CHAPTER - III

CONCEPTS AND METHODS

3.1 General

Titanium dioxide was first produced commercially in 1923. It accounts for approximately 70 per cent of the total volume of pigment production. Relatively small quantities of titanium dioxide are used for non-pigmentary purposes. In 2004, worldwide production of titanium dioxide was 4.4 million tonnes.

Titanium dioxide is obtained from a variety of ores that contain ilmenite, rutile, anatase and leucoxene, which are mined from deposits located throughout the world. Most of the titanium dioxide pigment is produced from titanium mineral concentrates by the chloride or sulfate process, either as the rutile or the anatase form. The primary particles are typically between 0.2 and 0.3 μm in diameter, although larger aggregates and agglomerates are formed. Ultrafine grades of titanium dioxide have a primary particle size of 10–50 nm and are used predominantly as ultraviolet blockers in sunscreens and plastics, and in catalysts. Most commercial titanium dioxide products are coated with inorganic (e.g. alumina, zirconia, silica) and organic (e.g. polyols, esters, siloxanes, silanes) compounds to control and improve surface properties.

Levels of occupational exposure to titanium dioxide during its manufacture have been reported from USA and Europe between 1970 and 2000. The highest levels of exposure were observed during packing and milling, although high
exposure also occurred in occupations such as site cleaning and maintenance. Levels of exposure to respirable dust in these occupations ranged between $< 1$ and $5 \text{ mg/m}^3$ (geometric mean) but have declined over time. No data were available that would allow the characterization or quantification of exposure to ultrafine primary particles. Workers in the titanium dioxide manufacturing industry may also be exposed to ore and other dusts, strong acids and asbestos.

Exposure to titanium dioxide in user industries is difficult to estimate and characterize due to the paucity of data. However, exposure levels are assumed to be lower in the user industries, with the possible exception of workers who handle large quantities of titanium dioxide. No significant exposure to titanium dioxide is thought to occur during the use of products in which titanium dioxide is bound to other materials, such as in paints.

The present study employs the standard budgeting techniques such as: Net Present Value (NPV), Internal Rate of Return (IRR) and simple pay back period analysis to verify the economic viability of the ilmenite and titanium mining venture in Tamil Nadu. It also adopts sensitivity analysis to find out the extent of the influence of the most important factors on the profitability of the venture. The research also tries to identify the most economic determinants of various elements of titanium mineral production of ilmenite and rutile. The various trend and ARIMA models are also adopted to forecast the production, consumption, export and price of ilmenite and rutile minerals. In this chapter the concepts related to
this study are discussed, followed by the various methods adopted. A section on the discussion of study area is also included at the end of the chapter.

3.2 Concepts

Mining

Mining is a form of extracting of surface deposits of dense materials weathered from rock and carried into a streambed, where shovel to dredges may be used to scoop materials and can be sorted. It also includes beneficiation which means the processing of minerals or ores for the purpose of regulating the size of a desired produce; removing unwanted constituents and improving the quality, purity or assay grade of desired product.

Capital Cost

The fixed cost includes expenditure incurred in the ilmenite and titanium mineral industry on land, building, machinery, transport vehicles, etc., in the mining, processing and transport sectors.

Annual Operating Cost

Annual operating cost includes the items of expenditures incurred on wages, fuel, electricity, royalty, insurance, maintenance and repair incurred during a year in the mining, processing and transport divisions.
Royalty

The holder of mining lease should pay a royalty amount in respect of any mineral removed or consumed by him or by his agent, manager, employee, contractor or sub-lessee, from million tonnes he leased, at the rate specified in the ‘Second Schedule’. The royalty rates are mentioned at the rate of two per cent of sale price on ad valorem basis for ilmenite, rutile, leucoxene (brown ilmenite) and zircon. It is charged at a rate of 2.5 per cent, 10 per cent, 3 per cent and 10 per cent of sales prices on ad valorem basis for sillimanite, kyanite, abrasive variety of garnet and gem variety of garnet, respectively. It is being charged at the rate of `125/- per tonne for monazite. The computation of royalty is linked to the actual sale price realization as submitted by the mine owners in their sales tax returns and the same is computed on a quarterly basis. According to the Central Sales Tax Act, 1956, the sales price actually realized less the cost of freight and delivery as submitted by the mine owners in their sales tax returns, should be considered for computing ad valorem royalty (The Gazette of India, 1997).

