A STUDY INTO STEEL PROCESSING AND RECYCLING INDUSTRY IN KENYA

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A Study into Steel Processing and Recycling Industry in Kenya

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university.

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This thesis has been submitted for examination with our approval as the University Supervisors.

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DEDICATION

This work is dedicated to my parents, Machira and Wangũi.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABBREVIATIONS

AAS	Atomic Absorption Spectrometry
AE	Annual Earnings
AOC	Annual Operating Costs
BOF	Basic Oxygen Furnace
CGE	Computable General Equilibrium models.
EA	Environmental Audit
EAF	Electric Arc Furnace.
EIA	Environmental Impact Assessment.
EMCA	Environmental Management and Co-Ordination Act.
FMR	Firms Mean for the period under Review
GDP	Gross Domestic Product.
IAE	Initial Annual Earnings, (before upgrade).
IAOC	Initial Annual operating costs, (before upgrade).
IISI	International Iron and Steel Institute
IM	Industry Mean for the Review Period
IMY	Industry Mean for the Year
INE	Initial Net Earnings, (before upgrade).
KAM	Kenya Association of Manufacturers.
KEBS	Kenya Bureau of Standards.
KISMA	Kenya Iron and Scrap Metal Association.
KNBS	Kenya National Bureau of Statistics

KRA	Kenya Revenue Authority.
Mt	Metric tonnes.
NE	Net Earnings.
NEMA	National Environment Management Authority.
NPV	Net Present Value
ppm	Parts per million
PV	Present Value
SPIM	Steel Plant Investment Model.
TIC	Total Initial set up Cost.
UAE	Upgraded Annual Earning.
UAOC	Upgraded Annual Operating Cost.
UNE	Upgraded Net Earning.
UPC	Upgrading Cost.

NOMENCLATURE

D	Density of the ore $[tons/m^3]$
DF	Present value factor
IU_t	Intensity of Use for steel in period t
K	Points at which steel consumption is known as a function of time.
MCP_{it}	Average quantity of steel per product of industry i in period t [tons]
MCP_t	Steel consumption of product of industry in period t in tons
N	Total number of points for which function values are known.
P	Approximating function
P_1	Linear function of steel consumption with time
PCI_t	Relative share of production of industry i to the gross domestic product
$P_b(t)$	Consumption of steel by bus and truck body building industry [tons]
$P_c(t)$	Consumption of steel by construction industry [tons]
P_i	Consumption of steel by industry i [tons]
P_{it}	Consumption of steel by industry i in period [tons]
$P_w(t)$	Consumption of steel by wire and wire products industry [tons]
Q	Quantity of iron ore [tons]
R	Discount rate
S_{it}	Steel consumption by industry i in period t [tons]
S_t	Total steel consumption in period t [tons]
t	Time period [years]
T_t	Time trend

V	Volume of the ore $[m^3]$
α	Constant term in the function of MCP_t
β_i	Rate of change of MCP_t with time
ρ_i	Rate of change of P_i with time
ϕ_i	Constant term in the function of MPC_t

ABSTRACT

The main objectives of the study were to determine the consumption patterns of steel and availability of iron ore, and establish the efficiency of the Kenyan steel industry. Currently, most of the information available is outdated and scattered over several sources, making it unreliable and inaccessible. The study was carried out on steel consumption patterns, efficiency of the local steel industry, and mechanical properties of steel obtained from local scrap.

The effects of the government policies and regulations, i.e., environmental policies, regulations on scrap metal dealership, taxation regimes on importation of raw steel and labor laws on the industry were also investigated. The various metal forming processes adopted in the country were also studied. The efficiencies of these processes were compared with the global practice.

Data was collected by use of questionnaires and interviews. Selected firms were visited so as to obtain specific industry information. The mechanical properties of the steel obtained from steel scrap were compared with the standard specifications for the products. This provided information on the suitability of the steel to the final application.

The results of this study show that the consumption of steel in 2008 was 0.9 million metric tons. It was projected that in 2030 the consumption will be 2.9 million metric tons. This projection was used in determining the size of the proposed steel plant. It was also observed that the mechanical properties of steel obtained from scrap satisfy the statutory requirements. Existing environmental policies and regulations that

impact directly on the steel industry were also established. The study also revealed that the Kenyan steel industry lags behind the global practice in terms of capacity utilization and efficiency. Global average capacity utilization rate was 72% while in Kenya it was only 46% on average.

The study also revealed that iron ore exists in sufficient quantities for commercial exploitation. In particular, 78 million tons of ore exist in Kithiori Area of Tharaka District, with an iron content of 62.35%.

During the study, it was assumed that the average gross domestic product growth would be at least 5% per annum. It was also assumed that no new materials will be developed that will substantially replace iron and/or steel in the identified sectors.

The results of the study will provide both existing and potential investors in the steel industry with information on the dynamics of the Kenyan steel market. Existing investors will be able to compare their efficiencies against the global practice, hence improve their competitiveness, while potential investors will have information on the viability of establishing steel plants, their sizes and locations in the country.

CHAPTER 1

INTRODUCTION

1.1 Overview

Iron is the most common of all commercial metals. It was first obtained from meteorites and was discovered five to six thousand years ago [1]. The most common iron ores are magnetic pyrites, magnetite, hermatite and carbonates of iron [2]. For economic extraction of iron from the ore, the ore should have at least 50% iron content. Otherwise, if the content is less, the iron content of the ore has to be increased through beneficiating [1]. To obtain iron, the ores are fused to remove oxygen, sulphur and other impurities. The melting is done in a blast furnace, directly in contact with coke and limestone as the flux. The resulting product is crude pig iron which requires subsequent re-melting and refining to obtain commercially pure iron. If iron contains more than 0.15 % chemically combined carbon it is termed as steel. The percentage content of carbon, among other elements determines the properties of the steel [2].

The value of the annual global steel production is way over US$ 200 billion. Over the past twenty years, in the industrialized countries, i.e., Japan, U.S.A., Germany among others, there has been massive investment in new products, new plants and technology. The result has been a considerable improvement in the performance of steel products and a related reduction in energy use and consumption of raw materials in their manufacture [3].

In Kenya, steel is mainly used in the construction industry and in the manufacture of wire products such as barbed wire, chain link and nails. The main sources of steel in the country are imports and local scrap. The main sub-sectors in Kenya's metal industry are steel smelting and hot rolling, manufacture of wire and wire products, pipes, galvanized and cold rolled steel products. These sub-sectors are interrelated as they depend upon each other for the supply of inputs [4].

With the current economic growth in Kenya, (0.5 % in 2002, 2.9 % in 2003, 5.1 % in 2004, 5.8 % in 2005, 6.3 % in 2006 and 7.1 % in 2007) [5–7], many opportunities will be created for investors. Since steel is a major raw material for most industries, high growth in the steel industry is expected. This makes it important to investigate the dynamics of the steel industry in the country. Furthermore, the Kenya Government recently launched 'Vision 2030'. This is a road map on how the country will transform into an industrialized middle-income state by the year 2030.

To attain this goal, increased skilled manpower, capital, energy and raw materials will be required. Steel, as a raw material, finds use in almost all industries including agricultural, construction and general metal industries among others. It is therefore necessary to have a thorough understanding of the status of the Kenyan steel industry.

1.2 Statement of the Problem

The consumption of steel in the world has been steadily increasing over time. In Kenya, the recent increase in economic growth has also resulted in increased steel consumption. The increased economic growth has been driven by increase in volumes rather than improvement in efficiency and productivity. While information on the Kenyan steel industry exists, it is scattered among numerous sources and therefore it is not easily accessible. Also, some of the information is outdated since no comprehensive study has been carried out in recent times. These factors necessitated a study on the Kenyan steel industry so as to identify firm level inefficiencies and identify ways to increase competitiveness. The study also seeks to provide stake-holders with a unified source of up to date information. The outcome of the study can be utilized in improving firm level efficiencies and competitiveness, resulting in creation of more jobs and reduction in construction costs, among other benefits.

1.3 Objectives of the Research

The main objective of the research was to develop an investment model, which can be used to determine the viability of establishing new steel plants, their sizes and locations in the country. To accomplish this objective, the following specific objectives had to be met.

To:

i) Study the patterns of steel consumption in Kenya over a period of time and establish projections.

ii) Determine the mechanical properties of steel obtained from local scrap.

iii) Establish the government environmental policies and regulations for the steel industry.

iv) Establish the efficiency of the Kenyan steel industry and compare it with the global practice.

v) Establish if iron ore exists in sufficient quantities in the country for commercial exploitation.

1.4 Outline of thesis

This thesis is organized in six chapters. Chapter one is the introduction while chapter two is a critical literature review on the steel industry. Chapter three describes the methodology that was adopted in carrying out the study. Chapter four describes the development of the investment model. In chapter five, results and discussions from the study are presented. Lastly, chapter six is dedicated to conclusions and recommendations.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

The metal products sub-sector, which falls under the manufacturing sector plays a vital role in the country's economy especially with the industrialization strategy [8]. Globally, steel consumption has been steadily increasing over time.

World iron and steel production has continued to show large increase since 2002, due to rapidly increasing steel demand in China, India and other developing countries. Annual crude steel production achieved the one billion tons mark for the first time in 2004 [9].

Data from the International Iron and Steel Institute, (IISI), shows that the annual world production of crude steel since 1950 has increased from 189 to 1244 million metric tonnes in 2006. The trend is presented in Table 2.1 [10].

In 2004, the prices of raw materials in steel production, i.e., coke and iron ore, increased by approximately 70%. This was however mitigated by the steady increase in the international price of steel, from about US$ 600 per ton in 2003, to about US$ 950 per ton in 2005 [9].

As early as the 1940s, deposits of iron ore had been prospected in Kenya. These included haematite and magnetite ores in Machakos, magnetite sands on the shores of Lake Victoria and pyrite ores in Nyanza Province. Some iron stone clays had also

Table 2.1: World Crude Steel Production from 1950 - 2006

Year	World Production (Million Metric tons)	Year	World Production (Million Metric tons)
1950	189	1997	799
1955	270	1998	777
1960	347	1999	789
1965	456	2000	848
1970	595	2001	850
1975	644	2002	904
1980	717	2003	970
1985	721	2004	1,069
1990	775	2005	1,142
1995	756	2006	1,244
1996	755		

been prospected in Coast Province. Other noticeable deposits are found in Marimanti area of Meru districts. [11].

The main sources of steel in Kenya are recycled scrap and imports. Steel is usually imported in the form of billets [12]. Recycling of steel scrap is preferred as it uses 60 % less energy to produce steel from scrap than from iron ore [3]. The government of Kenya banned the exportation of scrap steel in its 2009/2010 financial year budget [13]. This is expected to spur local recycling of steel.

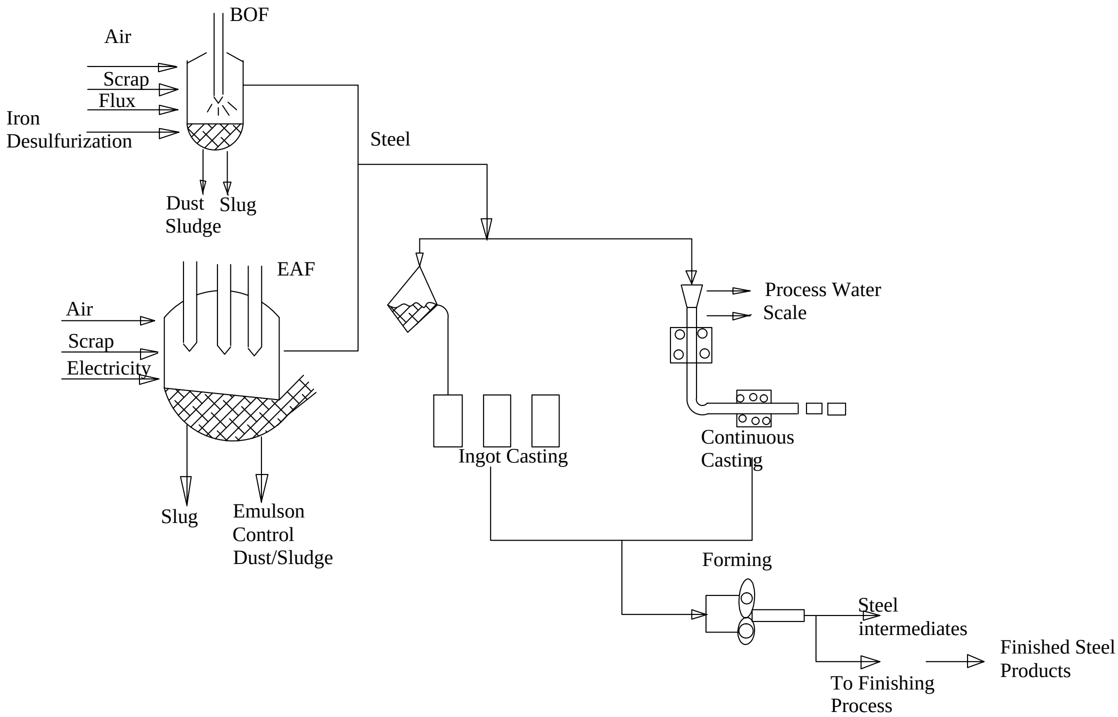

Figure 2.1: Schematic diagram of steel processing

In steel production, two processes are mainly adopted: using an integrated steel manufacturing process or a direct reduction process. A schematic diagram of the two processes is presented in Figure 2.1.

In the conventional integrated steel manufacturing process, the iron from the blast furnace is converted to steel in a Basic Oxygen Furnace (BOF). Steel can also be made in an Electric Arc Furnace (EAF) from scrap steel and in some cases, from directly reduced iron. Directly reduced iron is produced by reducing iron ore in the solid state at elevated temperatures (about 900^oC), using a reducing gas,(usually a mixture of hydrogen and carbon monoxide) or coal. Traditionally, BOF is typically used for high-tonnage production of carbon steels, while the EAF is used to produce carbon steels and low-tonnage special steels [14].

2.2 Steel as an Engineering Material

Steel is a major engineering material due to its availability, relatively low cost and high strength. It may be used in the 'as cast' form or it may be further processed by hot or cold working to become wrought steel. It is broadly classified either as plain carbon steel or alloy steel [15].

2.2.1 Plain Carbon Steels

These are steels with negligible amounts of alloying elements, usually less than 1.65% manganese, 0.6% silicon and traces of other alloying elements [2]. Plain carbon steels are used to make castings [2], though depending on the carbon content, they are used for other applications as described below.

Low carbon steels are those whose carbon content is less than 0.25%. These steels have high ductility and are easily cold-worked. Due to these properties, low carbon steel sheets are extensively used for sheet applications in the appliance and automotive industry [16].

Medium carbon steels contain 0.25 to 0.7% carbon [16]. They can be hardened by heat treatment due to the increased carbon content [2]. These steels are mainly used in structural applications.

High carbon steels are those whose carbon content is more than 0.7%. They have high hardness and low toughness. These properties make them useful in bearing applications where high wear resistance is required. In these applications, the loading is compressive which minimizes the risk of brittle fracture that might occur in tensile loading [16]. Specifically, steel with 0.8% carbon content, finds various uses depending on the microstructure. Two microstructures exist, i.e., pure pearlite and tempered martensite. The 0.8% carbon steel with a pure pearlite microstructure finds use in rail making and in the manufacture of high strength wire for ropes and cables, while the tempered martensite 0.8% carbon steel is mainly used for making bearings [17].

2.2.2 Alloy Steels

Plain carbon steels have limitations in terms of corrosion resistance, heat resistance, hardness, toughness and wear resistance. These drawbacks are addressed through the use of appropriate alloying elements. For instance, high manganese steels, i.e., 10 to 14% manganese; 1 to 1.4% carbon and 0.3 to 1.0% silicon have a high wear resistance and are used in the teeth for excavating and earth moving machinery, tractor shoes and in wear resistant castings.

Stainless steels are steel alloys whose main alloying element is chromium [2]. These steels are highly resistant to corrosion and are used in the food industries such as in dairy and catering industries. Vanadium is usually used together with chromium to make strong, tough and hard alloy steels. It increases the tensile strength and improves fatigue resisting qualities of steel [2]. Alloying elements generally increases the cost of production of the steel. For instance, to produce a stainless steel with 12% chromium, an extra cost of US$ 455 per ton would be incurred, over the equivalent plain carbon steel, since the international price of chromium was US$ 3790 per ton as of December 2007 [18].

Nickel is used as an alloying element, jointly with either chromium and/or molybdenum. Nickel-chromium steels are used where high tensile strength and high hardness are required. On the other hand, nickel-molybdenum alloy steels are characterized by high toughness and when case hardened, tough cores are obtained. When both molybdenum and chromium are jointly used with nickel in alloy steels, improved impact and oxidation resistance are achieved [2].

Though alloying elements improve the properties of steel, they increase the cost of producing the steel. For instance, the international price of nickel as of December 2007 was US$ 9855 per ton [18]. This implies that to produce a 5% nickel steel, an extra cost of at least US$ 500 per ton will be incurred. Molybdenum is an expensive alloying element, with an international price of US$ 73855 per ton as of December 2007 [18]. This would translate to an extra cost of at least US$ 740 per ton for a steel containing 1% molybdenum.

In Kenya, steel used in the construction industry is classified as either mild steel or high yield steel. Mild steel is normally used for manufacturing mild steel bars, cold worked steel bars and hot rolled steel sections. The maximum allowable content of elements are: carbon (0.28%), manganese (1.6%), sulphur (0.06%), phosphorous (0.06%) and nitrogen (0.008%). High yield steel on the other hand, has the following maximum allowable content: carbon (0.20%), manganese (1.50%), sulphur (0.05%), phosphorous (0.05%), silicon (0.35%), chromium (0.50%) and manganese plus chromium (1.60%) [19].

2.3 Processing of the Ore

Metals and their compounds are available from three sources. These, in ranked order, are the earth's crust, oceans, and from recycled scrap [20]. The availability of the metals for use is not governed by its abundance alone. For instance, though copper is the third most commonly used metal after iron and aluminium, its concentration in the earth's crust is very low (only about 0.01 %). Also, the annual consumption of iron outstrips that of aluminium, though iron is less abundant than aluminium in the earths crust [20].

High tonnage production of metal depends on:

- i) Accessibility of ore deposits.
- ii) Richness of ore deposits.
- iii) Nature of extraction and refining process for the metal.
- iv) Chemical and physical properties of the metal.
- v) High demand.

