%
Japan	0%
US	5-6%
EC (c)	4%-5%

(a) average figures
(b) some sub-categories have higher rates
(c) for countries without preference status

7.12 It would appear that, if Thailand is to align itself with other countries, in the long term the tariff for flat products should be set at about 10%; ie. the Government proposed rate for intermediate products. In the early years of the SSIC project it might need to be higher than this. A maximum of 20% would meant that it still had a rate of duty equal to or lower than that of finished products.

7.13 In the long products sector, there is an annual debate regarding the continuation of a temporary low tariff imposed when production was unable to keep pace with surging demand. While this has several disadvantages, principally uncertainty for the producers and speculative buying, it may be the type of arrangement that will be necessary in the early years of the flat products project. In this case discussion will revolve around the profits being made by SSIC and by steel consumers, and will take into account world steel prices. It will not be difficult, given a knowledge of the prices of slabs and finished products, to see whether disproportionate profits are being made. A bi-annual review might be the best approach, perhaps bounded by a pre-set upper and lower limit.

7.14 An alternative would be to fix in advance a gradually reducing target so that everyone would know where they stood and could make their plans accordingly. If this approach is to be adopted, decisions should be made as soon as possible in order to remove uncertainty, particulary for SSIC.

7.15 Tariff policy is not a practical or desirable method of "encouraging" SSIC to integrate backwards to steelmaking. It has been shown that, in present market conditions, steelmaking at Bang Saphan is unlikely to be a profitable venture. Increasing the duties on semi-finished products would necessitate the increasing of duties on hot and cold rolled coil. As we understand it, it would not be effective anyway as the BoI promotional terms will exclude SSIC from paying duties, at least in the early years.

Facilitating New Projects

7.16 It is common in most developed countries that infrastructure such as utilities, port facilities and inland transport links are provided by Government agencies. It is generally the case in developing countries as well though in a few recent projects, private sector steel producers have had to pay for their own electricity and water supplies. SSIC are paying for their own water supply system, the port, and a proportion of the costs of the temporary sub-station.

7.17 Thai Government agencies are, however, in a difficult position in this respect. SSIC have chosen their own location knowing that it is in an isolated position without many back-up services. Bang Saphan is also a single user site and so it is not in the same position as facilities provided by the Industrial Estates of Thailand. Bang Saphan is a reasonable location, however, for industries making heavy and capital goods and it should be to the benefit of Thailand if some joint venture arrangement could be made between IEAT and SSIC.

7.18 There are several small ways in which the Ministry of Industry might assist the current SSIC project:

- It could encourage the Highways Department to bring forward the rehabilitation of Road No 3169;
- It could involve itself in monitoring progress on the provision of an adequate power supply for SSIC, an area of concern for the project's managers;
- It could facilitate the provision of good local technical education for prospective employees at Bang Saphan;

- It could commission a detailed market survey of end users to help SSIC plan its cold mill. Such a study would also allow better decisions to be taken about further licences when the time arises;

- It could help SSIC to obtain speedy approvals for its port developments. This is of critical importance to the success of the project.

APPENDIX I

IMPORTS OF FLAT PRODUCTS
1988 - 1991

TABLE 1 - HOT ROLLED COILS AND SHEETS (>600mm)

Item	Customs Code	1988	1989	1990	1991
>10mm	7208.110	26,745	12,763	100	267
	7208.210	47,405	92,121	119,400	95,467
	7208.320	33,379	13,335	15,200	46,933
	7208.420	134,123	199,496	142,300	170,533
		241,715	317,715	277,000	313,200
4.75-10mm	7208.120	18,897	22,407	7,100	8,933
	7208.220	246,720	271.280	254.600	247,600
	7208.330	21,257	12,765	13,800	24,800
	7208.430	45,384	51,921	71,400	85,467
		332,258	358,373	346,900	366,800
3.00-4.75mm	7208.130	29,715	29.481	16,600	33,067
	7208.230	217,896	223,553	200,000	317,333
	7208.340	7,182	3,419	2,500	11,467
	7208.440	15,308	22,979	20,400	19,200
		270,101	279,432	239,500	381,067
<3mm	7208.140	104,224	144,510	67,900	106,133
	7208.240	260,732	481,956	461,000	669,067
	7208.350	8,936	7,077	4,900	4,000
	7208.450	8,037	25,887	15,100	11,067
		381,929	659,430	548,900	790,267
Other	7208.310	28	3,865	400	133
	7208.410	246	2,357	500	800
	7208.900	5,666	29,854	25,900	14,133
		5,940	36,076	26,800	15,067
Total	7208	1,231,880	1,651,026	1,439,100	1,866,400

1991 is Jan-Sept x 1.33

TABLE 2 - COLD ROLLED COILS AND SHEETS (>600mm)

Item	Customs Code	1988	1989	1990	1991
>3mm	7209.110	231	496	1,400	2,667
	7209.210	18,968	21,034	19,100	8.667
	7209.310	655	478	7,600	3,600
	7209.410	3,919	5,340	3,500	267
		23,773	27,348	31,600	15,200
1-3mm	7209.120	22,298	15,615	15,900	23,733
	7209.220	110,159	108,707	156,500	153,333
	7209.320	11,917	7,763	4,400	14,667
	7209.420	28,094	23,857	22,200	29,200
		172,468	155,942	199,000	220,933
0.5-1mm	7209.130	42,685	16,583	20,300	29,333
	7209.230	132,535	108,858	156,900	216,000
	7209.330	15,023	9,943	4,900	6,667
	7209.430	19,510	19,372	24,900	24,667
		209,753	154,756	207,000	276,667
<0.5mm	7209.140	217,206	328,651	358,100	410,800
	7209.240	162,518	84,328	107,000	98,800
	7209.340	3,245	3,168	2,800	3,200
	7209.440	1,918	2,847	3,900	6,000
		384,887	418,994	471,800	518,800
Other	7209.900	891	1,997	1,200	1,733
Total	7209	791,772	759,037	910,600	1,033,333

1991 is Jan-Sept x 1.33

TABLE 3 - OTHER FLAT PRODUCTS

Item	Customs Code	1988	1989	1990	1991
Width > 600mm					
Tinplate	7210.110/120	80,274	75,771	39,500	56,667
Electro-galvanised	7210.310/390	59,837	47,208	86,500	104,667
Hot-dip galvanised	7210.410/490	50,274	28,809	53,700	80,800
Other coated	7210 (nes)	65,298	67,305	54,500	94,667
Total	7210	255,683	219,093	234,200	336,800
Width < 600mm					
Hot-rolled	7211.110-290	14,583	17,811	10,900	13,600
Cold-rolled	7211.300-900	14,489	9,131	10,100	12,133
Coated (various)	7212	16,755	19,064	26,300	36,400
Total	7211-7212	45,827	46,006	47,300	62,133