Annual Revenue

The estimation of production yield is necessary for arriving at the figures for the annual revenue of a mineral mining venture. This study assumes 10,200 tonne for ilmenite and 3,000 tonnes for titanium minerals throughput treatment per annum. Recovery efficiency is assumed to be of 90 per cent.
Annual revenue is

\[ \text{Annual revenue} = \text{Annual sand throughput} \times \text{mineral content} \times \text{Recovery efficiency} \]

defined as the total cash receipts from million tonnes of the sale of ilmenite and titanium minerals. The life of the plant is assumed to be 20 years.

3.3 Methods

**Methodology for Economic Viability Study**

Economic return analysis was carried out by employing the standard budgeting techniques viz., Net Present Value (NPV), Internal Rate of Return (IRR) and the payback period analysis based on 2007-08 prices for ilmenite and titanium mining plant in the enriched area of Tamil Nadu.

Capital costs of the proposed ilmenite and titanium mining project were grouped into three major sectors, viz., mining, transportation, and processing sectors. The capital costs of these sectors were obtained from published literature and proprietary data from the mining enterprises. Annual revenue was estimated using the annual level of ilmenite and titanium mineral production, its average mineral composition, plant recovery efficiency and the actual price of minerals. The net cash flow was obtained by deducting annual operating costs from annual gross revenue. Using the above approach the capital costs and the annual net cash flow, NPV and IRR of the mining venture were estimated and thus, feasibility of mining project was found out.
Net Present Value

The net present value is an absolute figure to decide whether an investment in a particular project is desirable or not. The project is accepted, if NPV is positive and rejected for negative value of NPV. The NPV is estimated (Prasanna Chandra, 1997) as follows:

\[
NPV = \sum_{t=0}^{n} \frac{CF_t}{(1+r)^t} - C
\]

Where

- \( NPV \) = net present value
- \( CF_t \) = cash flow occurring at the end of the year \( t \) (\( t = 0, 1, 2 \ldots n \))
- \( n \) = life of the project
- \( r \) = discount rate
- \( C \) = initial capital cost

Internal Rate of Return

The internal rate of return is that discount rate, which equates the present value of the benefits to the cost streams over the life of the project. It is viewed as the discount rate which makes the net present value zero \((NPV=0)\) and also makes the benefit cost ratio unity \((BCR=1)\). If the IRR for a project is greater than/or equal to market rate of interest, then the project is viable (Lakshminarayanan, 1974). The IRR was estimated as:
\[
\text{IRR} = D_1 + \frac{(D_h - D_l) \cdot (\text{NPV}_i)}{(\text{NPV}_h) - (\text{NPV}_i)}
\]

Where

- \(D_1\) = lower discount rate
- \(D_h\) = higher discount rate
- \(\text{NPV}_i\) = NPV at the lower discount rate
- \(\text{NPV}_h\) = NPV at the higher discount rate

**Simple Pay Back Period**

The payback period is the length of time required to recover the initial cash outlay on the project. According to the analysis, the shorter the payback period, the more desirable is the project (Prasanna Chandra, 1997).