A metal is commonly used if it is readily available, easily produced with low cost and has desirable properties [20]. Steel production is dependent on oil for haulage of the iron ore and heating operations in the processing.

However, there have been large fluctuations in the price of oil (from US$ 16 in 1990 to over US$ 60 per barrel in 2005) [21]. These fluctuations have had a significant impact on the world economy and specifically on the metal industry due to increase in mining and processing energy costs [21]. The price of metals, like any other product, is governed by the law of demand and supply. Metal mineral resources are finite, but supply and demand will generally balance in such a way that if production declines or demand rises, the price will rise, motivating search for new deposits or technology to render marginal deposits economically viable or even complete substitution with other materials [21].

The economic recovery of metals from the ores depends on factors such as content and contained value. Content factor can be illustrated in an ore containing 1 part per million gold, which would be profitable to mine, as contrasted to an iron ore with 45% iron content which would be considered low grade. On the other hand, contained value is dependent on metal content and current price of the contained metal. Deposits are economically viable to exploit and can be classified as ore deposits if contained value per ton is greater than total processing costs per ton [21].

Once the ore has been mined, the next step in steel making is the refining to produce iron. This is usually done in the blast furnace. The iron ore together with coke and limestone are charged from the top and are heated by hot ascending gases that are fed from below the furnace. The impurities present, such as silicon, sulphur and alumina combine with the lime and float on top of the liquid iron as a molten slag which is later removed while the molten iron is obtained from the base of the furnace. [22, 23].

The product of the blast furnace is pig iron with 3 to 4% carbon; 1 to 3% silicon; 0.3 to 1.5% phosphorous; 0.1 to 1.0% manganese and less than 1% sulphur [24]. After the pig iron is obtained, it is then converted into steel in a BOF or in an EAF [14].

At this stage, various alloying elements can be added so as to produce steel with the required properties. The most common alloying elements include manganese and/or silicon. Others may be elements not normally found in carbon steels such as nickel, chromium and vanadium [15].

All commercial steels contain some manganese, which is usually introduced during deoxidizing and de-sulphurizing. Steels with 1.0 to 1.5% manganese are called carbon-manganese steels. Medium manganese steels have 2 to 9% manganese. Manganese increases the hardness and tensile strength of steel. High manganese steels, with 10 to 14% manganese content, are very hard and are machined with tungsten carbide or high speed steel tools. They are used in applications where wear resistance is a desirable property, such as in wear resistant castings [2]. As of December 2007, the price of manganese was US$ 1821 per ton [18]. This implies that alloying steel with manganese also increases the production cost. For instance, to obtain a steel with a 10% manganese content, an extra cost of at least US$ 182 per ton will be incurred.

Silicon is found in all commercial steels, usually 0.10 to 0.35% as a residue of the silicon used as a deoxidizer. However, the content may be increased as an alloying element, to between 3 and 5% to increase magnetic permeability. Silicon also improves wear resistance and acid resisting properties of steel. Silicon content of up to 1.75% increases the elastic limit and impact resistance without loss in ductility. Silicon increases electrical resistivity and decreases hysteresis losses, making silicon steel an important material for magnetic circuits where alternating currents are used [2]. The price of silicon as of December 2007 was US$ 1609 per ton [18]. Since silicon is used in small quantities when alloying steel, the increase in the cost of production will also be minimal. For instance to produce a steel with a 1.75% silicon content, an extra cost of approximately US$ 30 per ton will be incurred.

Vanadium, when present in small amounts in certain ferrous alloys, can significantly improve their properties. Manufacturers of automobiles and machinery recognized the toughness and fatigue resistance of vanadium alloys as far back as the early 1900's, incorporating the alloys in axles, crankshafts, gears, and other critical components. Vanadium has been used together with aluminum to give the required strength in titanium alloys used in jet engines and high-speed airframes [15]. The international price of vanadium pentoxide (V205) in 2007 was US$ 17,000 per ton [18]. This cost of production would increase proportionately depending on the vanadium content of the steel.

2.4 Main Forming Processes in the Steel Industry

Metal forming processes are possible due to the property of the metal to flow plastically in the solid state without deterioration of its properties. The processes are mainly classified as either hot working or cold working. The difference is that hot working is carried out above the metal's re-crystallization temperature, while cold working is carried out below the re-crystallization temperature [25].

The main advantages of hot working include [26, 27]:

i) There are no residual stresses.

ii) Percentage reduction can be higher than in cold working.

iii) Porosity of ingot is reduced.

iv) Less forces are required due to low elastic strength and high plasticity of metals at high temperatures.

v) There is refinement of grains, improving some mechanical properties.

The main disadvantages of hot working include [26, 27]:

i) There is usually rapid oxidation or scaling of surface, causing poor surface finish.

ii) Close dimensional tolerances are difficult to attain.

iii) Tool life is reduced due to working at high temperatures.

The main advantages of cold working include [26]:

i) Higher production rates since use of furnaces is avoided.

ii) Due to strain hardening, cold worked plain carbon steels can be used instead of costly alloy steels.

iii) Improved surface finish, scale free and bright surface.

iv) Closer dimensional tolerances can be easily achieved.

The main limitations of cold working include [26]:

i) Only small components, usually less than 25mm diameter can be cold worked. Larger components would require very high deforming forces, hence heavier and more expensive equipment.

ii) Residual stresses on cold worked components may compromise the mechanical properties.

iii) Cold working usually requires high tooling costs.

iv) Low ductility steels cannot be worked at room temperature.

2.5 Efficiency of Steel Plants

Efficiency is a measure of how well a firm consumes resources in order to produce unit output in a given time period [28]. The resources may be in terms of time, raw materials, labor or energy. When comparing efficiencies of different firms, a standard measure is required. Researchers [29], have identified two methods of determining efficiency of steel plants:

1. Labor hours per ton (Lhpt)

   This is defined as the total number of labor hours required to process one ton of steel. It is the ratio obtained by dividing the total number of hours worked in a year by the total steel processed in that year. This measure indicates how efficiently a firm utilizes the human resource and/or if the operations are labor intensive. A high index is undesirable as it indicates a high labor requirement and/or poor human resource utilization.

2. Value added per employee

   This is defined as the value added to the raw materials by each employee. The input to the plant are raw materials, which go through a transformation (value addition) process, to obtain the required product. To compute the value added per employee index, the cost of the raw materials is deducted from the ex-factory price of the total goods produced in a year. This gives the value addition, which is then divided by the total number of employees to give the value addition per employee. This index indicates the efficiency of both the process and the human resource. A high index indicates that the process and the employees are adding more value, other factors being constant.

2.6 Forecast of Steel Consumption

The fundamental purpose of forecasting is to reduce, or at least clarify the uncertainty of a future event. Most production forecasting systems are built upon extrapolating time series data, i.e., a historical record of past activity is used to determine projected future demand. The main assumption is that the future is related to the past in some way [30].

The most basic rate used in steel products consumption forecasting is intensity of steel use rate [31]. The intensity of steel use, in year t for industry i, (IU_{it}), is the quantity of steel consumed per GDP unit. Therefore, it can be determined for a given year as [31]:-

$$IU_{it} = \frac{M_{it}}{GDP_t} \tag{2.1}$$

where

M_{it}	Quantity of metal used in year t by industry i.
GDP_t	Gross Domestic Product in year t

According to Crompton, [32], the total quantity of steel consumed in year t is given as:-

$$S_t = \sum_{i=1}^{n} \left(\frac{S_{it}}{P_{it}} \times \frac{P_{it}}{GDP_t} \times GDP_t\right) \tag{2.2}$$

or

$$S_t = \sum_{i=1}^{n} (MCP_{it} \times PCI_{it} \times GDP_t) \tag{2.3}$$

or

$$S_t = \sum_{i=1}^{n} (IU_{it} \times GDP_t) \tag{2.4}$$

where

S_t	Total steel consumed by all industries in year t.
n	Total number of steel consuming industries
S_{it}	Steel consumed by industry i in year t
P_{it}	Total value of production by industry i in year t
IU_t	Average intensity of steel use across the n consuming industries in year t
MCP_{it}	Average quantity of steel per product of industry i in year t
PCI_{it}	Relative share of production of industry i to the Gross Domestic Product in year t
GDP_t	Gross Domestic Product in year t

Equation 2.2 can be simplified to

$$S_t = \sum_{i=1}^{n} S_{it} \tag{2.5}$$

Changes in steel consumption over time is mainly influenced by two factors. First, new technologies in manufacturing and/or product designing, and secondly, material substitution due to price changes and/or improvement in material characteristics. The uncertain impact of technological changes and the difficulty in forecasting material complicates steel consumption forecasting.

Due to these difficulties, Crompton, [32], has suggested that steel consumption is best approximated by a time trend. The general equation used is given as:

$$MCP_{it} = \alpha_i + \beta_i T_t \quad (2.6)$$

where

MCP_{it}	Material consumption of product in period t for industry i
α_i	Constant term
β_i	Rate of change of consumption with time
T_t	Time period in years

2.7 Investment Models

Investment models are tools that are employed to estimate the benefits of improvements and balance the benefits of these improvements against their costs. Investment models should identify the assumptions made and address how these assumptions alter the estimates [33]. Such models are usually employed when making decisions involving very large investments.

Steel mills are very large industrial real investments. They require large initial investments and have long economic lives [34]. Typical initial costs are US$ 4.2 billion for a 6 million tonnes per year integrated steel plant proposed in 2009 by Essar Steel Ltd in Gujarat, India [35] and a 1 million tons per year, mini steel plant that had been proposed by Ruia Group in 2005 in West Bengal India, at a cost of US$ 125 million [36].

Very large industrial real investments are defined as those with the following three characteristics [34]:

1. Large irreversible initial investments.

   Investments are said to have a high degree of irreversibility when they have attributes that make capital specific to the product, firm or location.

2. Long economic lives, usually over five years.

   The further into the future projections are made, the more difficult it is to forecast accurately.

3. Long time to build, usually several months.

   Very large investments usually take a long time to build. During the period between the investment decision and completion, no revenues are generated. This should be put into consideration when developing the model

2.8 Summary

From the available literature, the following knowledge gaps are evident

1. Available data showed that steel consumption was increasing globally over time. However, consumption trends in the country had not been studied. Through this study, current consumption trends were studied to establish the national steel consumption trend.

2. Previous studies indicated that iron ore was available in the country. However, there was no evidence of studies of how commercially viable it would be to exploit

the ore for the production of iron and steel. This study developed an investment model for determining the viability of establishing new steel plants.

3. One major source of raw material in the steel industry is scrap. However, studies have not been carried out on the quality of steel products obtained from such scrap. Through this study, the mechanical properties of such steel products were tested against the statutory requirements.

4. The efficiency of steel plants in the country had not been established. In this study, selected firms were analyzed to determine the efficiency of a typical Kenyan steel plant.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this study, various tools were used so as to achieve the objectives. These were questionnaires, projections and experiments.

3.2 Questionnaires

A sample of twenty-five firms was selected and questionnaires distributed to them. The questionnaire is included in the appendix of this report. From the questionnaires, the following information was being sought.

3.2.1 Age of Equipment

This was obtained from the date of the last equipment upgrade. Obtaining the age of the equipment aimed at addressing the hypothesis that the age of equipment affects the efficiency and establishing the average age of machines used in the Kenyan steel industry.

3.2.2 Duration Since Commissioning

Generally, the age of an organization affects the efficiency. Old firms would be more efficient if they had continued commitment to continuous improvement and adoption of emerging technologies. Conversely, lack of this commitment would lead to a lag in technology, leading to low efficiency as compared to industry average.

3.2.3 Number of Employees per Shift

The purpose of this information was to obtain data to compute productivity. The parameters proposed by Cyert, R.M. and Fruehan, R.J [29] are labor hours per ton and value added per employee. In this study, labor hours per ton of steel was selected to compare the productivity of the Kenyan steel industry with that of other countries. Labor input was taken as the total hours worked by a firm's employees during the year. This is a productivity measure in which the total number of man-hours required to produce one ton of steel is computed.

3.2.4 Hours of Operation

This information was obtained for the computation of productivity measures, such as labor hours per ton.

3.2.5 Design Capacity and Capacity Used

This information was used to determine if there is sufficient excess capacity to absorb increase in demand of steel.

3.2.6 Market of Products

This was to be used in determining how much the local industry has penetrated the regional market.

3.2.7 Annual Sales, Net Income and Book Value of Assets

These were used in computing the productivity and performance indicators and return of assets. Return on assets is defined as the ratio of net income to the book value of assets.

3.2.8 Quantity and Sources of Raw Materials

This was required for computing the trend and identifying the prospects of import substitution.

3.2.9 Quantities and Costs of Furnace Fuel and Electricity

This was required to compare the productivity of various firms in terms of furnace fuel utilization. The index sought was the ratio of total steel produced in a year to the total fuel consumed in that year.

3.2.10 Research and Development

This was aimed at testing the hypothesis that firms that set aside sufficient funds for research and development have higher efficiency.

3.3 Secondary Data

Most of the secondary data was mainly obtained from the Kenya National Bureau of Statistics.

3.4 Environmental Management

3.4.1 Overview

Environmental management has lately posed great challenges to the steel industry. In 1999, the Kenya Government enacted the Environmental Management and Co-ordination Act, EMCA 1999. In 2002, the government began the implementation of the EMCA 1999, through the National Environmental Management Authority, NEMA. It then became mandatory for all industries to undertake Environmental Audits, (EA), before the end of that year. It also became necessary that all new projects in certain specified areas had to go through Environmental Impact Assessments, (EIAs), before the commencement of any project.

3.4.2 Environmental Impact Assessment

The main goal of an EIA is to ensure that all environmental concerns are integrated in all development activities so as to contribute to sustainable development [37].

As detailed in the guidelines [37], the following information is sought:

- location and nature of project
- soils and geology
- water resources
- drainage
- climate

- vegetation
- land use
- population characteristics
- infrastructure
- justification for the site selection
- materials to be used in the project
- project output including wastes

On addressing the above issues, a project EIA report was prepared. The report mainly dealt with impact identification, impact assessment, adequacy of proposed mitigation measures and the comprehensiveness of the environmental management plans.

3.5 Experiments

3.5.1 Introduction

In Kenya, steel is also obtained from smelting of scrap. Hence it was necessary to analyze the steel obtained from the scrap. The objective of these tests was to determine the tensile strength. The tests were conducted by the Kenya Bureau of Standards Testing Laboratories staff, over a period of one year. The samples had been availed to the laboratory as either private samples, quality control samples or as standard development samples. The tensile test was carried out in accordance with Kenya Standards, Specification for Tensile Testing [38].

3.5.2 Sampling Frequency

The test specimen were collected and sampled as detailed in each relevant standard. For samples tested for conformity to KS02 572 [39] and KS 445 [40], the frequency of sampling was 10 randomly selected samples from each batch not exceeding 35000kg. For samples tested for conformance to BS 4449 [41], a test piece was selected for every batch not exceeding 30000kg, with at least three test pieces per test unit and nominal diameter. For all the samples tested for conformity to KS 573 [42], for the various nominal sizes, the frequency of sampling was as shown in Table 3.1.

Table 3.1: Sampling Frequency

Nominal Size (mm)	Quantity
Under 10	1 sample for each batch not exceeding 25000kg
10 - 16 inclusive	1 sample for each batch not exceeding 35000kg
Over 16	1 sample for each batch not exceeding 45000kg

3.5.3 Preparation of Samples

The samples were prepared as recommended in KS 06 141 [38]. The test pieces tested were of circular, square and rectangular cross sections. For test pieces of rectangular section, the ratio of width to thickness did not exceed 8:1, as recommended in the standard.

Where practicability permitted, proportional test pieces were used (proportional test pieces have the ratio of their dimensions specified through standard specifications). To assure the quality of the test results, the tensile testing machine had initially been calibrated. Prior to commencing the tests, routine quality control checks were performed.

3.5.4 Testing Techniques

In carrying out the actual tests, the limiting straining rates and the rates of stress application, as recommended in KS 06 141 [38] were not exceeded.

3.6 Derivation of the Approximating Polynomial

3.6.1 Normal Equations

Since steel consumption is a function of time, the data obtained from the review period was used to obtain a continuous function, s(t).

$$s(t) \approx P(t, C_0, C_1, ..., C_n) = \sum_{i=0}^{n} C_i(t^i) \tag{3.1}$$

where n is the degree of the polynomial, and

C_0, C_1, ... , C_n are parameters to be determined [43].