**Sensitivity Analysis**

It was intended to identify if the change in the parameters has any significant effect on net present value and internal rate of return of the ilmenite and titanium mining unit. Here, the objective was to find out the parameter for which the profitability is most sensitive. This analysis was used to find the withstanding capacity of a project for some given changes in the related factors, leading to risks affecting costs and benefit in the future (Pitale, 1982). This analysis will identify those factors which are affecting the profitability of the ilmenite and titanium mining venture.
Methodology for Forecasting

The present study carried out the forecasting analysis by making use of trend analysis for the titanium minerals, viz., ilmenite and rutile. In this study, linear, quadratic, logarithmic, cubic, and exponential trend models were attempted to forecast different important economic parameters of the titanium market up to the year 2013 A.D.

Box-Jenkins methodology was applied in forecasting the production, consumption, price, export and the world production of the minerals, such as, ilmenite and rutile. For this purpose, the ARIMA model of various dimensions was attempted. Multiple regression model was adopted in order to identify this significant factors in the production of ilmenite and rutile.

Trend Model Forecasting

Trend models, otherwise called deterministic models often catch the fluctuations occurring in business and economic variables. Most frequently used trend models are linear, quadratic, logarithmic, cubic and exponential. The trend models employed in this study are presented below.

1. Linear Trend Model  \[ Y = a + b \ T + u_t \]
2. Quadratic Trend Model \[ Y = a + b + c \ T^2 + u_t \]
3. Logarithmic Model \[ \log Y = a + b \log T + u \]
4. Cubic Trend Model \[ Y = a + bT + c \ T^2 + d \ T^3 + u_t \]
5. Exponential Trend Model \[ Y = a + b \ e^{ct} + u_t \]
Where,  \( T = \) Time variable

\( a, b, c, d = \) co-efficients of the regression model to be estimated

\( u_t = \) value of error variable at time ‘T’

**ARIMA Methodology**

ARIMA (Auto-Regressive Integrated Moving Average) models were developed during 1970’s by George Box and Jenkins for the purpose of short-run forecasting of a time series. The ARIMA model combines three univariate models viz., Auro-regressive (AR), Differencing (Integration and Moving Average (MA) into one (Trivedi, 2002).

**AR Model**

Normally in time series data successive values tend to be fairly close. Modelling of such behavior is called Auto-regression. The simplest Auto-regressive scheme is AR (1).

\[ Y_t = \alpha + \beta Y_{t-1} + \epsilon_t \]

The \( p^{th} \) order scheme, denoted by AR (p), may be written as

\[ Y_t = \alpha + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + \ldots + \beta_p Y_{t-p} + \epsilon_t \]

Where,  
\( \alpha = \) the constant term

\( \beta = \) the (auto) regressive co-efficient

\( \epsilon_t = \) the error term

The properties of \( \epsilon_t \) are given as:
\[
E(\varepsilon_t) = 0, \\
\text{Var}(\varepsilon_t) = \sigma^2 \\
\text{Cov}(\varepsilon_t, \varepsilon_{t-k}) = 0, \ K \neq 0 \\
\text{Cov}(\varepsilon_t, Y_{t-k}) = 0, \ K > 0
\]

The condition that \(\text{Cov}(\varepsilon_t, Y_{t-k}) = 0, \ K > 0\) states that the new error is independent of past values of the process.

**Moving Average Schemes**

The moving average scheme was adopted to understand the persistence of random effects over time. Independent from the AR process, each element in the series can be influenced by the past error (or random shock) that cannot be accounted for by the AR components. The model may be written as:

\[
Y_t = \mu + \varepsilon_t - \theta \varepsilon_{t-1}
\]

Where, the term \(\varepsilon_{t-1}\) reflects the carry over from one period to the next. This is explained to mean that each observation is made up of a random error part (random shock, \(\varepsilon_t\)) and a linear combination of prior random shocks. The above model represents a first order moving average scheme MA (1). The general \(q^{th}\) order moving average schemes, that is, MA (q) may be given as

\[
Y_t = \mu + \varepsilon_t - \theta \varepsilon_{t-1} - \ldots - \theta_q \varepsilon_{t-q}
\]

In a pure MA process, a variable is expressed in terms of the current and previous white noise disturbances.
Where,

\[ E(Y_t) = \mu \quad \text{since} \quad E(\varepsilon_t) = 0 \quad \text{and} \]
\[ \text{Var}(Y_t) = E(Y_t - \mu)^2 \]
\[ = \sigma^2 (1 + \theta_1^2 + \theta_2^2 + \ldots + \theta_q^2) \]

**ARMA and ARIMA Schemes**

The model combining AR (p) and MA (q) components is called ARMA (p, q) schemes and it is expressed as

\[ Y_t = \alpha + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + \ldots + \beta_p Y_{t-p} + \varepsilon_t + \theta_1 \varepsilon_{t-1} + \ldots - \theta_q \varepsilon_{t-q} \]

In order to make the given series a stationary one, the differencing technique was necessarily applied. For any series on ‘y’ the first differencing components is given as \((Y_t - Y_{t-1})\) and the second differencing components is given as \((Y_t - 2Y_{t-1} + Y_{t-2})\). The second difference of any series is analogues to a second derivative of a continuous function. It measures the “acceleration” or “curvature” of the given function at a given point of time. In this process, for \(d\)th order of differencing if the new series is \(w_t, w_{t-1}, w_{t-2}, \ldots, w_{t-p}\), then the ARIMA (p,d,q) model is given as:

\[ W_t = \alpha* + \beta*1 W_{t-1} + \beta*2 W_{t-2} + \ldots + \beta*p W_{t-p} + \varepsilon_t - \theta*1 \varepsilon_{t-1} - \ldots - \theta*q \varepsilon_{t-q} \]

Various dimensions of AR, MA and ARIMA models were tried for forecasting the production, consumption, price, export, and world production of ilmenite, rutile, garnet, zircon, and monazite and the selection of best fitted model is carried out based on the value of the standard error of the model and the significance of the individual co-efficients.
Reliability and Validity of the Tools and Data and Limitations

This study employed the capital budgeting techniques and sensitivity analysis in a systematic manner to work out the profitability and economic viability of the ilmenite and titanium mining project. But there were many other factors affecting the calculations of the feasibility study. The economic and other political determinants such as recession, inflation, technology changes, devaluation or revaluation, price distortions, development of substitutes and political instability were found individually or collectively to upset the calculations. This study also uses the statistical tools such as the trend models and multiple linear regressions which may have inherent defects.

3.4 Data Source

The present study used purely secondary data relating to production, consumption, price of Indian ilmenite, rutile and titanium minerals. The data have been collected for the period from 1980 to 2008 from the publication of Indian Bureau of Mines, Nagpur, and World Mineral Statistics and many other governmental organisations. The data on world market have been collected from the Mineral Year Books and special publication volumes of Bureau of Mines, USA, and TZMI publication and from various journals such as Metal Bulletin. The accuracy of economic return analysis primarily depends on the accuracy with which the data have been furnished by the industrialists. A major portion of the data was collected from published sources and the remaining from unpublished
sources. Hence, the accuracy of the results of the study may mainly depend on the reliability of the secondary data, and the assumptions of the econometric tools and the capital budgeting techniques.

3.5 Study Area

India Profile

Known for its cultural heritage and warm and friendly people, India is one of the oldest civilizations on earth. In Hindi, India is known as Bharat or Hindustan. Officially known as the “Republic of India”. It is the largest liberal democracy of the world. India is divided into 31 states and six union territories. The language, geography and climatic conditions and huge natural resources are hardly comparable with any other country.

India is strategically located in southern Asia, bordering Pakistan China, Nepal, and Bhutan on the north; Bangladesh, Myanmar and the Bay of Bengal on the east; the Palk Strait and the Gulf of Mannar and the Indian Ocean on the south and the Arabian Sea and Pakistan on the west. New Delhi is the capital of India and is one of the largest cities.