To obtain the approximating polynomial, the least squares approximation method was used. In this case, the parameters to determine were C_0, C_1, ... , C_n such that

$$I(C_0, C_1, ..., C_n) = \sum_{k=0}^{N}[s(t_k) - \sum_{i=0}^{n} C_i(t_k)^i] = minimum \tag{3.2}$$

In this case, the values of s(t) are given at N+1 distinct points, t_0, t_1, ... , t_N

Other researchers, [31, 32] have suggested a linear function. However, to validate this assumption, higher order polynomials of up to the third degree were tested. The cubic function that was adopted was of the form:

$$P_3(t) = C_0 + C_1 t + C_2 t^2 + C_3 t^3 \tag{3.3}$$

The quadratic and linear functions are expressed as equations 3.4 and 3.5 below, respectively.

$$P_2(t) = C_0 + C_1 t + C_2 t^2 \tag{3.4}$$

$$P_1(t) = C_0 + C_1 t \tag{3.5}$$

To minimize equation 3.2 partial differentiation was employed, with respect to C_0 , C_1 , C_2 and C_3 respectively, and equated to zero.

$$I(C_0, C_1 t, C_2 t^2, C_3 t^3) = \sum_{k=0}^{N} (s(t_k) - C_0 - C_1 t_k - C_2 t_k^2 - C_3 t_k^3)^2 \tag{3.6}$$

$$\Rightarrow \frac{\partial I}{\partial C_0} = 2 \sum_{k=0}^{N} (s(t_k) - C_0 - C_1 t_k - C_2 t_k^2 - C_3 t_k^3) \times (-1) = 0 \tag{3.7}$$

$$\Rightarrow \sum_{k=0}^{N} s(t_k) - (N+1) C_0 - C_1 \sum_{k=0}^{N} t_k - C_2 \sum_{k=0}^{N} t_k^2 - C_3 \sum_{k=0}^{N} t_k^3 = 0 \tag{3.8}$$

$$\frac{\partial I}{\partial C_1} = 2\sum_{k=0}^{N}(s(t_k) - C_0 - C_1 t_k - C_2 t_k^2 - C_3 t_k^3) \times (-1) \times t_k = 0 \tag{3.9}$$

$$\Rightarrow \sum_{k=0}^{N} s(t_k) \times t_k - C_0 \sum_{k=0}^{N} t_k - C_1 \sum_{k=0}^{N} t_k^2 - C_2 \sum_{k=0}^{N} t_k^3 - C_3 \sum_{k=0}^{N} t_k^4 = 0 \tag{3.10}$$

$$\frac{\partial I}{\partial C_2} = 2\sum_{k=0}^{N}(s(t_k) - C_0 - C_1 t_k - C_2 t_k^2 - C_3 t_k^3) \times (-1) \times t_k^2 = 0 \tag{3.11}$$

$$\Rightarrow \sum_{k=0}^{N} s(t_k) \times t_k^2 - C_0 \sum_{k=0}^{N} t_k^2 - C_1 \sum_{k=0}^{N} t_k^3 - C_2 \sum_{k=0}^{N} t_k^4 - C_3 \sum_{k=0}^{N} t_k^5 = 0 \tag{3.12}$$

$$\frac{\partial I}{\partial C_3} = 2\sum_{k=0}^{N}(s(t_k) - C_0 - C_1 t_k - C_2 t_k^2 - C_3 t_k^3) \times (-1) \times t_k^3 = 0 \tag{3.13}$$

$$\Rightarrow \sum_{k=0}^{N} s(t_k) \times t_k^3 - C_0 \sum_{k=0}^{N} t_k^3 - C_1 \sum_{k=0}^{N} t_k^4 - C_2 \sum_{k=0}^{N} t_k^5 - C_3 \sum_{k=0}^{N} t_k^6 = 0 \tag{3.14}$$

Equations 3.8, 3.10, 3.12 and 3.14 are the normal equations. These equations were presented in matrix form as shown below:

$$\begin{pmatrix} (N+1) & \sum_{k=0}^{N} t_k & \sum_{k=0}^{N} t_k^2 & \sum_{k=0}^{N} t_k^3 \\ \sum_{k=0}^{N} t_k & \sum_{k=0}^{N} t_k^2 & \sum_{k=0}^{N} t_k^3 & \sum_{k=0}^{N} t_k^4 \\ \sum_{k=0}^{N} t_k^2 & \sum_{k=0}^{N} t_k^3 & \sum_{k=0}^{N} t_k^4 & \sum_{k=0}^{N} t_k^5 \\ \sum_{k=0}^{N} t_k^3 & \sum_{k=0}^{N} t_k^4 & \sum_{k=0}^{N} t_k^5 & \sum_{k=0}^{N} t_k^6 \end{pmatrix} \begin{pmatrix} C_0 \\ C_1 \\ C_2 \\ C_3 \end{pmatrix} = \begin{pmatrix} \sum_{k=0}^{N} s(t_k) \\ \sum_{k=0}^{N} s(t_k).t_k \\ \sum_{k=0}^{N} s(t_k).t_k^2 \\ \sum_{k=0}^{N} s(t_k).t_k^3 \end{pmatrix}$$

Row reduction was then performed to determine the constants C_0, C_1, C_2 and C_3 for each industry.

The obtained polynomials were tested for accuracy on the historical data, validating the assumption of a linear approximating function.

The validating data is presented in Table 3.2

Table 3.2: Validation of the Approximating Polynomial, Wire Products

Period	Actual	Linear Function		Quadratic Function		Cubic Function	
		Projected	% Error	Projected	% Error	Projected	% Error
0	4246	5218	23	5453	28	6649	57
1	7414	5561	25	5559	25	4383	41
2	6093	5904	3	5759	5	4571	25
3	5320	6247	17	6053	12	6037	13
4	6238	6590	6	6441	3	7605	22
5	6211	6933	12	6923	11	8099	30
6	8205	7276	11	7499	8	6343	24
			14[a]		13[b]		30[c]

[a] Mean error for the linear approximation function

[b] Mean error for the quadratic approximation function

[c] Mean error for the cubic approximation function

3.7 Prediction of Kenyan Steel Industry for the Period 2010 to 2030

3.7.1 Introduction

In Kenya, steel is mainly used in the construction industry, bus and truck body building and in the manufacture of wire and wire products. This study employed an intensity of use model for the period 2010 to 2030. The three major steel consuming industries identified above were analyzed. Steel consumption for each industry was decomposed into two determinants:-

1. The average quantity of steel used per unit
2. The number of units

Forecasts of these determinants for each industry were then used to establish individual industry and total steel consumption forecasts.

3.7.2 Steel Consumption in Kenya

In this study, the method used by Crompton [32], was adopted. In this model, steel was disaggregated by end-use industry, such that in the general case presented below, there are n steel industries.

$$S_t = \sum_{i=1}^{n} S_{it} \tag{3.15}$$

where

S_{it} is the quantity of steel consumed by industry i in period t

S_t is the total steel consumed in period t across all n steel consuming industries

3.7.3 Forecasts of Kenyan Steel Consumption

To compute the forecasts, individual industry consumption data was required. This was obtained from the Kenya National Bureau of Statistics, KNBS. Using the obtained approximating polynomial for each industry, the total projected consumption was then obtained for the period 2008 to 2030.

3.8 Establishing the Size of the Plant

In the context of this study, a steel plant was considered as the entire facility that would produce steel products, finished or semi-finished from iron ore. The processes would involve smelting the ore in the blast furnace, reducing the iron into steel in the basic oxygen furnace and casting the steel to finished or seni finished products.

In establishing the size of the plant, two approaches were suggested: either to build a large capacity plant from the onset, or to build a smaller capacity plant and then increase capacity in 2018.

The proposed steel plants are either 1 million tons per year, (large plant) or a 500,000 tons per year (small plant). The estimated initial set up cost for a 0.5 million ton per year integrated steel plant is US$ 158 million, while that of a 1 million tons per year plant is US$ 300 million, since similar plants had been proposed in India at these approximate initial costs [44].

For the period between January 2008 and February 2009, the lowest monthly average international price of steel was US$ 640 per ton [45]. This price was used to estimate the annual gross income from sales for the proposed plants.

Mittal Steel, one of the market leaders in steel production globally, was used as the reference in bench-marking the proposed plants. For the period between January 2005 and December 2008, the total operating costs averaged 85% of the gross sales [46, 47]. To estimate the annual operating costs for the proposed plants, this percentage was used.

To determine which of the two approaches was more profitable, Net Present Value analysis was used. The parameters in each case were discount rate, initial plant set up cost, annual operating costs and expected annual earnings from sales. The analysis was carried out for each option for the period 2009 to 2030.

CHAPTER 4

INVESTMENT MODEL DEVELOPMENT

4.1 Introduction

To meet the increasing demand, existing steel processing firms will have an opportunity to expand and/or improve technology, while new investments into the steel industry will be attracted.

4.1.1 Required Technologies

The following are the technologies that the local industry requires to incorporate:

1. Thin slab casting

   This casting method produces a slab of approximately 50mm minimum thickness, as contrasted to conventional casting which produces slabs of approximately 250mm minimum thickness. With thin slab casting, the need for large roughing mills to work on large slab is eliminated, leading to reduced energy and capital requirements.

2. Continuous casting

   In this method, molten steel is cast directly into semi-finished shapes. These semi-finished products are then subjected to the final rolling to attain the required dimensions. The elimination of the roughing rolling processes leads to capital, labor, and energy saving.

3. Electric arc furnace

This is a batch smelting process, whose energy source is electrical. To smelt the metal, the charge material is exposed to an electric arc. The whole process from charging to tapping can take as low as 40 minutes. The main advantages of electric arc furnace are the low energy requirements and high production rates. However, this method is only appropriate in areas with cheap and reliable electricity supply.

4.1.2 A Typical Modern Steel Plant

A typical Electric Arc Furnace (EAF) plant, using the technology mentioned in the preceding section, uses steel scrap as the main raw material, though some pig iron is occasionally added for chemical balance [48] . Car bodies are the preferred source because the scrap obtained is homogenous. The bodies are shredded, and then separated into ferrous and non-ferrous scrap. The scrap is first reduced in size into nuggets. The ferrous scrap in then charged into the EAF for steel production.

Once the scrap is charged into the EAF, it is smelted and continuously cast into semi-finished shapes. These semi-finished shapes are then rolled to the required dimensions. These plants have computer controlled furnace and stand rolling mills together with automated straightening, continuous cutting to length and stacking equipment. The finished products are then stored in a warehouse. Products of a typical American EAF steel plant are channels, flats, angles, beams, rounds and squares.

A schematic diagram of the continuous casting process is presented in Figure 4.1.

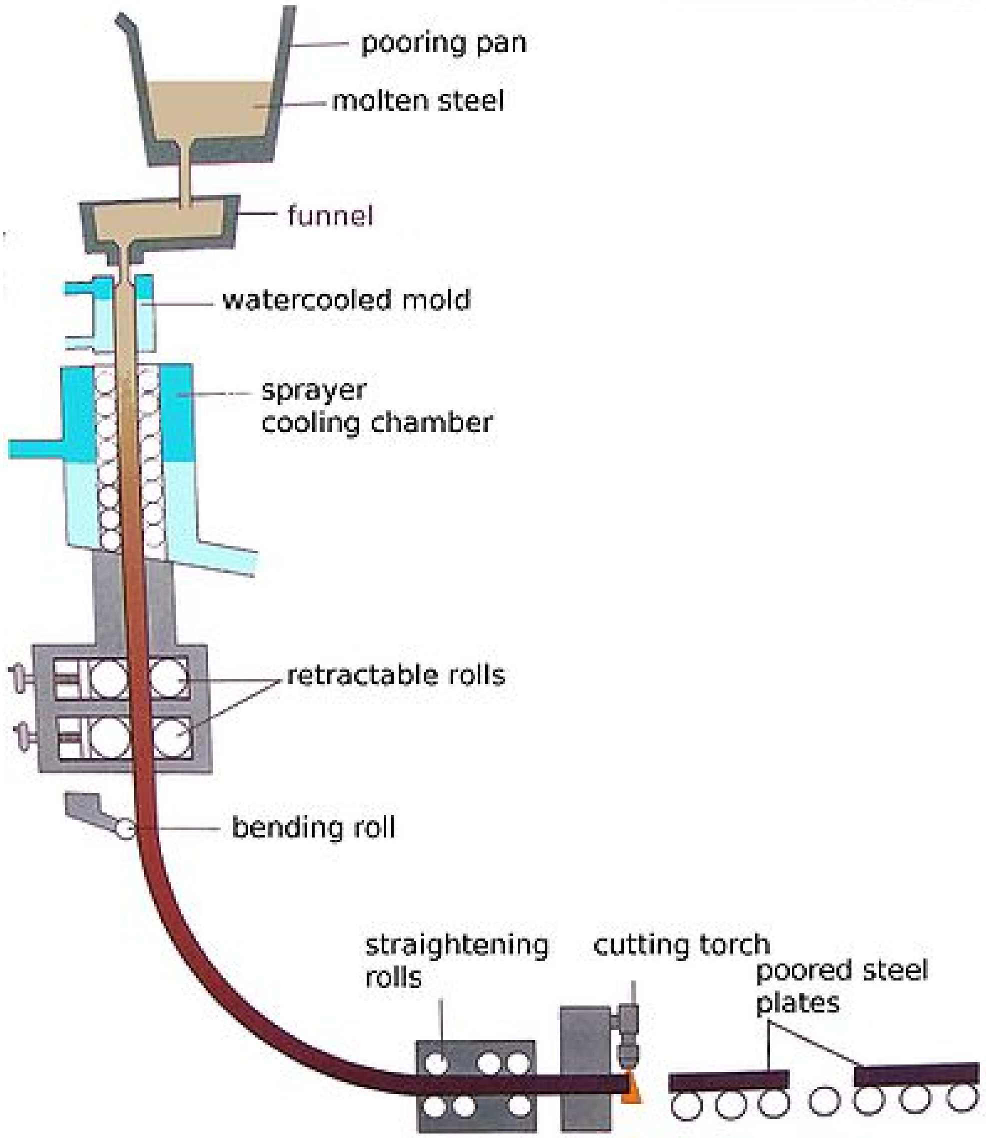

Figure 4.1: Schematic diagram of the Continuous Casting Process

4.1.3 Typical Kenyan Steel Plant

The main source of raw materials is imported ingots and billets, supplemented with steel from local scrap. The imported billets and ingots are reheated and rolled to the required shapes and dimensions. Scrap obtained from the local market is charged into the furnace, which is usually oxy-fuel and/or oil-fired. The ingots are then reheated and rolled to the final shapes and dimensions. Typical products are reinforcing bars, hollow sections, flats, wire and wire products.

4.1.4 Limitations of the Kenyan plant

In the Kenyan plant, the following limitations were evident:

1. Continuous casting:

   The Kenyan industry had not adopted this method. Steel scrap was cast into ingots that were subsequently rolled to the desired shape and size. This led to higher energy, labor and capital requirements, when compared to plants using continuous casting.

2. Automation:

   For the typical Kenyan plant, most of the handling of raw materials and finished products was manual. The lack of automation led to high labor requirement.

3. Import substitution:

   The main source of raw materials for the Kenyan plant was imported billets and ingots. This resulted in exploitation of foreign exchange reserves. The typical EAF plant used almost 100% local steel scrap as the source of raw materials.

4.2 Model Development

The purpose of the Steel Plant Investment Model, (SPIM) is to estimate the benefits of establishing new large plants against establishing small ones. In the process, SPIM, suggests the optimal set of investments over time. In the model, the main components considered are:-

- Engineering inputs such as reliability estimates, maintenance plans and costs among others
- Steel supply and demand, which encompasses detailed information on the Kenyan steel industry, consumption patterns, etc.
- Optimization which due to budget constraints, identifies the optimal set of investment options such as construction of existing plants or rehabilitation of new plants, over a period of twenty years.
- Initial set up cost.
- Running costs, including cost of labor.
- Cost of money, i.e., interest rate
- Period to recover investment.

The assumptions made in SPIM are largely based on the supply and demand of steel. In the study, the following main assumptions were made:-

1. No new material will be developed as a substitute for steel in the twenty years period.
2. The economy will grow at an average of at least three per cent during the twenty years period.

4.2.1 The Modeling Continuum

Simplifying assumptions must be made within SPIM due to time, data and resource limitations. In making the assumptions, the following key factors were considered:-

1. The theoretical model that serves as a starting point for the analysis.
2. How the simplifying assumptions deviate from the theoretical model.
3. The reasonableness of the assumptions as compared to what is known about the real world situation.

Economic models vary in terms of sectoral, spatial and temporal detail. At one extreme are spatially detailed Computable General Equilibrium, (CGE), models, while on the other extreme there are specific sectoral models. CGE models are adopted in projects expected to have economy-wide effects. If economy-wide effects are not realistically associated with the project under consideration, trade-offs must be made [33].

4.2.2 Conceptual Spatially Detailed Partial Equilibrium Model

For SPIM, a spatially-detailed partial equilibrium model was assumed. This assumption was made based on the fact that steel has some distinct features in the market, which are listed below:-

1. It has derived demand resulting for example, from the demand of houses, buses and trucks.

2. Its supply requires a combination of both private and public input.

3. It is part of a linked decision process by multiple economic agents such as producers, consumers and distributors.

A complete representation of the steel industry should capture these features. Although all aspects of the steel industry are intrinsically linked, a theoretical derivation of demand from the point of view of the producer is made. In this study, focus is first made on the short run and then projected for the long run behavior.

4.2.3 Main Components of the Model

To accurately analyze the complete costs and benefits of establishing new steel plants in Kenya, a comprehensive financial model is required.

This study has developed such a model and its main components are:-

- Cost of the machinery and equipment

- Cost of land

- Productivity

- Cost of labor

- Capacity utilization

The model compares the net present values of proposed plants of different capacities. Current costs are factored in their present form. When the costs are to be incurred in future, such as equipment upgrade, these costs are reduced to their present values.

In this study, all the components were modeled together. The model is interactive in that all inputs can be adjusted to match individual cases.

The following key inputs were given special consideration:

1. Interest rates: This is a very key consideration in that it affects the cost of doing business and largely affects the net present value of the assets. It also affects the 'cost' of the capital in the case of projects that have been financed through loans.

2. Initial set up cost: This is very important for any start up. However, other factors also require consideration together with it. For instance, highly

automated plant would require high initial cost, but in the long run may be cheaper than labor intensive plants due to reduced labor cost.

3. Upgrading cost: This future cost was to be incurred to raise the capacity of the plant.

4. Operation costs: These are the total costs that the plant will incur so as to remain in business. They include labor costs, energy costs, depreciation, government taxes, maintenance, among others.

5. Period to recover investment cost: Steel plants have long economic lives and hence it is desirable for the investor to recoup their investment so as to earn interest within a reasonably short period of time.

6. Discount Rate: This indicates the return on capital if a different investment had been financed. Since the objective of an investment is to obtain returns, the investor will always go for the vehicle with the highest returns.

4.2.4 Establishing the Viabilty of Plant

To establish the viability of the proposed plant, the net present value analysis was used.

In this case, a large plant, with a one million metric ton per year capacity was proposed.

The net earning, N.E, is the difference between the annual earnings from sales, A.E, and the annual operating cost, A.O.C, and is presented as equation 4.1 below:

$$N.E = A.E - A.O.C \tag{4.1}$$

To reduce the future earnings from the steel plant to a present value, a present value factor, D.F, was used, and is expressed as equation 4.2 below:

$$D.F = (1 + R)^{-J} \tag{4.2}$$

where

R	Discount Rate
J	Time period of the cash flow, in years

The present value factor was used to reduce the future earnings to a present value, P.V, as expressed in equation 4.3.

$$P.V = N.E \times D.F \tag{4.3}$$

The net present value, NPV, is then obtained by summing all the present value over the analysis period, and is expresses as equation 4.4 below:

$$NPV = \sum_{j=1}^{20} (P.V)_j \tag{4.4}$$

Equations 4.2 to 4.3 were used to determine the net present value for a particular capacity of a plant.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 Status of the Local Steel Industry

5.1.1 Capacity Utilization Rate

Capacity utilization rate is defined as the ratio of the used capacity to the design capacity. For the selected firms, as indicated in Table 5.1, it varied from 21.67% to 67.50%, with an average of 45.69%.