India believes in “spiritual integrity” and “unity in diversity”. The secular nature of India has attracted philosophers and researchers from across the globe to explore India. Peace, prosperity and religious tolerance are other integral parts of India’s composite culture.
India is also the land of the Vedas - the oldest scriptures in the world. It is divided in four-volumes and is regarded as the storehouse of national thoughts. India’s love for complex art forms is evident in the various religious and mythological references.

Today, India is the world’s seventh largest country in terms of area and second in terms of population. The sights, sounds, the ancient temples and the lush paddy fields make the country unique and amazing. It has 22 major languages with 844 dialects, making this country and its people culturally diverse.

**Profile of Tamil Nadu**

**Geography**

Tamil Nadu is situated on the southeastern side of the Indian peninsula. It is bounded on the east by Bay of Bengal, in the south by the Indian ocean, in the west by the states of Kerala and Karnataka and in the North by the Karnataka and Andhra Pradesh. The land mass of the state can be divided into two natural divisions,

(1) The Eastern Coastal Plain

(2) The hilly region along the North and the West

Along the whole length of the western part, the sea varying at a distance from, 80 to 160 km runs the range of the Western Ghats, a steep and rugged mass averaging 1220 metres above the sea level and rising to 2,440 metres at the highest point. The Palghat Gap about 25 km in width is the only marked break in the great
mountain wall. To the south of this gap, the range is known as Anamalai (Elephant Hills)

Palani Hills is on the east, on which the famous hill station Kodaikanal is situated. The slopes of the Western Ghats are covered with heavy evergreen forests. The Nilgiris and the Anamalai are the hill groups with the maximum height. In the famous Ootacamund area of the Nilgiris district, is the highest peak Doddabetta, 2640 metres above the sea level. Ootacamund is known as the 'Queen of Hill Stations' in India. Almost every district has a hill-station or a sea-side resort.

Area

It lies between 8 5' and 13 35' of northern latitude and 76 15' and 80 20' of eastern longitude with an area of 1,30,058 square kilometres. It is the 11th state in India in area forming 4.11 per cent of the union areas.

Population

The state of Tamil Nadu has an area of 130,058 sq. km. There are 30 districts, 385 blocks and 16,317 villages. The population of Tamil Nadu stood at 62,110,839 comprising 31,268,654 males and 30,842,185 females. The population of Tamil Nadu constitutes 6.05 per cent of the India’s population. It ranks 6th among the states/union territories. The population which was 55,858,946 in 1991, has gone up by 6,251,893 over the last 10 years representing an increase of 11.19 per cent. The density of population per sq. km. is 478 in 2001 as against 429 in
1991. The state has the population density of 479 per sq. km. (as against the national average of 312). The decadal growth rate of the state is 11.72 per cent (against 21.54 per cent for the country) and the population of the state continues to grow at a much faster rate than the national rate.

About 75 per cent of Tamil Nadu’s population is literate, higher than the national average of 65 per cent. In 2001, 82.4 per cent of males and 64.4 per cent of females could read and write. There is a steady increase in the literacy rate among males and females over the past decades.

**Climate and Temperature**

Tamil Nadu has an equatorial, tropical climate in the inland and an equatorial, maritime climate in its coastal regions. In the inland, the temperature may go to extreme in some places while it tends to be moderate in the coastal areas.
Map: 3.1 – Study Area
By and large, the average temperature for most parts of the state ranges between 28\(^0\)C and 40\(^0\)C in the summer season and between 18\(^0\)C and 26\(^0\)C in the short-lived winter seasons. In the more hilly terrain, the maximum temperature may be as low as 26\(^0\)C and the minimum temperature may go down to 3\(^0\)C. The normal rainfall is 945.0 mm.

**Administrative Division**

The state of Tamilnadu is divided into 29 administrative districts, which in turn are further bifurcated into smaller divisions and sub-divisions, including a total of 16,317 villages. The state capital, Madras now renamed, as Chennai is the fourth largest city in the Indian sub-continent and 30\(^{th}\) largest city in the world. It extends over an area of 174 sq. km.

**The Languages**

This history of Tamilnadu dates back to Paleolithic age. The Official languages spoken in the state is Tamil one of the oldest languages greatly influenced by its rich and colourful past. Concerted efforts have been made over the last decade or so to preserve the purity and identity of the Tamil language. More recently, there has been a steady stream of people migrating into the state from all parts of India, particularly to the state’s urban centres, making Tamilnadu truly cosmopolitan in its composition. Today, one can hear several languages such as Telugu, Malayalam, Hindi and other Indian languages being spoken in the state.
Above all, the foreign visitor need have no fear of not being understood as English is spoken with considerable fluency in most parts of the state. Two prominent English newspapers and a number of economic dailies, besides several newspapers in the local vernacular are brought out here.

**Culture and Tradition**

Tamilnadu has a legacy of ancient tradition and rich cultural heritage. Dance forms like Bharathanatyam and various forms of music, including carnatic music, have flourished here for centuries. The awe-inspiring sculptures at the Shore Temple in Mahabalipuram and other similar art forms and sculptures found in the state date as far back as the 7th century AD. Famous temples, which still stand in all their pristine glory in several parts of this land, speak for themselves of the rich heritage of the Tamil people. Handicrafts include the most intricately carved designs in wood, stone and metal. The exquisitely carved Bronze and Tanjore plates deserve special mention here.

**Extent of Wealth in Minerals**

Minerals like limestone, lignite, granite, clay, gypsum, feldspar and graphite are found abundantly in Tamilnadu. Besides these, small quantities of gold, copper, magnesite, kaolin, bauxite, asbestos, etc. are also found here. Many industrial units have been set up for optimum utilisation of these mineral resources. The total area under forest cover is 17 per cent. Of the 22,742.42 sq.km.
of forest, timber and sandal wood are the main products while tea, wattle bark and cashew are some of the minor products.

**Heavy Minerals in the Study Area**

Tamil Nadu is rich in placer deposits containing ilmenite, rutile and titanium. The total percentage of these three heavy minerals works out to be more than 27 per cent in the enriched area of Tamil Nadu. The various properties of these minerals are discussed below.

![Garnet, Ilmenite, Zircon, Rutile](image)

**Ilmenite**

Ilmenite is an economically important and interesting mineral. It is named for its place of discovery (such places are called type localities) at Ilmen Lake in the Ilmen Mountains, Miask in the southern portion of the Ural Mountains of Russia. Ilmenite forms as a primary mineral in maficigneous rocks and is
concentrated into layers by a process called "magmatic segregation". It crystallizes out of a magma relatively early before most of the other minerals. As a result, the heavier crystals of ilmenite fall to the bottom of the magma chamber and collect in layers. It is these layers that constitute a rich ore body for titanium miners. Ilmenite also occurs in pegmatites and some metamorphic rocks as well as in the sedimentary rocks that are formed from the weathering and erosion of them.

Ilmenite is found to be dominant in the sands of the study region along with the economic minerals like garnet and zircon in the finer fractions. The ilmenite concentrates are found to vary from 8.65 per cent in the southern sector, 7.41 per cent in the central sector and 1.61 per cent in the northern sector. In India the production of ilmenite at 678,772 tonnes in 2007-08 decreases by two per cent as compared to that in the preceding year. Tamil Nadu was the leading producer of ilmenite during the year contributing 46 per cent of the total production followed by Orissa 30 per cent and Kerela 24 per cent.