Table 5.1: Capacity Utilization Rate, as a Percentage, 2001 to 2008

Firm	2001	2002	2003	2004	2005	2006	2007	2008	FMR[a]
a	35.56	33.33	42.22	48.89	62.22	66.67	57.78	64.44	51.39
b	30.00	32.00	31.00	39.00	60.00	57.50	58.50	60.00	46.00
c	32.00	30.00	35.00	38.00	60.00	58.00	56.20	60.00	46.15
d	30.00	28.00	36.00	44.00	60.00	56.00	62.00	60.00	47.00
e	30.67	26.67	33.33	40.00	57.33	57.33	53.33	60.00	44.83
f	32.50	31.25	36.25	45.00	65.00	62.50	62.50	67.50	50.31
g	28.33	25.00	30.00	40.00	53.33	51.67	51.67	56.67	42.08
h	32.00	30.00	30.00	40.00	60.00	54.00	55.00	58.00	44.88
i	26.67	21.67	25.00	40.00	46.67	53.33	46.67	48.33	38.54
IMY[b]	30.86	28.65	33.20	41.65	58.28	57.44	55.96	59.44	45.69[c]

[a] Firm's mean for the review period

[b] Industry mean for the year

[c] Industry mean for the review period

All the firms except firm i were rolling mills whose main products were reinforcing steel bars. Firm i was producing cast and machined components for the transport, mining, agriculture and process industries.

Firm (a) had the highest capacity utilization rate, which varied from 33.33% to 66.67%, with a mean of 51.39%. Though this firm had the highest capacity utilization rate in the sample, it is still below the global average of 72.34%. However, with the anticipated economic growth, the firm is expected to increase production, thereby reducing the excess capacity.

Firm (b) was ranked fifth in terms of capacity utilization, with the rate varying between 30% and 60%, with a mean of 46%. However, this is expected to improve since the firm has embarked on targeting the regional markets. This coupled with the anticipated growth in demand of steel locally, will result in reduction of the unutilized capacity.

Firm (c) had a capacity utilization rate varying between 30% and 60%, with a mean of 46.15%. This mean is above the industry mean of 45.69%. This firm only served the local market. By targeting the regional markets, this market can increase production hence reducing the unutilized capacity.

Firm (d) had the lowest installed capacity among the steel rolling plants in the sample. The capacity utilization rate varied between 28% and 62%, with a mean of 47%, and the firm was ranked third. However, this firm has adopted a strategy of increasing capacity in tandem with increasing demand.

Firm (e) had a capacity utilization rate ranging from 26.67% to 60%, with a mean of 44.83%. This firm has not ventured into the regional markets. This makes the firm to be highly vulnerable to fluctuations in the local political or economic climate. This firm was ranked seventh. However, by manufacturing for the regional markets, this firm would cushion itself from the local climate and utilize more capacity to meet the regional demand.

Firm (f) was ranked second, with a capacity utilization rate varying from 31.25% and

67.50%, with a mean of 50.31%. This mean is higher than the industry mean. Though the firm only supplied local markets, used capacity was more closely matched to the design capacity, when compared to other firms in the sample.

Firm (g) was ranked eighth in terms of capacity utilization. The rate varied from 25% to 56.67% with a mean of 42.08%. This is one of the oldest steel plants in the country. The low capacity utilization rate could have been caused by the loss of market share to new entrants, scaling down the production which resulted in increased unutilized capacity. Also the firm, despite having been in existence for longer than the other firms, has not been producing for export. This over-reliance on the local market, combined with the reduced market share could have caused the low capacity utilization rate.

Firm (h) had a capacity utilization rate varying between 30% and 60%, with a mean of 44.88%. The trend of this firm is very similar to the mean trend of the industry. This is a typical Kenyan steel processing firm, serving only the local market. This exposes the firm to the risks associated with the local political and economic environment.

Firm (i) had the lowest capacity utilization rate among the sampled firms, varying between 21.67% and 53.33%, with a mean of 38.54%. However, the core business of this firm was casting while the other firms mainly engaged in steel rolling. Imports have captured some of the market share of this firm, resulting in low capacity utilization.

The economy in Kenya has been steadily increasing over the review period (0.5% in 2002, 2.9% in 2003 5.1% in 2004, 5.8% in 2005, 6.3% in 2006, and 7.1% in 2007 [5–7]). In 2002, with the change in government, investors had more confidence in the country. This resulted in accelerated growth, especially in the building construction industry.

In turn, demand for steel increased, resulting in increased capacity utilization for the existing steel plants. Projecting this trend, it is expected that by the year 2012, existing plants will have exhausted their capacity. If no new investment is made in the steel industry before then, the demand will outstrip supply pushing up prices of steel and steel products. Since steel is a major raw material in most sectors of the economy, it will be required in increasing quantities, resulting in increased markets for steel plants.

This explains the general trend of an increasing capacity utilization rate, which is presented in Figure 5.1.

By building a firm with large capacity, the investors avoided the risks of accelerated inflation and higher future construction costs. Through over-capacity, firms also avoid the risk of losing business in future due to inadequate capacity. However, very large excess capacity has its own disadvantages. Firstly, very large capacity firms also require heavier capital costs. This ties up capital for the investor, which would have been put into alternative investments to earn interest. This raises the fundamental question of whether to overbuild from the start, whether to expand in lumpsum, or gradually. Usually, this can be addressed through forecasts of demand and also on the competitive strategy of the organization.

The world steel industry has been operating at an average 72.34%, but the excess world capacity is expected to diminish [29]. With the steel consumption in Kenya expected to increase as indicated by the projections, the overcapacity will also diminish in the country. The increase in demand will also attract new investors. The new entrants

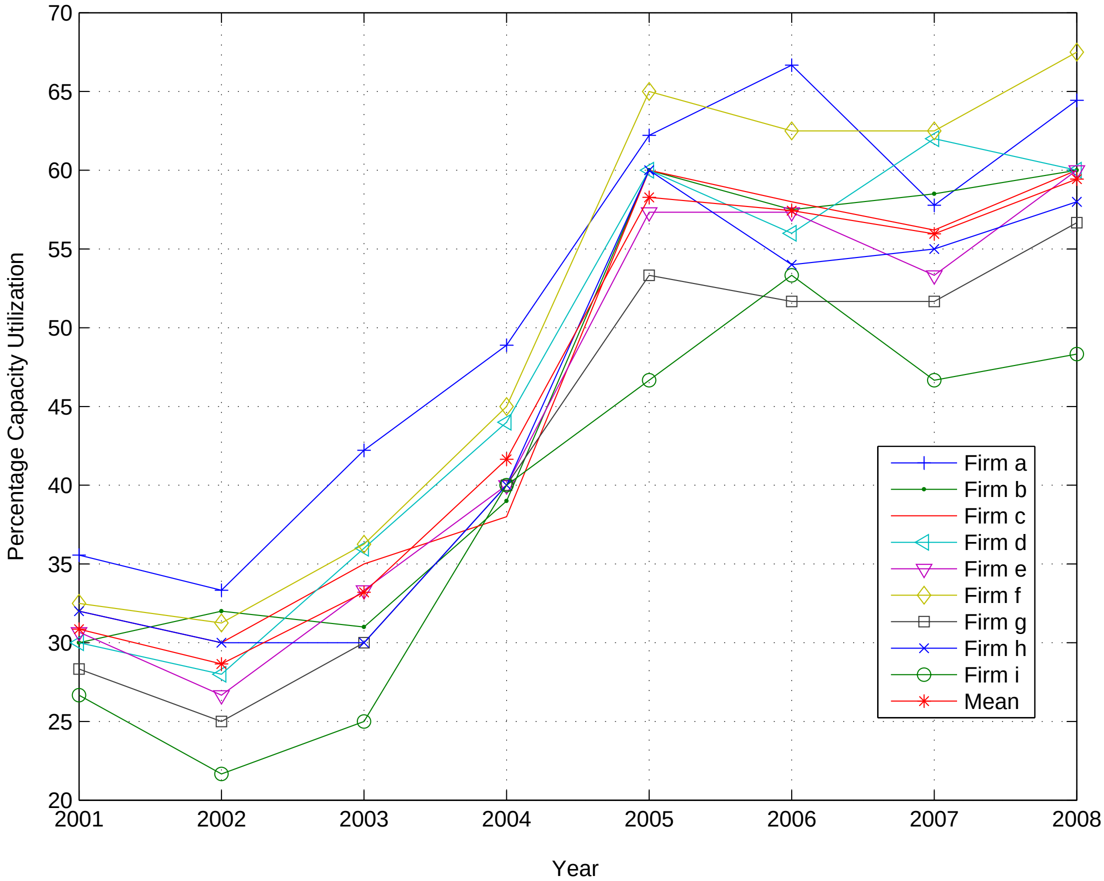

Figure 5.1: Capacity Utilization Rate for Selected Kenyan Firms

will preferably adopt new and efficient processing methods so as to gain a competitive edge over the existing players. This will force small and inefficient firms to close down or merge and adopt new methods so as to remain afloat.

5.1.2 Labor Productivity

Productivity is an indicator of how efficiently resources are being utilized by an organization [49]. It is a partial productivity measure defined as the ratio of total output to total labor input. In this case, the total output is considered as the total value (i.e. ex-factory price) of the products in a year, while the total labor input is the wage bill of the organization for the respective year.

Labor productivity is therefore defined as the ratio of total output of the firm to labor input. Table 5.2 gives the labor productivity for selected firms and each Firm's Mean for the period under Review, FMR and the Industry Mean for the Year, IMY. A high value of the labor productivity indicates a high return on labor. The Industry Mean for the Year varied from a low of 22.14 to a maximum of 32.20, with a mean of 27.58 for the entire review period. The factors that affect this index are the quantity of steel produced in that year, the prevailing steel prices and the average labor costs. All the firms in the sample were rolling plants, except firm (i) whose core business is casting of steel products.

Table 5.2: Labor Productivity for Selected Firms, 2001 to 2008, in Ksh/Ksh

Firm	2001	2002	2003	2004	2005	2006	2007	2008	FMR[a]
a	24.35	22.83	21.69	25.11	25.57	25.57	19.79	22.07	23.37
b	36.53	38.96	28.31	35.62	43.84	42.02	35.62	36.53	37.18
c	24.35	22.83	19.98	21.68	27.40	26.48	21.39	22.83	23.37
d	22.83	21.31	20.35	25.11	27.40	25.57	23.59	22.83	23.62
e	23.34	20.29	19.03	22.83	26.18	26.18	20.29	22.83	22.62
f	26.38	25.37	22.07	27.40	31.66	30.44	25.37	27.40	27.01
g	20.70	18.26	16.44	21.92	29.22	22.65	22.65	20.70	21.57
h	24.35	22.83	17.12	22.83	27.40	24.66	20.93	22.07	22.77
i	48.71	39.57	34.25	54.79	51.14	58.45	42.62	44.14	46.71
IMY[b]	27.95	25.81	22.14	28.59	32.20	31.34	25.81	26.82	27.58[c]

[a] Firm's mean for the review period

[b] Industry mean for the year

[c] Industry mean for the review period

Firm (a) has a design capacity of processing 450,000 metric tons of steel per year. However, only a maximum of 300,000 metric tons per year capacity was utilized during the review period. The plant runs for 24 hours with 200 employees per shift. The annual quantity of steel processed varied from 150,000 metric tons in 2002 to a maximum of 300,000 metric tons in 2006 during the review period. The firm maintained an average of 600 employees during the review period. Thus, the variation in labor productivity is caused by variation in steel production and the periodic changes in labor costs. This firm exhibited labor productivity indices less than the industry average, varying between 19.79 and 25.57, with a mean of 23.37 for the review period.

Firm (b) had the largest capacity in the sample. The organization has a design capacity of 2,000,000 metric ton per year, with only a maximum capacity of 1,200,000 metric tons per year being utilized. An average staffing level of 500 employees per shift was maintained. Among the firms whose core business is steel rolling, this firm had the highest labor productivity, of between 28.31 and 43.84 with a mean of 37.18 for the review period. The relatively high productivity as compared to other firms is as a result of the high production, resulting in lower cost of production per unit. This firm also has a good market share in the region, with at least 20% of their products exported to the East Africa Region.

Firm (c) has a design capacity of 1,000,000 metric tons per year. However, during the review period only a maximum of 600,000 metric tons of steel per year was processed. The firm maintained 400 employees per shift during the review period. The quantity of steel processed varied from 300,000 metric tons in 2002 to 600,000 metric tons in

2008. The labor productivity index varied from 19.98 to 27.40, with a mean of 23.37. Taking firm (b) as the benchmark, firm (c) was expected to be second best in terms of labor productivity, since it had the second largest capacity. However, this was not the case and the firm was ranked fourth. This can be attributed to poor human resource utilization, since bench-marking with firm (b), this organization would only have required 250 employees per shift, and not 400, (60% overstaffing) as is the current case.

Among the rolling plants, firm (d) had the lowest design capacity, of 250,000 metric tons per year. The maximum production during the review period was only 155,000 metric tons in a year. This firm exhibited labor productivity indices varying between 20.35 and 27.40, with a mean of 23.62. These indices are lower than the industry average. During the review period, the firm maintained a staffing level of 100 employees per shift. However, using firm (b) as the benchmark, only 65 employees would have been required. This is 54% over-staffing level, leading to the low productivity index.

Firm (e) had a design capacity of 750,000 metric tons, and only utilized 450,000 metric tons per year. The firm maintained a staffing level of 300 employees per shift. However, bench-marking with firm (b), only 188 employees would have been required. This explains the low productivity indices of between 19.03 and 26.18 with a mean of 22.62.

Firm (f) has a design capacity of 400,000 metric tons per year, but only utilized a maximum annual capacity of 270,000 metric tons. The firm maintained a staffing level of 150 employees per shift, while only 113 employees would have been required, when bench-marked against firm (b). The over-staffing was 32% and the firm was ranked third in terms of labor productivity.

Firm (g) is among the oldest firms in the country. It has a design capacity of 600,000 metric tons per year, though only a maximum annual capacity of 340,000 metric tons was used. The firm maintained an average staffing level of 250 employees per shift. However, bench-marking with firm (b), only 142 employees per shift would have been required. This represents an over-staffing level of 76%. This high over-staffing level contributed to the low indices, varying between 16.44 and 29.22, with a mean of 21.57, less than the industry average of 27.58. The firm was ranked last among the sampled firms.

Firm (h) had a design capacity of 500,000 metric tons per year, though only a maximum annual capacity of 290,000 metric tons was used. The firm maintained a staffing level of 200 employees per shift, as compared to the bench-marked level of 120 employees. This represents an over-staffing level of 67%, and the firm was ranked sixth among the sampled firms.

Firm (i) is different from all the other firms in the sample in its line of business. While for all the other firms, the core business is steel rolling, firm (i) was involved in casting as per customer requests. Therefore, this company was not bench marked with firm (b) as was the case with the other firms. The firm has also diversified in other areas, such as trucks and trailers body building. This diversification, coupled by the high value of the products explains why the firm had the highest indices, varying between 34.25 and 58.45, with a mean of 46.71.

From Table 5.2, the labor productivity varied from 16.44 to 58.45 for the selected firms during the period under review. The low levels of labor productivity can be attributed to the low levels of mechanization and automation. This not only increases the cost of production, but also affects the consistency of the products quality. Labor productivity can also be improved by increasing the output from the same labor input. This can be achieved through such methods as reducing machine idle time during change over, proper scheduling and higher penetration to regional markets so as to increase demand. Larger firms exhibited higher productivity indices. This is mainly due to the fact large firms generally utilize their resources better than their smaller counterparts and the cost of production per unit is lower since it is distributed over more units.

The trend in the labor productivity of each firm sampled is represented in Figure 5.2. The variation in the trends exhibited by the various firms is caused by the variation of the products and the technology adopted by various firms. Some of the firms in the sample had more labor intensive processes, but their products had a higher market value than the rest, resulting in higher indices. Generally, the period before the year 2003 had low labor productivity indices. This was mainly due to power outages, and depressed steel demand from the low economic growth.

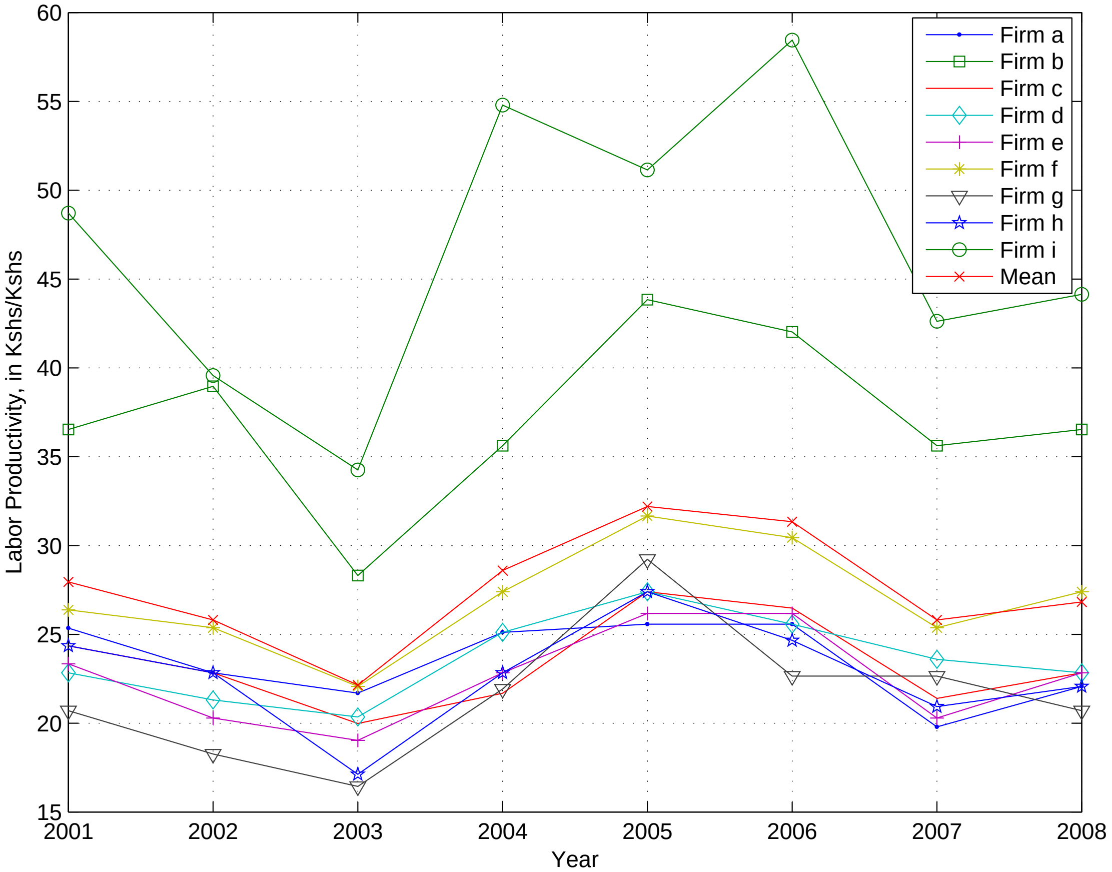

Figure 5.2: Labor Productivity for Selected Kenyan Firms

5.1.3 Labor Hours Per Metric Ton (Lhpt)

This is the ratio of the labor hours required to process one ton of steel. It is computed by dividing the total number of hours utilized by the total quantity of steel, in tons, produced in a year. This index indicates how labor intensive the adopted production process is. It is also an indicator of how efficiently a firm is utilizing its human resource. Thus a firm with an optimum staffing level, efficiently utilized and/or less labor intensity will have a low index, while the converse also holds. In this study, labor input was taken as the total hours worked by the employees in the year. From Table 5.3, it varied from 3.65 to 14.60 Lhpt, with a mean of 7.87 Lhpt during the review period.