V.V. Mineral (VVM) is India's largest mining, manufacturer and exporter of garnet and ilmenite. At the global level, they are poised to rise above their number two position. VVM is the first private ilmenite exporter in India. Established in 1989, they have achieved significant market share in Europe, Middle East, East Asia, Australia and USA. (www.vvminerals.com)
**Rutile**

Rutile is a mineral composed primarily of titanium dioxide, TiO₂. Rutile is the most common natural form of TiO₂, with two rarer polymorphs anatase (sometimes known by the obsolete name 'octahedrite'), a tetragonal mineral of pseudo-octahedral habit; and brookite, an orthorhombic mineral. Rutile has the highest refractive indices of any known mineral and also exhibits high dispersion. Natural rutile may contain up to 10 per cent iron and significant amounts of niobium and tantalum. Rutile derives its name from the Latin *rutilus*, red, in reference to the deep red colour observed in some specimens when viewed by transmitted light.

In India the production of rutile was at 20,518 tonnes in 2007-08 which increased by 27 per cent as compared to that in the previous year. Kerala was the leading producer of rutile accounting for 40 per cent of the total production followed by Orissa 34 per cent and Tamil Nadu 26 per cent.

**Titanium**

Titanium dioxide pigment (TiO₂) is a white powder with high opacity, brilliant whiteness, excellent covering power and resistance to colour change. These properties have made it a valuable pigment and opacifier for a broad range of applications in paints, plastic goods, inks and paper. The pigment is manufactured by processing naturally occurring titanium-containing rutile or ilmenite minerals. Rutile is an impure form of titanium dioxide whereas ilmenite
contains titanium combined with iron as a compound oxide. Though common throughout the world, they are most readily exploited in Australia, USA, India and South Africa.

More than half of the world’s titanium sponge production capacity is located in the CIS. Revival of the titanium metal industry is continuing since 2003. The main sources of growth in demand have been the industrial applications, aerospace industry and military applications. Companies have been increasing output of titanium sponge from existing facilities as well as adding new production capacity. In all the countries the export of titanium oxide and dioxide increased to 35,772 tonnes in 2007-08 from 16,682 tonnes in 2006-07.

Ilmenite obtained from Mineral Separation Plant (MSP) is chemical by treated to obtain synthetic rutile (90% TiO2) in Synthetic Rutile Plant (SRP). Indian Synthetic Rutile plants are based on reduction roasting followed by acid leaching with or without the generation of hydrochloric acid. Plant of IREL (OSCOM) and KMML depend on acid regeneration from the leach liquor while those of Cochin Minerals and Rutile Ltd (CMRL) and Dhrangdhra Chemical Works Ltd (DCW) use fresh acid and recover ferric chloride from the leach liquor for its use in water purification.

At OSCOM plant of IREL, reduction-roasting of ilmenite with coal is followed by leaching with HCl to separate iron as soluble ferrous chloride. The leached ilmenite is calcined to yield synthetic rutile and the acidic leach liquor is
treated in an acid regeneration plant to recover HCl for recycling with iron oxide as waste. The unit stopped production in 1997 as it was economically not viable.

The KMML is manufacturing rutile grade titanium dioxide pigment by chloride route at its Sankaramangalam plant near Chavara in Kerala. The project for the production of one lakh tonnes of TiO₂ in a phased manner is under implementation stage. The KMML is proposing to commence manufacture of titanium sponge to maximize value-addition and also to make the country self-sufficient in this product.

The DCW Ltd procures ilmenite from Manavalakurichi which is then roasted with coke fines to convert Fe₂O₃ into FeO. The reduced ore is leached with concentrated hydrochloric acid to remove oxides of iron and other metals. The leached ore is washed and calcined to get upgraded ilmenite which contains more than 95% TiO₂. The upgraded ilmenite is micronized to two microns by using high-pressure steam. This is marketed as Titox. The liquor from ilmenite leaching process contains fine TiO₂ particles and chlorides. The TiO₂ recovered by filtration and washing in filter presses is marketed as Utox. The company has plans to install facilities for the manufacture of ferrite grade iron oxide from the effluent of the ilmenite plant.