Table 5.3: Labor Hours per Ton, 2001 to 2008

Firm	2001	2002	2003	2004	2005	2006	2007	2008	FMR[a]
a	10.96	11.68	9.20	8.00	6.24	5.84	6.72	6.08	8.09
b	7.30	6.84	7.06	5.62	3.65	3.81	3.74	3.65	5.21
c	9.58	10.22	8.76	8.06	5.11	5.29	5.46	5.11	7.20
d	11.68	12.51	9.73	7.96	5.84	6.26	5.65	5.84	8.18
e	11.43	13.14	10.51	8.76	6.11	6.11	6.57	5.84	8.56
f	10.11	10.51	9.06	7.30	5.05	5.26	5.26	4.87	7.18
g	12.88	14.60	12.17	9.13	6.84	7.06	7.06	6.44	9.52
h	10.95	11.68	11.68	8.76	5.84	6.49	6.37	6.04	8.48
i	10.95	13.47	11.68	7.30	6.25	5.47	6.27	6.04	8.43
IMY[b]	10.65	11.62	9.98	7.88	5.66	5.73	5.90	5.55	7.87[c]

[a] Firm's mean for the review period

[b] Industry mean for the year

[c] Industry mean for the review period

Compared to the industrialized world, the Kenyan average index is higher. For instance, in the early 1960s,the Japanese steel industry required 15 to 30 Lhpt, which improved to less than 5 Lhpt in the early 1990s [29].

In the United States, it varied between 7 to 14 Lhpt in 1964, and is currently less than 4 Lhpt for most integrated producers and less than 2 Lhpt for most EAF producers. Firms employing the new thin-slab casting technology require less than 0.5 Lhpt [29].

From the sample, during the review period, firm (b) had the lowest index, varying between 3.65 and 7.30 Lhpt, with a mean of 5.21 Lhpt. This firm was again used as the benchmark for other firms.

Firm (a) was ranked fourth, with an index varying between 5.84 and 11.68 Lhpt, while the firm's mean for the review period, FMR, was 8.09 Lhpt. This index was higher than the industry average, which was 7.87 Lhpt. This higher index is caused by the over-staffing level discussed earlier on. Since the staffing level remained constant during the review period, then the fluctuations in the index are caused by the variations in production.

As previously observed, firm (b) had the lowest index among the sampled firms. However, this firm still uses ingot casting techniques when re-smelting scrap. This explains the higher index as compared to the United States or Japan.

Firm (c) was raked third, with an index varying between 5.11 and 10.22 Lhpt, with a mean of 7.20 Lhpt during the review period. This index is higher than the industry average, and can be lowered by more efficient human resource utilization, and/or increasing production capacity at the same staffing level.

During the review period, firm (d) had an Lhpt index varying between 5.65 and 11.68 Lhpt, with a mean of 8.18 Lhpt and was ranked fifth. The staffing level of this firm was maintained at 100 employees per shift, while the bench-marked level is 65 employee per shift. This implies that the firm retained over 50% of staff who were not directly contributing to the actual production, raising the index, which is higher than the industry average.

Firm (e) was ranked eighth among the sampled firms, with the index varying between 5.84 and 13.14 Lhpt, with an average of 8.56 Lhpt. It was lowest in 2008 and highest in 2002, when production was highest and lowest respectively. This high index was also caused by the high over-staffing, of 59%. If the bench-marked staffing level was maintained, the average index of this firm would have been reduced to 3.66 Lhpt.

Firm (f) maintained an average staffing level of 150 employees per shift. However, the optimal level would have been 113. This represents an over staffing level of 32%. This relatively low level of overstaffing resulted in the relatively low indices, varying between 4.87 Lhpt and 10.51 Lhpt, with a mean of 7.18 Lhpt. The firm was ranked second among the sampled firms.

Firm (g) had the highest index among the sampled firms, which varied between 6.44 Lhpt and 14.60 Lhpt, with an average of 9.52 Lhpt. This high index could have been caused by the high overstaffing level, when bench-marked with firm (b). The firm maintained a staff level of 250 employees per shift, while the bench-marked level could have been 142 employees, representing an over staffing level of 76%. Though the firm has been in existence since the 1960s, the high levels of Lhpt index indicates an organization that has not been updating their production methods to at least match those of new entrants.

Firm (h) also had a relatively high index, varying between 5.84 Lhpt and 11.68 Lhpt, with a mean of 8.48 Lhpt. Similar to firm (g), the firm also had a high overstaffing level. While the optimum bench-marked staffing level would have been 120 employees per shift, the firm maintained an average of 200 employees, representing a 67% overstaffing. The firm was ranked seventh in the sample.

Firm (i) had a higher average index of 8.43 Lhpt for the period under review, with a variation of between 5.47 Lhpt and 13.47 Lhpt. This firm was ranked sixth in Lhpt, while it was ranked first in labor productivity. This is because the firm is involved in labor intensive processes, producing higher value products than the other firms in the sample. While labor productivity takes into consideration the value of the products, labor hour per ton only considers the quantities and mainly indicates how labor intensive a process is. Since this firm's core business is different from that of other firms, bench-marking was not done.

The trend of the Lhpt index for selected firms is shown in Figure 5.3. During the period preceding 2003, the index was generally increasing. This was mainly due to the low production during the period. At low production levels, the per unit cost of production was higher, since overhead costs which included labor costs were distributed over few units. After 2003, the index has been improving steadily. This improvement was attributed to improved demand for steel and steel products. This led to increased

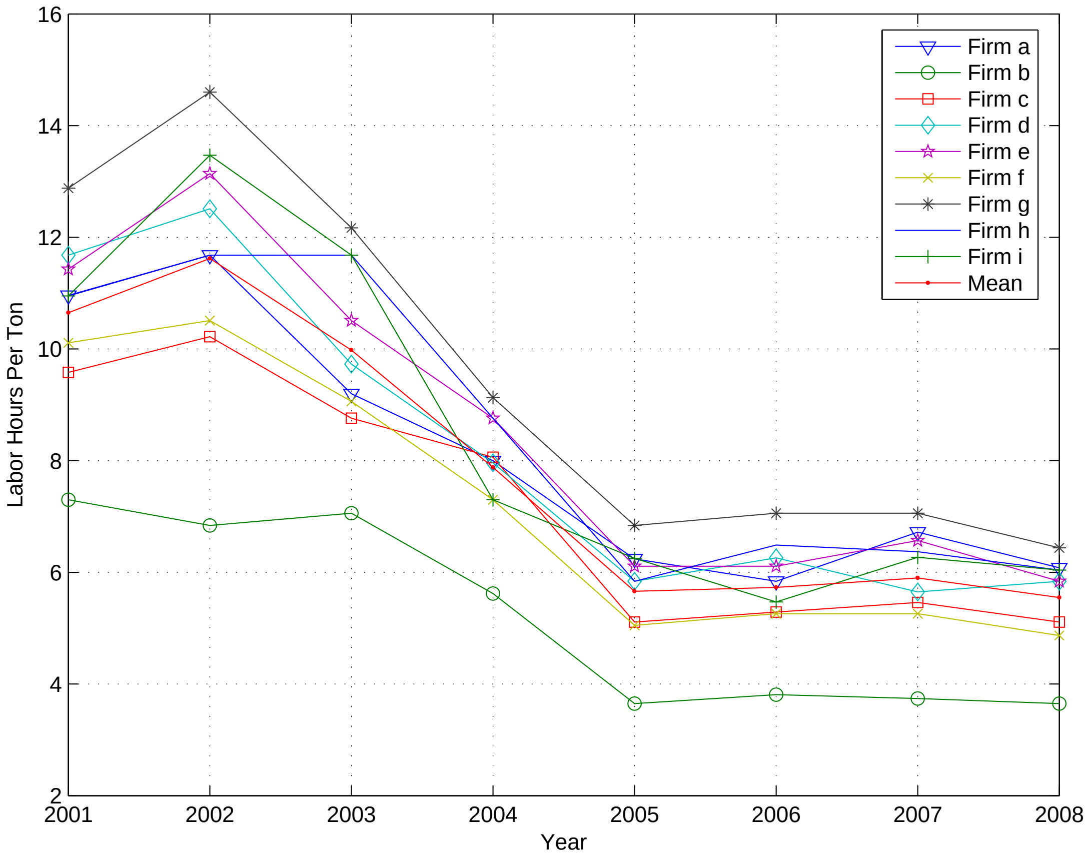

Figure 5.3: Labor Hours Per Ton for Selected Kenyan Firms

production and more efficient labor utilization. The index then stabilizes in 2006 and beyond. This stabilization was attributed to the limitation of the technology currently in use. To further improve the index, modern technology (such as continuous casting), which is less labor intensive would have to be adopted.

The relatively high Lhpt index of the Kenyan industry can be attributed to lack of research and development, and use of outdated production methods. For instance, Kenyan industry is still using ingot casting techniques, while elsewhere (USA, Japan, Korea and others), more efficient methods such as EAF thin-slab casting are adopted.

The Kenyan steel industry should also employ these methods and embrace mechanization and automation so as to remain competitive internationally .

5.1.4 Fuel Productivity

This ratio is obtained by dividing the total steel produced, in kilograms, by the total furnace fuel consumed, in liters, in a particular year. The obtained index indicates how efficiently a firm utilizes fuel in steel processing. Firms aim at high ratios, as they indicate that more steel is processed for each unit of fuel. Fuel productivity, is directly proportional to the capacity utilization rate. This is because for big plant, at low capacity utilization rates, more fuel will still be needed to run the furnaces, without a corresponding production. This leads to a low fuel productivity index.

For the sampled firms, as indicated in Table 5.4, the furnace fuel productivity for the selected firms varied from 92.9 to 384.6 kg per liter, with an average of 308.7kg/liter. In all the sampled firms, furnace fuel was used to heat and/or smelt steel (no firm utilized the Electric Arc Furnace).

Table 5.4: Fuel Productivity, 2001 to 2008, in Kg/liter

Firm	2001	2002	2003	2004	2005	2006	2007	2008	FMR[a]
a	246.2	220.6	267.6	289.5	350.0	384.6	325.0	341.2	303.1
b	214.3	228.6	206.7	243.8	363.6	359.4	354.5	352.9	290.5
c	228.6	214.3	253.6	253.3	384.6	362.5	330.6	342.9	296.3
d	214.3	233.3	290.3	297.3	384.6	350.0	378.0	345.8	311.7
e	230.0	227.3	213.7	250.0	358.3	358.3	320.0	346.2	288.0
f	206.3	192.3	228.3	257.1	366.2	347.2	324.7	337.5	282.5
g	226.7	187.5	236.8	279.1	372.1	352.3	344.4	354.2	294.1
h	246.2	214.3	200.0	256.4	375.0	341.8	335.4	341.2	288.8
i	123.1	92.9	100.0	150.0	177.2	200.0	179.5	170.6	149.2
IMY[b]	215.1	201.2	221.9	252.9	348.0	339.6	321.3	325.8	278.2[c]

[a] Firm's mean for the review period

[b] Industry mean for the year

[c] Industry mean for the review period

Firm (a) had the ratio varying from 220.6kg/liter to 384.6kg/liter, with a mean of 303.1kg/liter and was raked second. This firm had the best capacity utilization rate of 51.39%. The high capacity utilization rate led to the high fuel productivity index.

Firm (b) had the index varying between 206.7kg/liter and 363.6.4kg/liter, with an average of 290.5kg/liter and was ranked fifth. This index is lower than the industry average. Since the firm had both the highest design and used capacity among the sampled firms, effects of inefficiencies are magnified. However, with the projected growth in steel consumption, the firm will attain higher capacity utilization, leading to higher fuel productivity.

Firm (c) was ranked third, with the index varying between 214.3 and 384.6kg/liter and an average of 296.3kg/liter. The mean of this firm was less than the local industry average. The low index can be attributed to the same factors affecting firm (b) above. This is because firm (c) had the second largest design capacity. (The capacity utilization rate for firms (b) and (c) were 46.00% and 46.15% respectively).

Firm (d) had the highest fuel productivity index in the sample, varying between 214.3kg/liter and 384.6kg/liter, with a mean of 311.7kg/liter. This firm had the lowest design capacity in the sampled rolling plants. The relatively high capacity utilization rate, coupled with low design capacity led to inefficiencies in fuel productivity being less pronounced when compared to the larger capacity firms.

During the review period, firm (e) was ranked seventh with the fuel productivity index ranging from 213.7kg/liter to 358.3kg/liter, with a mean of 288kg/liter. The general trend in fuel productivity of this firm is very similar to the general industry trend.

Firm (f) was ranked eighth with an index of varying from 192.3kg/liter to 366.2kg/liter, and a mean value of 282.5kg/liter. Since this firm had the second best capacity utilization rate, then the low fuel productivity indices indicate that the firm adopted methods that were not suited for their intended purpose.

Firm (g) had an index varying from 187.5kg/liter to 372.1kg/liter, with a mean value of 294.1kg/liter and was ranked fourth in the sample. Considering that this firm is older than most other steel rolling plants in the sample, (having began in the 1960s), it can be deduced that the firm has not been keeping up with the technological changes in the country.

Firm (h) had an index varying between 200kg/liter and 375kg/liter, while the mean was 288.8kg/liter. Since this firm had a design capacity of 500,000 metric tons per year, while firm (a) had a design capacity of 450,000 metric tons per year, their fuel productivity were expected to be very similar, all other factors remaining constant. Since this is not the case, it can then be inferred that the this firm employed less efficient processes than its peers in the industry.

Firm (i) is different from the other firms in the sample. The core business of this firm is production of castings, as contrasted to the other firms in the sample, whose core business in steel rolling. The index varied from 92.9kg/liter to 200kg/liter, with a mean of 149.2kg/liter. Most of the operations depended on furnace oil as the source of energy. This explains the low indices of this firm. This firm operates almost as a monopoly in the country (with the exception of imports).

The trend of the fuel productivity index is shown in Figure 5.4. Before 2003, the index was generally decreasing. This period had been characterized by severe droughts which resulted in power rationing. This forced plants to revert to use of generators as a source of power. This further increased the quantity of fuel required to process a unit of steel.

From the study, it is apparent that at low production levels, fuel productivity is also low. This is because once the furnace has been started, it runs continuously until

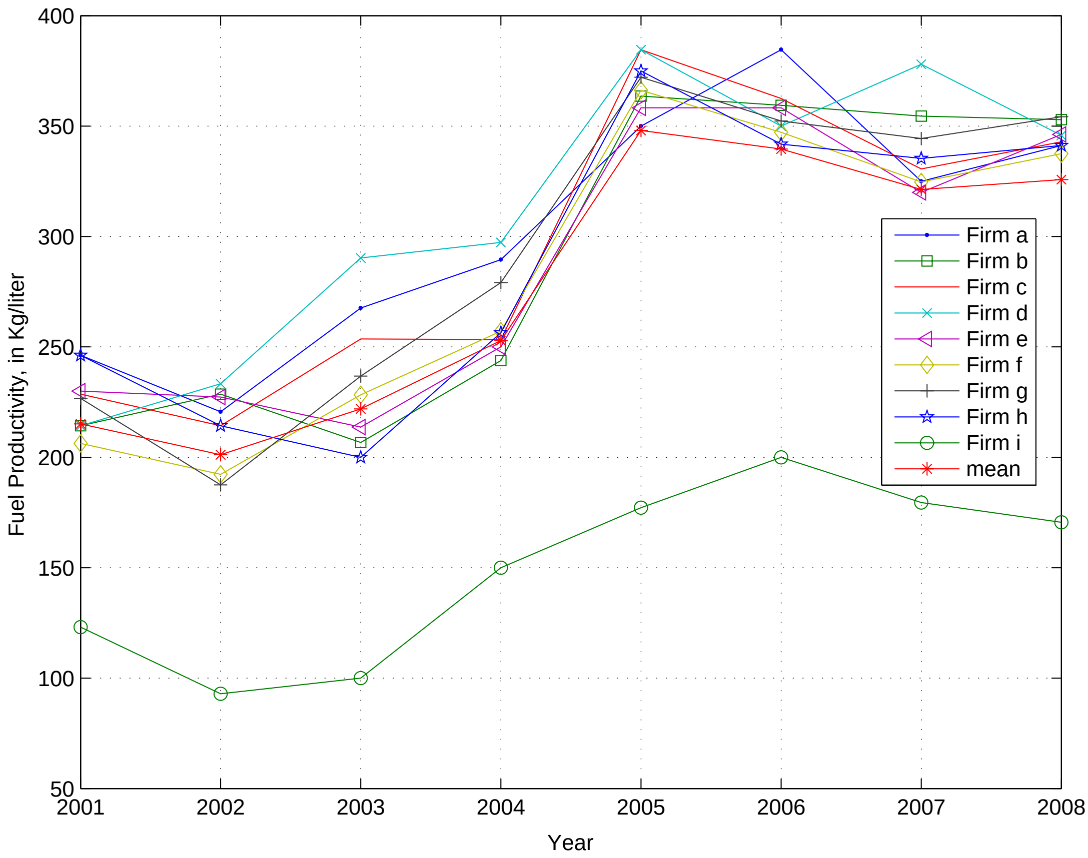

Figure 5.4: Fuel Productivity for Selected Kenyan Firms

there is need for repair or reline [50]. This implies that should production drop, fuel would still be used to run the furnace, without correspondingly processing steel, hence lowering the fuel productivity. The only way to counter this is for the firms to increase their inventory, or venturing into other markets. This productivity measure could not be compared with the industry leaders in other countries, since similar firms use the EAF method to produce steel from scrap. The EAF method is more efficient and the Kenyan industry should adopt it. This is particularly important due to the current unpredictability of oil prices in the international markets.

5.1.5 Energy Productivity

This is a partial productivity measure and is the ratio of the total value (ex-factory price) of output to the overall cost of energy in a given year. In the study, the total cost of energy was obtained by adding the total cost of electricity to the total cost of fuel in a particular year. A high index indicates a high return on energy. One major challenge that the firms in the sample faced was higher electricity tariffs, than those of the region [51]. Secondly, fuel prices have been increasing over the years, from US$ 16 in 1990 to a high of over US$ 60 per barrel in 2005 [21]. This increase in oil prices coupled with high electricity tariffs led to a depressed energy productivity index. For the sampled firms, as indicated in Table 5.5, it varied from 14.14 to 34.75, with an industry mean of 22.32.

Table 5.5: Energy Productivity, 2001 to 2008, in Ksh/Ksh

Firm	2001	2002	2003	2004	2005	2006	2007	2008	FMR[a]
a	17.98	16.30	19.84	21.71	26.44	28.60	23.48	24.65	22.38
b	15.96	17.20	15.97	18.75	28.43	27.77	26.98	26.36	22.18
c	17.02	15.99	18.62	18.86	28.87	27.38	24.28	25.38	22.05
d	15.99	16.86	20.70	21.81	28.82	26.20	27.98	25.70	23.01
e	16.95	13.73	16.09	18.94	27.15	26.82	23.38	24.75	20.98
f	15.45	14.35	16.94	19.35	27.93	26.41	23.86	24.39	21.09
g	16.81	14.14	17.33	20.73	27.64	26.54	25.28	25.48	21.74
h	17.98	15.99	15.01	19.32	28.32	25.97	25.26	25.06	21.61
i	20.91	16.69	17.34	26.11	30.54	34.75	30.95	29.81	25.89
IMY[b]	17.23	15.69	17.54	20.62	28.24	27.83	25.72	25.73	22.32[c]

[a] Firm's mean for the review period

[b] Industry mean for the year

[c] Industry mean for the review period

Firm (a) was ranked third, with the index varying from 16.30 to 26.44, with a mean of 22.38. This index is higher than the industry average. Since the firm had been ranked second in fuel productivity, the high index in energy productivity indicates that the value addition process was also efficiently done.

Firm (b) was ranked fourth with the index varying from15.96 to 28.43, with a mean of 22.18. This firm, as earlier discussed had the highest capacity, with average utilization. This high capacity capacity, with average capacity utilization caused the low energy productivity index. This is explained in that more fuel was required to run the furnaces, without corresponding production. The low energy productivity index can be addressed if the firm installs Electric Arc Furnaces, EAFs, which can be put on and off for batch production.

Firm (c) was ranked fifth, with the index ranging from 15.99 to 28.87, with a mean of 22.05. This firm had similar challenges to those of firm (b) since it had the second largest design capacity. However, firm (c) was more affected since it only served the local market, as compared to firm (b) which also served the regional markets.

Firm (d) was the ranked second among all the sampled firms and first among the rolling plants. The index varied between 15.99 and 28.82, with a mean of 23.01. Notably, this firm had the least installed capacity among the rolling plants in the sample. This firm also had the best fuel productivity index in the sample.

Firm (e) had the least index in the sample, varying between 13.73 and 27.15, with a mean of 20.98, and was ranked ninth. This firm consistently exhibited poor indices in all parameters investigated. This indicates a firm which requires improvement in the production process and in the management of the human resource.

Firm (f) was ranked eighth with the index varying between 14.35 and 27.93, and a mean of 21.09. Compared to other firms, this firm had a low fuel productivity. Since the firm was involved in the manufacture of similar products to the other firms, the low fuel productivity index indicates that more fuel is required to process 1 ton of steel. This then led to the low energy productivity index.

Firm (g) was ranked sixth, with the index varying between 14.14 and 27.64, with a mean of 21.74. This below average index indicates that the firm needs to update its manufacturing processes, since the firm has been in existence since the 1960s, and new entrants have higher indices.

Firm (h) was ranked seventh in the sample, with the index varying between 15.01 and 28.32, with a mean of 21.61. The trend of this firm is very similar to the general industry trend. This can be associated to the operating conditions of this firm: low capacity utilization, over-reliance on domestic markets and low fuel productivity.

Firm (i) had the highest energy productivity index, varying between 16.69 and 34.75, with a mean of 25.89. This is despite the fact that this firm had the lowest fuel productivity, implying that the firm required more fuel and/or energy to process 1 ton of steel, when compared to each of the other firms in the sample. However, since the value of the products was higher than that of the other firms, the energy productivity index was higher.

The trend of each firm is shown graphically in Figure 5.5. The period between 1999 and 2001 was characterized by severe droughts in the country. Since most of the electrical power generated was from hydro stations, the droughts resulted in reduction of the power generated. The power utility company resorted to power rationing and contracted independent power producers (who generated power from thermal sources). These factors, combined with a depressed steel and steel products market led to low energy productivity indices. Despite the high power prices among other challenges, the steel industry exhibited growth which led to the improved indices. This growth was

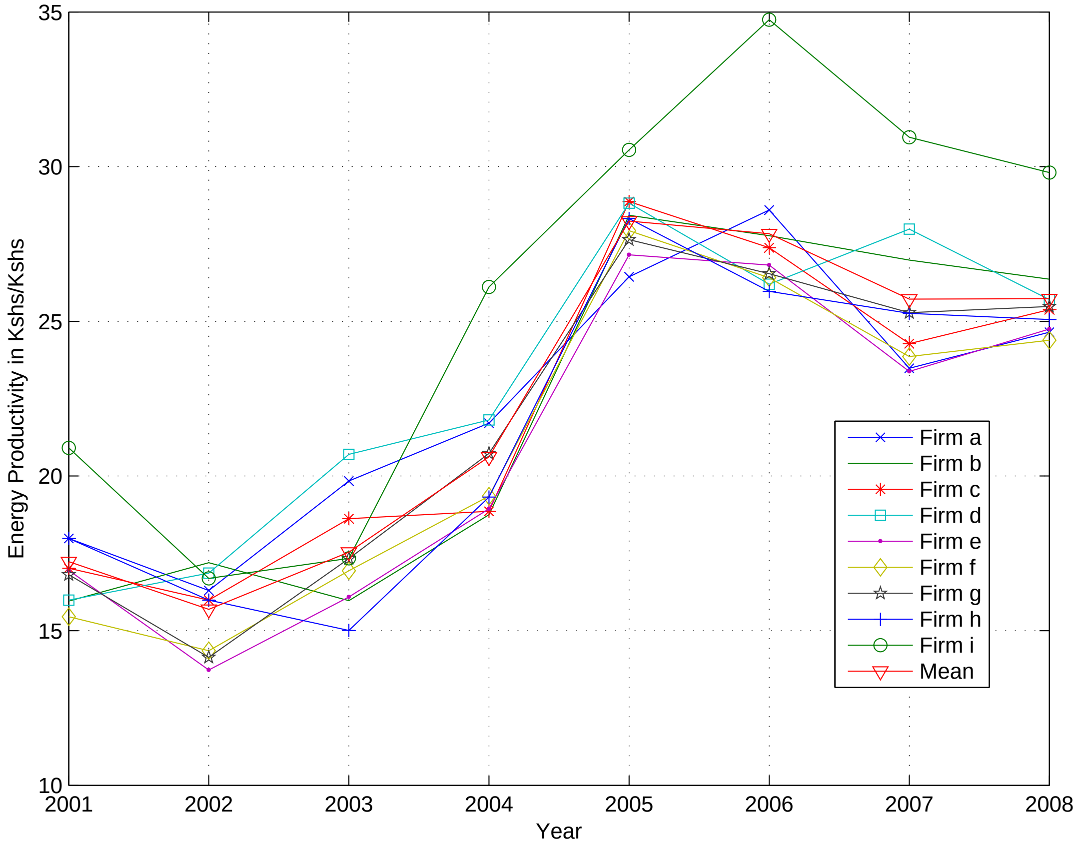

Figure 5.5: Energy Productivity for Selected Kenyan Firms

from improved revenues from higher sales. The improvement in the energy productivity index stabilizes in 2005. The variations after 2005 are due to fluctuations in the cost of electricity. To improve the index further, the investors would have to invest in modern methods of steel processing such as the electric arc furnace. The government would also have to intervene to bring down the cost of power in the country so as to spur growth in the steel industry.

This index is more objective than the fuel productivity index because it also takes into account the value of the products. For instance, two firms, using the same amount of fuel to process the same amount of steel, will have different energy productivity indices if the value of the products is different.

Steel industry is heavily energy intensive [52], which explains the low values. This is further worsened by high energy costs in the country as compared to other countries in the region [51]. To mitigate these challenges, the government should lower the taxes on fuel and review the power tariffs in the country while industry should adopt more efficient production methods.

5.2 Projection of Steel Consumption

5.2.1 Introduction

To compute the projections, the main steel consuming industries in the country were identified. These are bus and truck body building, wire and wire products industry and the building construction industry. The consumption data for each of these industry was obtained from the Kenya National Bureau of Statistics [5–7]. Rebiasz [31], Crompton [32] among other researchers have suggested that a linear relationship exists between steel consumption and time. An expression for the approximating polynomial was established and used to forecast consumption of each respective industry. To obtain the total projected steel consumption, the projections for all the industries were summed up. The sample period for the study was from 2001 to 2007, both years inclusive. This is the data that was used to obtain the approximating polynomial.

5.2.2 Bus and Truck Body Building Industry

Table 5.6 shows the steel consumed annually by the bus and truck body building industry [5–7].

Table 5.6: Steel Consumption in Kenya, Bus and Truck Body building Industry

Year	No. of New Registrations			Total Steel Consumed (mt)
	Lorries & Trucks	Buses	Trailers	
2001	1,283	4,088	603	35,767
2002	1,919	4,403	503	40,037
2003	2,069	3,521	861	38,359
2004	2,461	5,277	1,112	52,863
2005	3,113	4,961	1,351	56,139
2006	3,610	4,570	1,706	59,118
2007	6,329	6,258	2,193	86,737

Using the data in Table 5.6, projections were made for the period 2008 to 2030.

The consumption by the bus and truck body building industry varied from 35,767 Mt in 2001 to 86,737 Mt in 2007. Using the approximating polynomial, equation 5.1, the projected consumption was obtained and is presented in Table 5.7.

$$Pb(t) = 30340 + 7458t \tag{5.1}$$

Table 5.7: Projected Steel Consumption, Bus and Truck Body Building Industry

Year	Period	Projected Consumption (Metric Tons)
2001	0	30340
2002	1	37798
2003	2	45256
2004	3	52714
2005	4	60172
2006	5	67630
2007	6	75088
2008	7	82553
2009	8	90012
2010	9	97471
2011	10	104930
2012	11	112389
2013	12	119848
2014	13	127307
2015	14	134766
2016	15	142225
2017	16	149684
2018	17	157143
2019	18	164602
2020	19	172061
2021	20	179520
2022	21	186979
2023	22	194438
2024	23	201897
2025	24	209356
2026	25	216815
2027	26	224274
2028	27	231733
2029	28	239192
2030	29	246651

The projected trend of steel consumption for the bus and truck body building industry is presented in Figure 5.6

For this industry, the major assumption made was that even with the expanded railway network, for both cargo and passenger transport as envisioned by 'Vision 2030', the demand for road transport will still exist to serve the various railway stations. It is expected that the buses and trucks will be running 'perpendicular' to the railway line

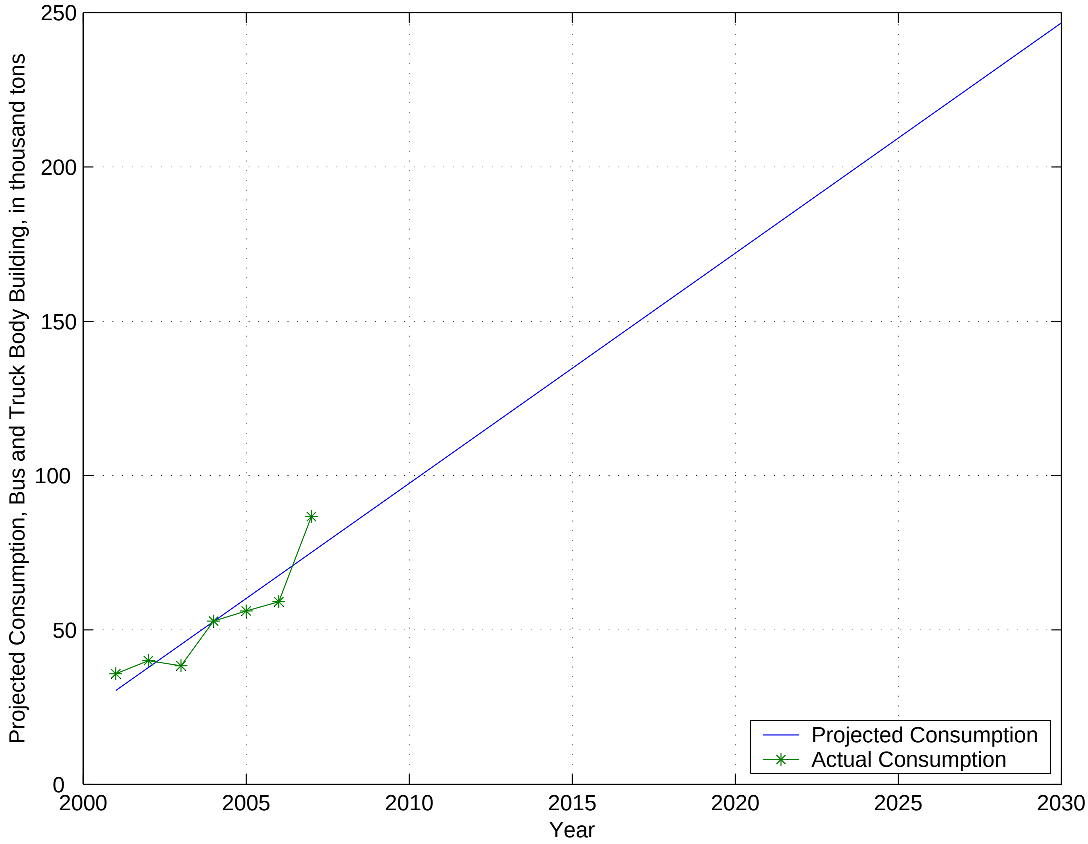

Figure 5.6: Projected Steel Consumption, Body Building Industry

and not ‘parallel’ as is the case today. However, if the current set up of the railway and road transport running parallel, with the expansion of an efficient railway system road haulage will be pushed out due to high operating costs. This will result in low demand for buses and trucks, reducing the steel demanded.

5.2.3 Wire and Wire Products

Table 5.8 shows the steel consumed annually by the wire and wire products industry, during the review period [5–7].

Table 5.8: Steel Consumption in Kenya for the Wire and Wire Products Industry

Year	Total Steel Consumed (mt)
2001	4,246
2002	7,414
2003	6,093
2004	5,320
2005	6,238
2006	6,211
2007	8,205

Using the data in Table 5.8, projections were made for the period 2008 to 2030. The consumption by the wire and wire products increased from 4,246 metric tons in 2001 to 8,205 metric tons in 2007. The approximating polynomial, equation 5.2, was used to obtain the projected consumption.

$$Pw(t) = 5218 + 343t \tag{5.2}$$

For the period under review, the growth can be attributed to the growth in the agricultural and manufacturing sectors of the economy. The projected growth for this industry is expected to be sustained since the implementation of 'Vision 2030' strongly favors the growth of this sub-sector. Table 5.9 shows the projected steel consumption for this industry.

The projected trend of steel consumption for the wire and wire products industry is presented in Figure 5.7

5.2.4 Construction Industry

Table 5.10 shows the steel consumed annually by the Building Construction industry, during the review period [5–7].

Using the data in Table 5.10, projections were made for the period 2008 to 2030.

The consumption of steel by the construction industry grew from 290,250 metric tons in 2001 to 847,500 metric tons in 2007. The approximating polynomial for this industry, equation 5.3, was used to obtain the projected consumption for the period 2008 to 2030. This is one sector that will be greatly favored by the 'Vision 2030' in that provision of housing is a key agenda item.

Table 5.11 shows the projected steel consumption for the construction industry.