The CMRL, which began production at its 10,000 tonnes per year synthetic rutile plant in Kerala in 1990, has gradually raised the production capacity to around 36,000 tonnes per year in 2005-06 for export.
The Travancore Titanium Products Ltd. (TTPL), a Kerala state Government undertaking, manufactures titanium dioxide pigment by sulphate process at its plant at Kochuveli, Thiruvananthapuram district. Ilmenite is reacted with sulphuric acid in digesters and a porous cake is formed. The mass in the solid form is dissolved in dilute sulphuric acid to get their sulphate. The liquor is reduced using scrap iron. When ferric iron gets completely reduced to the ferrous state, the liquor is clarified, concentrated and boiled to precipitate the titanium content as hydrated titania by using elemental sulphur. Till recently TTPL was the only unit producing anatase grade titanium dioxide pigment in India. TTPL has proposals to expand its capacity to 27,000 tonnes per year, modernize and diversify in stages to produce both anatase and rutile grades titanium dioxide pigment.

Tata steel has proposed a project to produce 1,00,000 tonnes titanium dioxide per year from ilmenite mined from beach sands of Triunelveli and Thoothukudi districts in south Tamil Nadu.

**Mineral based Industries**

The main mineral wealth of the state is granite, limestone and lignite. The availability of different varieties of granite in different parts of the state has resulted in a booming granite industry. Over the year, the granite industry has grown from strength to strength contributing more than 35 per cent of the country's exports. During 1996-97, Tamilnadu exported granite products valued at `4.0 billion and other minerals `5.10 billion. The current annual production of
cement is over five million tonnes. Lignite is being used to generate power. Graphite is yet another mineral offering opportunities for down-stream industries.

**Mining and Mineral Based Projects**

India is well endowed with substantial mineral resources and a high geological potential which is yet to be fully explored and exploited. India currently produces 84 different types of minerals of which four are fuel minerals, 11 metallic minerals, 49 non-metallic minerals and 20 mining minerals. The gap between projected demand and supply is widening in respect of number of minerals. Though India exports a number of raw processed minerals it continues to be a net importer of metals. Foreign equity upto 50 per cent in the mining sector is permitted on an Automatic Approval basis except for precious metals and stones. The growing demand for processed minerals and metals offers attractive investment opportunities for investors.

**3.6 Overview**

India, is richly endowed with heavy minerals along its coastline from Ratnagiri coast on the West to the Orissa coast on the east. It has a major share in the total world placer reserves for some of the strategic placer minerals. For example in the case of ilmenite, the Indian reserves distributed in the beaches form 46 per cent of the world’s reserves and in the case of monazite, India has a lion’s share of 75 per cent of the total world reserves (Krishnan, 2001). However, India’s
production of these minerals does not commensurate with the reserves especially against the backdrop of its low Human Development Index. India’s average share in the world production of titanium minerals is at three percent. Where as, for Australia it is 31 per cent, South Africa 24 per cent, Canada 17 per cent, Norway nine per cent, USA none per cent and for Sierra Leone it is five per cent (TZMI, 1998).

The underutilization of this natural resource is also evidenced by the minor role played by it in the economic development of the country. The lower level of ilmenite mining activity may be primarily due to the lack of awareness, on the part of business community in India, about the potentials of ilmenite mining venture in the future. Here, forecasting studies will provide the necessary information and motivation for the industrial community to come forward with their investment programmes in the coastal region. The present research aims at forecasting ilmenite, rutile and titanium mineral markets in India and the world.

Thus, the description of the study area points out that, in Tamil Nadu, the majority of people depend on agriculture and in the coastal region, a large section of the population relies on fisheries for their livelihood. This high dependence on agriculture and fisheries, which are largely seasonal in nature, indicate the presence of unemployment and poverty. This fact also has been revealed by the lower per capita income of the coastal people than the state’s one. In this connection, the titanium mineral extraction works offer a ray of hope for the economic development of the Tamil Nadu.