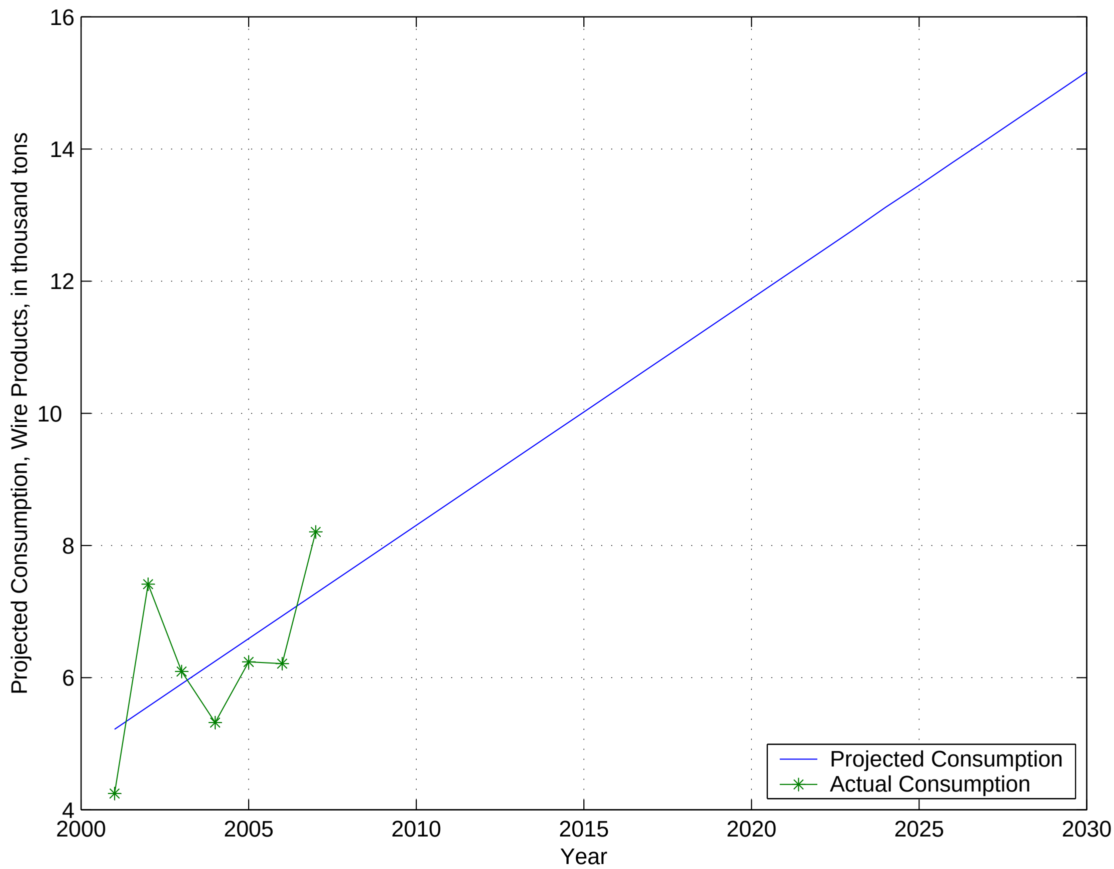

Figure 5.7: Projection for Steel Consumption, Wire Products Industry

Table 5.9: Projected Steel Consumption, Wire and Wire Products Industry

Year	Period (t)	Projected Consumption (Metric Tons)
2001	0	5218
2002	1	5561
2003	2	5904
2004	3	6247
2005	4	6590
2006	5	6933
2007	6	7276
2008	7	7619
2009	8	7962
2010	9	8305
2011	10	8648
2012	11	8991
2013	12	9334
2014	13	9677
2015	14	10020
2016	15	10363
2017	16	10706
2018	17	11049
2019	18	11392
2020	19	11735
2021	20	12078
2022	21	12421
2023	22	12764
2024	23	13117
2025	24	13450
2026	25	13796
2027	26	14136
2028	27	14479
2029	28	14822
2030	29	15165

$$Pc(t) = 293052 + 81304t \tag{5.3}$$

The projected trend of steel consumption for the construction industry is presented in Figure 5.8

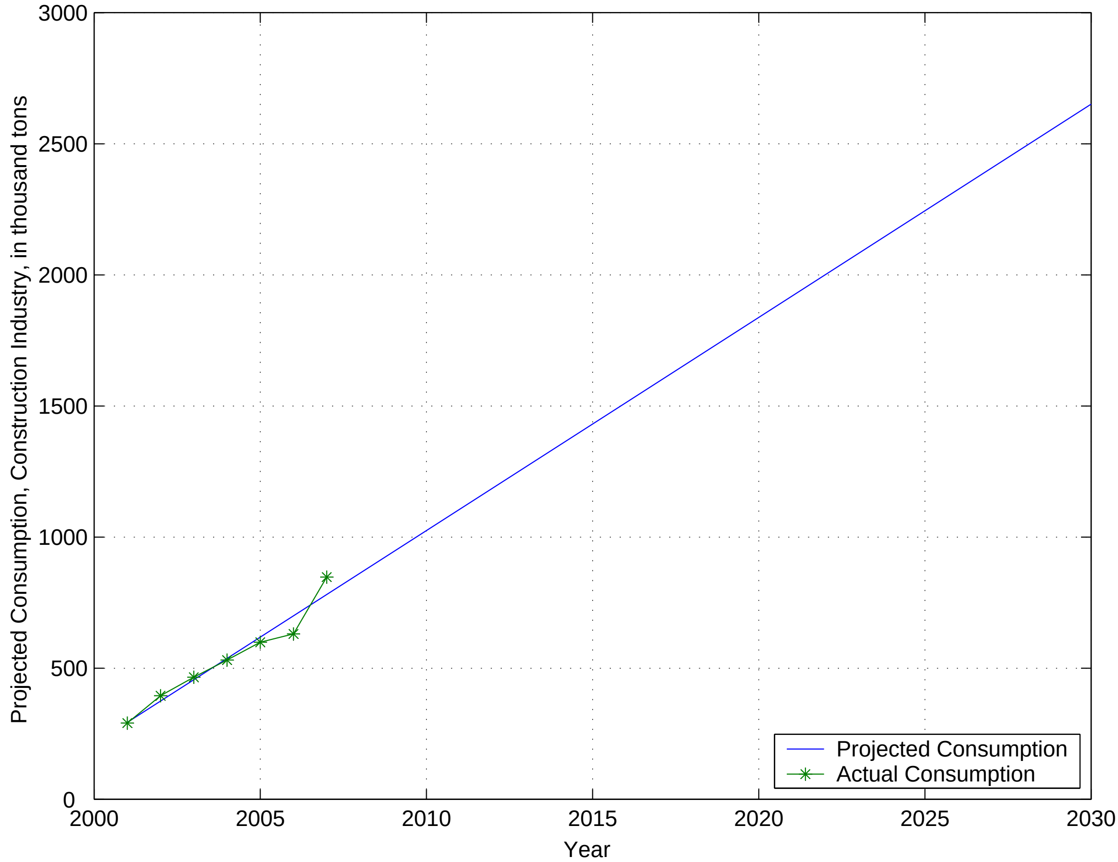

Figure 5.8: Projection for Steel Consumption, Construction Industry

Table 5.10: Steel Consumption in Kenya for the Construction Industry (2001 - 2007)

Year	No. of Buildings		Total Steel Consumed (mt)
	Residential	Non-Residential	
2001	9,410	110	290,500
2002	10,400	270	395,000
2003	11,420	360	465,500
2004	17,040	210	531,000
2005	18,150	290	598,750
2006	19,030	310	630,750
2007	23,500	520	847,500

5.2.5 Total Steel Consumption Projection

From the projections, the total consumption of steel in 2018 is expected to be 1,843,412Mt, double the consumption of 2008, and 2,912,684 Metric tons in 2030, more than three times the 2008 consumption. This increase in projected steel consumption was the basis in the establishing the capacity of the proposed plants.

The projected trend of the total steel consumption is presented in figure 5.9

5.3 Environmental Policies and Regulations

5.3.1 Overview

Environmental policies and regulations are spelt out in the Environmental Management and Co-ordination Act of 1999, EMCA 1999. The National Environmental Man-

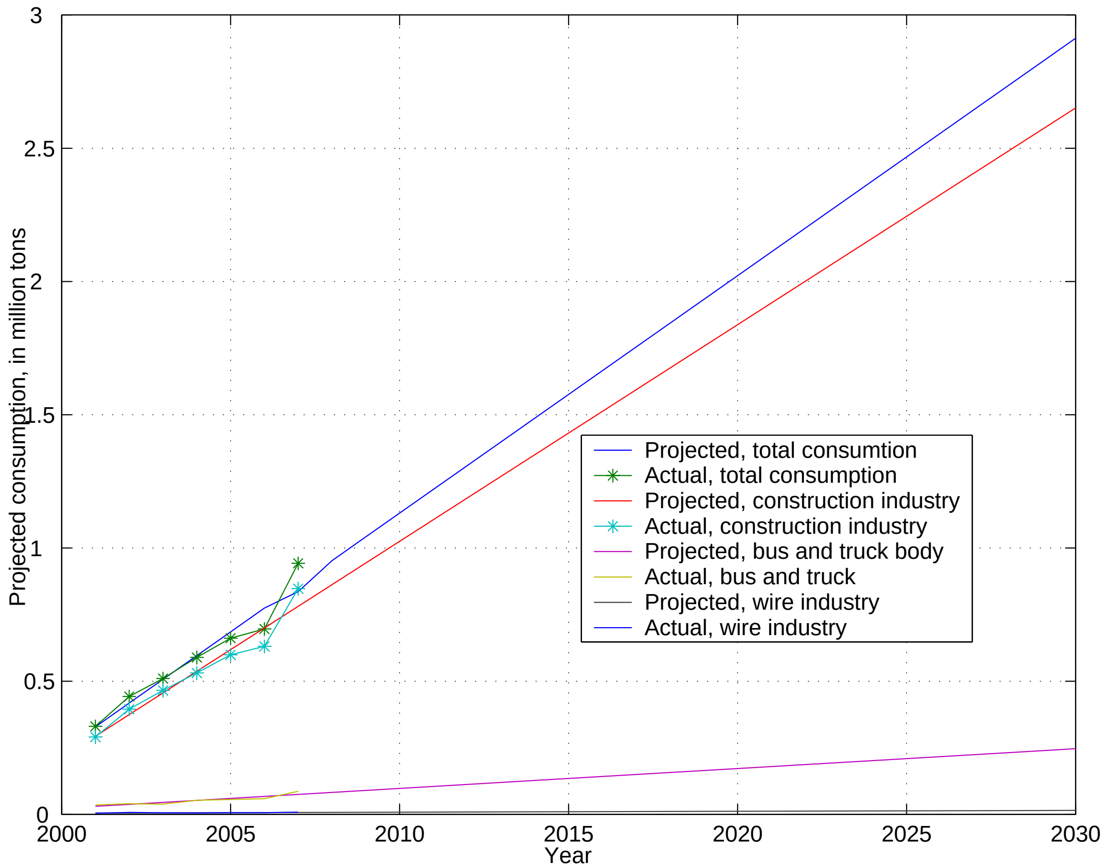

Figure 5.9: Projection for Total Steel Consumption in Kenya

Table 5.11: Projected Steel Consumption, Construction Industry

Year	Period	Projected Consumption (Metric Tons)
2001	0	293052
2002	1	374356
2003	2	455660
2004	3	536964
2005	4	618268
2006	5	699572
2007	6	780876
2008	7	862180
2009	8	943484
2010	9	1024788
2011	10	1106092
2012	11	1187396
2013	12	1268700
2014	13	1350004
2015	14	1431308
2016	15	1512612
2017	16	1593916
2018	17	1675220
2019	18	1756524
2020	19	1837828
2021	20	1919132
2022	21	2000436
2023	22	2081740
2024	23	2163044
2025	24	2244348
2026	25	2325652
2027	26	2406956
2028	27	2488260
2029	28	2569564
2030	29	2650868

agement Authority, NEMA is created under that act and is mandated with the implementation of the act. Enactment of the act brought about harmonization of several statutes that existed before.

5.3.2 Environmental Policies

The main environmental policies are enumerated below [53]:

1. Every person is entitled to a clean and healthy environment and has the duty to safeguard the environment

2. Polluter pays principle: Under this principle, the cost of cleaning up any element of the environment damaged by pollution, compensating victims of pollution, and the costs, and other costs connected or incidental to pollution are to be paid by the polluter.

3. Intergenerational equity: This policy ensures that in exploiting the environment, it is maintained or enhanced for the benefit of future generations.

4. Intra-generational equity: This policy ensures that all people within the present generation have the right to benefit equally in exploiting the environment, and that they have an equal entitlement to a clean and healthy environment.

5.3.3 Environmental Regulations

Before financing, commencing and proceeding with a project, the project proponent shall undertake an Environmental Impact Assessment, EIA and submit the report to NEMA for approval [37]. EIA is a systematic analysis of projects, policies and plans to determine their potential environmental impacts and propose measures to mitigate the negative impacts.

5.3.4 Environmental Audit and Monitoring

Once the project has been commissioned and is in operation, periodic environmental auditing is required. The audit assesses actual environmental impacts, the effectiveness of the environmental impact mitigation measures and the functioning of the monitoring mechanisms. According to the regulations, two types of environmental audits are provided, namely control audit and self audit, which are undertaken by NEMA and project proponent respectively. A typical Environmental Impact Assessment report for a steel plant is appended as Appendix C.

5.4 Occurrence of Iron Ore

Iron ore was being exploited in Tharaka (37M 382000, UTM 9980335; M37 383040, UTM 9980306; M37 384642, UTM 9978792), Mutomo (37M 407000, UTM 9902000; M37 410000, UTM 9820000; M37 402500, UTM 9910000) and Taita (37M 419016, UTM 9978792; 37M 418415,UTM 9633657; 37M 418670, UTM 9634103) Districts. The ore in Mutomo and Tharaka district was being used in cement manufacture and none is refined to produce iron and steel. For Taita District, the alluvial and reef ore is exported. Of these areas, an elaborate study had been carried out by the Department of Geology and Mines on surface occurrence and valuation of iron ore deposits in Tharaka District at Kithiori area of Marimanti Division [54].

5.4.1 Location and Accessibility

The study area is accessed by road from Nkubu. The roads were mainly earth roads but they were well maintained and motorable.

5.4.2 Iron Ore Deposits Qualitative Analysis

The method used for the analysis was the Atomic Absorption Spectrometry, (AAS). The results of the analysis are presented in Appendix D. Samples were collected through trenching and pitting, both in the claim area and outside the claim area [54].

Some of the samples had very low Fe_2O_3 content, indicative of host rocks and not ores. After filtering out these samples, i.e. sample numbers 2,5,6,12,15,16 and 20, the average content was found to be 62.35 %, which was of high grade and can be commercially exploited for iron and steel production.

5.4.3 Iron Ore Deposits Reserve Estimation

The average ore content of the pits, by volume was found to be 15 %. In estimating the reserves, the following assumptions were made:-

- The area was assumed to be square, 10Km by 10Km
- Since the sampled pits and trenches were between 0.8m and 1.3m, an average depth of 1m was assumed.

The mass of the reserve is given by:-

$$Q = V \times D \tag{5.4}$$

where Q is the quantity of the ore in tons, V is the volume of ore in m^3 and D is the density of the magnetite ore, which is 5.2 $tons/m^3$.

Total Volume, = Total Area $\times depth = 100,000,000 m^3$

Volume of ore, V = 15% of total volume = $15 \times 10^6 m^3$

hence, $Q = V \times D = 15 \times 10^6 \times 5.2 = 78 \times 10^6$ metric tons

The computed figure of 78 million metric tons of ore is conservative due to the following reasons:-

- Some losses are incurred during trenching and pitting.
- The computation is based on 1m depth, while it was observed in old mines for some bands to be more than 5m deep.

5.5 The Size of the Proposed Plant

From the projection data, two approaches were adopted. The first one was to build a large plant from the onset while the second one was to build a small plant and then upgrade after 10 years. Both were subjected to the Net Present Value analysis, using a discounting factor of 20% and the results were compared.

The results of the Net Present Value analysis, are presented in tables 5.12 , 5.13 and 5.14. From these results, the investor has a higher return on capital by setting up a large plant from the onset. There is also the advantage of reducing the risk of lost earnings from canceling orders due to lack of capacity, if a small plant is set up. From the survey, one firm controls 60% of the steel market in the East African region. By starting a large plant from the start, the investor will also be able to target a share of this vast regional market.

Table 5.12: Net Present Value Analysis for a 500,000 tons annual capacity plant

Period	Net Annual Earnings in billion KES	Net Present Value in billion KES
0	Set up	(10.00)
1	0.95	-9.15
2	1.10	-8.27
3	1.26	-7.37
4	1.44	-6.45
5	1.62	-5.53
6	1.81	-4.61
7	2.02	-3.70
8	2.24	-2.80
9	2.46	-1.91
10	upgrade by KES 16b	-17.91
11	3.09	-16.66
12	3.50	-15.46
13	3.93	-14.32
14	4.38	-13.23
15	4.86	-12.19
16	5.36	-11.21

Period	Net Annual Earnings in billion KES	Net Present Value in billion KES
17	5.89	-10.28
18	6.42	-9.40
19	6.98	-8.57
20	7.56	-7.79
	Net Present Value	**-7.79**

Table 5.13: Net Present Value Analysis for a 750,000 tons annual capacity plant

Period	Net Annual Earnings in billion KES	Net Present Value in billion KES
0	Set up	(13.20)
1	1.43	-11.93
2	1.65	-10.61
3	1.90	-9.26
4	2.15	-7.89
5	2.43	-6.51
6	2.72	-5.13
7	3.03	-3.76
8	3.35	-2.41
9	3.69	-1.08
10	upgrade by KES 12b	-13.08
11	4.35	-11.83
12	4.67	-10.63
13	4.99	-9.49
14	5.32	-8.40
15	5.67	-7.36
16	6.03	-6.38
17	6.39	-5.45

Period	Net Annual Earnings	Net Present Value
18	6.77	-4.56
19	7.16	-3.73
20	7.56	-2.95
	Net Present Value	**-2.95**

Table 5.14: Net Present Value Analysis for a 1 million ton Annual capacity plant

Period	Net Annual Earnings in billion KES	Net Present Value in billion KES
0	Set up	(20.00)
1	1.81	-18.38
2	2.02	-16.77
3	2.24	-15.18
4	2.46	-13.61
5	2.70	-12.08
6	2.95	-10.59
7	3.21	-9.14
8	3.48	-7.73
9	3.76	-6.38
10	4.05	-5.07
11	4.35	-3.82
12	4.67	-2.62
13	4.99	-1.48
14	5.32	-0.39
15	5.67	0.64
16	6.03	1.63
17	6.39	2.56

Period	Net Annual Earnings in billion KES	Net Present Value in billion KES
18	6.77	3.44
19	7.16	4.27
20	7.56	5.05
	Net Present Value	**5.05**

5.6 Experimental Results

5.6.1 Introduction

Various National Standards specifications have been developed for the country by the Kenya Bureau of Standards, KEBS, for steels. These standards mainly specify the tensile properties and the tests that are to be conducted. The standards also specify the frequency of sampling. KEBS routinely conducts tests on these steels, for conformance to respective standard specification.

5.6.2 Tensile Tests

The tensile tests were conducted in accordance to KS06 141 [38]. Table 5.15 shows the results of the tensile test. All the samples satisfied the tensile strength requirements, with the exception of sample number 6. Similarly the ductility specifications, indicated by the percentage elongation, were satisfied by all the samples except samples number 15 and 26.

The samples had been collected as recommended by the respective standard. Basically, a number of samples were collected from each batch. The samples included steel bars and sections rolled from both imported billets and from steel obtained from scrap. The samples had been collected from manufacturers, private samples and as quality control samples. Private samples were submitted privately by any party, interested in obtaining the properties of steel. This included traders who were tendering to supply, and were required to have the properties ascertained by an independent party. They were also submitted by consulting firms. Quality control samples were collected by

Quality Assurance officers of KEBS both from the market and from the manufacturers.

This broad mix of sources ensured that the samples were more representative.

Table 5.15: Tensile Tests Results

Sample	Type	Tensile Strength (N/mm^2)		Standard	Elongation (%)	
		Results	Specs.		Result	Specs.
1	T25	621	485-650	BS 4449	16	min 6
2	T20	750	,,	,,	15	,,
3	T16	625	,,	,,	19	,,
4	T12	484	,,	,,	25	,,
5	T10	496	,,	,,	24	,,
6	T8	269	,,	,,	25	,,
7	Y16	578	min 460	KS 573	18	min 12
8	Y16	605	,,	,,	-	,,
9	Y20	668	min 425	,,	14	min 14
10	Y25	601	,,	,,	-	,,
11	Y32	711	,,	,,	-	,,
12	Angle 80x80x8	554	min 250	KS02 572	34	min 22
13	Angle 70x70x6	563	,,	,,	31	,,
14	Angle 60x60x6	520	,,	,,	31	,,
15	Angle 100x75x9.5	620	,,	,,	17	,,
16	Y8	456	min 460	KS 573	18	min 12
17	Y10	466	,,	,,	20	,,
18	Y12	535	,,	,,	20	,,
19	Y16	575	,,	,,	13	,,
20	Y20	624	min 425	,,	15	min 14
21	Y25	636	,,	,,	17	,,
22	Y8	465	min 460	,,	15	min 12
23	Y16	688	,,	,,	-	,,
24	Y10	649	,,	,,	12	,,
25	Y12	548	,,	,,	18	,,
26	Y20	620	min 425	,,	13	min 14
27	D16	551	485-650	BS 4449	23	min 6
28	D20	550	,,	,,	26	,,
29	D25	622	,,	,,	26	,,
30	Angle 20x20x3	602	min 250	KS02 572	23	min 22
31	Angle 20x20x3	948	,,	,,	-	,,
32	Flat 30x3	498	,,	,,	28	,,
33	Angle 30x30x2	453	,,	,,	25	,,
34	Angle 40x20x1.2	340	,,	,,	23	,,
35	Z Section	647	min 355	KS02 445		
36	,,	580	,,	,,		
37	Angle 25x25x1.3	576	min 250	KS02 572	27	min 22
38	Angle 30x30x1.2	417	,,	,,	40	,,
39	Angle 40x25x1.9	448	,,	,,	28	,,
40	Angle 20x20x1.3	422	,,	,,	25	,,
41	Y10	550	min 460	KS 573	31	min 12

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

In the recent past, steel consumption had been increasing steadily in the country. The demand had been satisfied mainly through imports. Since most of the steel scrap was exported and semi-processed steel imported, this contributed to the negative balance of trade in the country. Since from the study, the steel obtained from scrap meets the statutory requirements for their intended applications, export of steel scrap should be discouraged. Steel processors will thus be encouraged to increasingly use scrap steel as their main raw material, resulting in creation of jobs and save foreign exchange.

During the study period, it was observed that the Kenyan steel industry utilized only about 45% of the installed capacity. However, the capacity utilization was projected to improve with time due to the projected increase in steel consumption. Once the capacity utilization rate improved to over 90% , the existing steel plants would no longer be able to satisfy the demand. The unsatisfied demand, coupled with the availability of iron ore in the country, would attract new investment in the industry.

From the results of the study, the following conclusions were made:

1. The net present value for initially large plants is higher than that of small plants. Therefore building a large plant from the onset is better than a small plant to be upgraded later.

2. Steel obtained from recycled scrap meets the statutory requirements for the intended use.

3. The average efficiency of the Kenyan steel industry, based on the total number of labor hours per ton of steel, is lower than that of other market players. The value is 7.87 contrasted to less than 4 for integrated steel plants and less than 0.5 for mini steel plants.

4. Iron ore exists in sufficient quantities in the country for commercial exploitation. For instance, in the Kithiori Area, Tharaka District, there exists deposits of at least 78 million tons of ore, with 62.35% iron content.

6.2 Recommendations

From the study, it was observed that the local steel industry faced various challenges. These included high production costs, low efficiency and high set up costs for new plants. Various opportunities, such as increasing projected steel consumption in the country were also identified.

Based on the findings of this study, the following recommendations were made

- Since the viability of establishing a 1 million tons per year integrated steel plant was determined, it was recommended that a comprehensive feasibility study be carried out.

- The cost of establishing new steel plants is usually very high. Steel plants also have very long lives, increasing the uncertainties when making the investment decisions. To mitigate against these challenges, it was recommended that the government provide infrastructure for Public Private Partnerships.

- The economic benefits of establishing integrated steel plants in the country are very many. In this regard, it was recommended that the government should encourage investment in this industry through fiscal incentives such as tax breaks for imported equipment, spares and on locally obtained raw materials; and non-fiscal incentives such as preferential immigration treatment and simplified customs procedures.

- The study only covered the Kenyan steel market. However, with the integration of the Eastern Africa countries, a similar study for the region is recommended.

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APPENDIX A: Questionnaire

QUESTIONNAIRE

RESEARCH TOPIC: *A STUDY INTO STEEL PROCESSING AND RECYCLING INDUSTRY IN KENYA*

1. COMPANY PROFILE

   COMPANY NAME:………………………………………………………

   ADDRESS:……………………………………………………….

   TEL:………………………… EMAIL:…………………………..

   COMMISSIONED:…………………………………. (YEAR)

   LAST TIME CORE EQUIPMENT UPGRADED :……………….(YEAR)

   OPERATION: 8 hrs____ 24____hrs Other(Specify) _______ ______

   NO. OF EMPLOYEES PER SHIFT:___________

   DESIGN CAPACITY:……………………………..…METRIC TONS PER YEAR

   USED (ACTUAL) CAPACITY:…………………….. METRIC TONS PER YEAR

   MARKET OF PRODUCT

   LOCAL:………..% EXPORT:…………%

2. MAIN EQUIPMENTS (e.g. Rolling mills, furnaces, etc)

	TYPE	**YEAR OF PURCHASE**	**YEAR OF MANUFACTURE**
1			
2			
3			
4			
5			

Page 1 of 10 pages

3. PRODUCTION DATA

YEAR	ANNUAL SALES		NET INCOME (Kshs)	BOOK VALUE OF ASSETS (Kshs)
	Quantity (metric tons)	Gross Sales (Kshs.)		
2001				
2002				
2003				
2004				
2005				
2006				
2007				
2008				

4. QUANTITY OF RAW MATERIALS (Metric tons)

	2001	2002	2003	2004	2005	2006	2007	2008
SEMI PROCESSED STEEL								
STEEL SCRAP								

5. RAW MATERIALS DATA

YEAR	QUANTITY						TOTAL COST (Kshs)	
	Semi processed steel (metric tons)			Scrap steel (metric tons)			Semi processed steel	Scrap steel
	Local	Imports	Total	Local	Imports	Total		
2001								
2002								
2003								
2004								
2005								
2006								
2007								
2008								

6. COST OF LABOR (Kshs)

	2001	2002	2003	2004	2005	2006	2007	2008
Total No. of permanent employees								
Average No. of leave days/employee per year								
Annual labor cost Kshs.								

7. QUANTITY OF FURNACE FUEL USED (Metric tons)

2001	2002	2003	2004	2005	2006	2007	2008

8 COST OF FUEL AND ELECTRICITY

	2001	2002	2003	2004	2005	2006	2007	2008
FURNACE FUEL (Kshs per ton)								
ELECTRICITY (Total Cost Kshs)								

9. HAS THE ORGANIZATION BEEN CONDUCTING RESEARCH AND DEVELOPMENT? YES [ ] NO [ ]

10. IF YES, WHAT HAS BEEN THE PERCENTAGE OF THE RESEARCH BUDGET TO TOTAL SALES?

	2001	2002	2003	2004	2005	2006	2007	2008
RESEARCH BUDGET (%) OF SALES								

11. MAIN PRODUCTS (Please tick [√] as appropriate)

(a) Wire products…..……………………………......…[ ]

(b) Hollow sections……………………………………[ ]

(c) Reinforcing steel……..…………………………..…[ ]

(d) Roofing sheets………..…………………………....…[ ]

(e) Castings………………………………..………...…[ ]

(f) Reinforcing steel……..………………………….…[ ]

(g) Fabricated products.....………………………..........[ ]

(h) Auto parts (i) Springs……………………[ ]

(ii) Brake drums……………....[ ]

(iii) Bus and Truck bodies……..

(i) Others (specify) (i) ..…………………………..…...…

(ii)………………………………..

(iii)…………………….……..……

12. MAIN PRODUCTION PROCESSES ADOPTED

(Please tick [√] as appropriate)

(a) Wire drawing.…..……………………………...…[ ]

(b) Hot rolling……………………………………… [ ]

(c) Cold rolling…………..…………………………...…[ ]

(d) Forging…………..…..…………………………...…[ ]

(e) Continuous casting…………………..………...…[ ]

(f) Ingot casting…………………..……..………...…[ ]

(g) Fabrication…………..…………………………..…[ ]

(h) Others (specify) (i) ..………………………..…...…

(ii)………………………………..

(iii)……………………..………

13. DO YOU CARRY OUT ANALYSIS ON THE CHEMICAL COMPOSITION OF THE PRODUCT? YES [ ] NO [ ]

14. IF YES, PLEASE FILL IN THE FOLLOWING DETAILS:

PRODUCT TESTED:………………………………………..

ELEMENT	**EQUIPMENT USED**	**RELEVANT STANDARD (e.g. Kenya Standard)**
		ALLOWABLE LIMITS
CARBON		
SULPHUR		
PHOSPHOROUS		
SILICON		
MANGANESE		

15. AS A QUALITY CONTROL CHECK, ARE TESTS CARRIED OUT TO DETERMINE THE MECHANICAL PROPERTIES OF THE MAIN PRODUCT?

YES [ ] NO [ ]

16. IF YES, PLEASE FILL IN THE FOLLOWING DETAILS

PRODUCT TESTED:………………………………………..

TEST	**EQUIPMENT USED**	**RELEVANT STANDARD (e.g. Kenya Standard)**
		ALLOWABLE LIMITS
UNIAXIAL TENSILE TEST		
OTHER TESTS: (SPECIFY)		

17. DO YOU SMELT SCRAP STEEL? …….YES [ ] NO [ ]

IF YES, PLEASE INDICATE THE FOLLOWING:

(a) NUMBER OF FURNACES USED:………….

(b) DETAILS OF THE FURNACES

	INITIAL COST (KSHS)	**YEAR OF PURCHASE**	**YEAR OF MANUFACTURE**	**CAPACITY (TONS PER YEAR)**	**VOLUME OF FURNACE (M^3)**	**FUEL TYPE**
FURNACE 1						
FURNACE 2						
FURNACE 3						
FURNACE 4						
FURNACE 5						

(c) QUANTITY OF STEEL SMELTED (Metric tons)

2001	2002	2003	2004	2005	2006	2007	2008

18. ANY OTHER COMMENT

……………………………………………………………………..…………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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…………………………………………………………………………………………………

…………………………………………………………………………………………………

Name:………………………………………………………

Designation:……………………………………………….

Date:……………………….

YOUR EFFORT AND TAKING TIME TO FILL THIS QUESTIONNAIRE IS GREATLY APPRECIATED.

APPENDIX B: AAS Results

The table below shows the ore content of the samples that were analyzed.

Sample Number	Fe_2O_3 Content (%)
1	42.1
2	15.5
3	82.5
4	665.4
5	24.7
6	25.2
7	55.5
8	58.9
9	68.5
10	45.8
11	42.7
12	36.1
13	66.6
14	74.4
15	30.6
16	21.7
17	68.3
18	79.0
19	61.0
20	18.5
Average	**49.15**

APPENDIX C: Typical EIA Report for a Steel Plant

Proposed Steel Plant

P.O. Box ....

Tel:......................

PIN No.............

Contact Person:........................ Designation:....................

PROJECT TITLE

Proposed National Steel Processing Plant.

OBJECTIVES AND SCOPE OF PROJECT

The main objective of the project is to establish a steel processing plant, with a capacity of 1 million metric tonnes per year. The project report covers from the construction stage, commissioning through the operation phase, to decommissioning.

PROJECT DESCRIPTION

The proposed project is a steel processing industry. It is intended that the factory will be situated on a 25 acre land in Tharaka District. The factory will be built on a currently fallow land and the project commencement will be construction of buildings and provision of services such as drains and sewers, and construction of access roads within the factory site.

Main Activities During Project Construction

- Excavations to lay foundations for the buildings. This will involve the use of heavy commercial vehicles and earth moving equipment.
- Civil works: These will involve the actual construction of the buildings. For the construction of access roads, among other activities, soil compaction will also be done. Provision of drainage and sewerage services will also be carried out. It is proposed that sewerage disposal services be provided through septic tanks, since the area is not served by municipal sewers.

PROJECT OPERATION

Once the project construction is complete, it will be followed by installation of production machinery. Once the machines are installed and commissioned, production will then commence. This will involve processing of iron ore, to produce iron and finally steel. The steel will then be continuously cast to produce steel bars and rods of various sizes and shapes as required. The project is expected to run for 80 years before decommissioning. This project is expected to provide 2,000 direct jobs and over 10,000 indirect jobs to the economy. It will also save the country the much needed foreign capital as it will reduce the amount of steel imported.

MATERIALS TO BE USED

The project intends to use locally available iron ore as the main raw material. Other raw materials, such as coal, will be ferried to the factory, since they are not locally available. The final product will be steel bars and rods, while the bye-products will be slug which will be sold to cement manufacturers and road construction companies.

POTENTIAL ENVIRONMENTAL IMPACTS AND PROPOSED MITIGATION MEASURES

a) During Construction

Environmental Impact	**Proposed Mitigation**
Dust	Use of water to reduce dust
Noise	Provision of protective gear to the workers
Excavated soil	Dump in designated sites.

b) During Operation

Environmental Impact	**Proposed Mitigation**
Air emissions	Full capture of emitted gases

	Recycling, especially of carbon monoxide gas
	Minimizing sulphur content of the fuel to reduce sulphur dioxides emissions
Particulate Matter	Installation of collection hoods.
	Use of electrostatic precipitation pulse systems
	High pressure wet scrubbing systems
Waste water	Recycling of cooling water.
	Use of dry techniques for dust removal
Noise	Enclosing process buildings.
	Enclosing fans
	Provision of safety gear in locations with very high noise levels

During the project life cycle, a comprehensive environmental, safety and health guidelines will be developed. To ensure safety of local community and customers, among other measures, entry to the premises will be restricted. Persons will only be allowed entry after undergoing a safety induction and on wearing safety gear. For the staff, regular safety drills and clinics will be conducted.

ECONOMIC BENEFIT

- Employment

The project will result in new jobs, both skilled and unskilled. This will greatly benefit the local community in that all unskilled labor will favor the local community as part of corporate social responsibility, while skilled labor will be competitively sourced.

- Save Foreign Exchange

  Since all the steel currently used is imported, with local steel production, foreign exchange will be saved.

- Real Estate

  Once the plant becomes operational, there will be a need to provide the staff with housing. This will spur real estate development in the area with the associated facilities. The company also intends to export some of its products to the COMESA and EAC markets, and thus earn the much needed foreign currency.

APPENDIX D: Glossary of Terms

Annual Expected Earnings	Gross revenue expected per year.
Annual Operating Costs	Total cost of running a plant per year.
Alloying Elements	Elements added to a metal to improve the properties.
Approximating Polynomial	Function developed to relate consumption and time.
Atomic Absorption Spectrometry	A technique of determining the concentration of a metal element in a sample
Basic Oxygen Furnace	Section in an integrated steel mill where molten iron is converted into steel.
Beneficiating	A process of increasing the iron content of low grade ores.
Billets	Thick bars with rectangular section.
Blast Furnace	A furnace that smelts iron ore and coke to produce pig iron.
Capacity	Quantity produced by a process per unit time.
Capacity Utilization Rate	Ratio of capacity used to the design capacity.
Consumption	The quantity of a product used per unit time.
Demand	Quantity which consumers are willing and able to buy at a particular price.
Discounting Factor	A ratio used to calculate the present value of future cash flows.

Efficiency	The ratio of actual output to standard output.
End of Life Scrap	Scrap that is obtained from obsolete steel products
Environmental Audit	A systematic documented verification process to determine if specified environmental activities, events and conditions meet the audit criteria
Environmental Impact Assessment	An evaluation of possible effects that a proposed project may have on the environment, and to propose mitigation measures against the negative ones
Environmental Management	Planned activities aimed at protecting,conserving and sustainably using the various components of the environment.
Electric Arc Furnace	A furnace that heats charged material through an electric arc.
Firm Level Efficiency	The efficiency of a particular steel plant.
Forecasting	A scientific method of predicting a future event.
Furnace	An appliance in which heat is generated and transferred to a solid or fluid mass so as to effect physical/ chemical change.
Ingots	Castings made in simple shapes for further working through forging,rolling,etc.
Initial set up costs	The total cost of setting up a plant and it includes land, equipment and licence fees.

Input	What is fed into a transformation process.
Integrated steel mill	A steel plant that produces steel from ir-on ore.
Large capacity plant	A plant with sufficient capacity to meet demand in a particular period of time.
Martensite	The microstructure of quenched eutectoid steel.
Metal forming	A metal working process whereby the desi-red shape is obtained through the applicat-ion of stresses
Meteorites	A natural object from outer space that sur-vives the impact with the earth's surface.
Mini steel mill	A plant that produces steel wholly from sc-rap.
Net earnings	The gross revenue less all the costs of produ-ction.
Net present value	The sum of discounted cash flows
Ore deposits	Deposits of a mineral that can be economica-lly exploited.
Output	The expected result /outcome of a process.
Parallel	A situation where road transport serves areas that are also served by railway lines, side by side.

Pearlite	A microstructure obtained when eutectoid steel is cooled slowly and homogenously.
Perpendicular	A situation where road transport connects railway stations with the hinterland areas not served by rail.
Pig iron	Metallic product, resulting from the reduction of iron ore when smelted in a blast furnace.
Present value	The current value of future cash flows
Productivity	The ratio of outputs to inputs
Proportional test piece	A test piece with a specified ratio of cross sectional area to gauge length.
Small capacity plant	A steel plant whose capacity cannot satisfy demand in a given period.
Steel	Iron with more than 0.15% chemically combined carbon.
Supply	The quantity of steel that steel producers are willing and able to avail to the market at a particular price.
Upgrading cost	The cost incurred to increase the capacity of a plant