CHAPTER – VIII

SUMMARY OF FINDINGS, SUGGESTIONS AND CONCLUSIONS

8.1 General

Minerals are valuable natural resources being finite and non-renewable. They constitute the vital raw materials for many basic industries and are a major resource for development. Management of mineral resources has, therefore, to be closely integrated with the overall strategy of development; and exploitation of minerals is to be guided by long-term national goals and perspectives.

8.2 Findings

The present study has analysed the viability of ilmenite mining plant producing ilmenite in the heavy mineral enriched areas of Thoothukudi, Tirunelveli and Kanyakumari districts in Tamil Nadu. The capital cost of ilmenite is estimated under three heads, viz., mining sector, processing sector and transport sector. The capacity of the plant is estimated to be 10,200 tonnes per annum throughput. Total capital cost is estimated at `789.50 lakhs.

The operating cost is also estimated under the three sectors and it is found to be at `259.75 lakhs. The annual revenue and the net cash flow of the ilmenite mining industry are calculated to be at the order of `362.10 lakhs and `102.35 lakhs.
The economic return analysis shows that for the base case, the capital cost, operating cost, and annual revenue are ₹789.50, ₹259.75, and ₹362.10 lakhs, respectively. The internal rate of return (IRR) is estimated at 17.75 per cent and is observed to be well above the average current rate of interest at 12.50 per cent (State Bank of India, 2009). This indicates that the ilmenite mining venture is economically feasible in the study area. The payback period of the ilmenite mining venture is estimated as 7.71 years. Therefore the first hypothesis that ‘the mining of ilmenite mineral in India is economically viable’ is proved.

The risk impact analysis has been worked out for 10 per cent and 25 per cent variation in capital cost, operating cost and annual revenue. In applying the sensitivity analysis, high risk is attached to the capital cost. So, capital cost is moved up and down by 10 and 25 per cent. The effects of 10 per cent changes in capital cost on the profitability of the project are estimated. The IRR for the case of 10 per cent increase in capital cost is 15.75 per cent and the payback is 8.49 years. For the 10 per cent decrease, the IRR increases to 20.50 per cent and the payback period decreases to 6.94 years. It is observed here that an unexpected rise of capital cost by 10 per cent has not significantly affected the profitability of the ilmenite mining unit in the study area.

In the case of increasing capital cost by 25 per cent from the base case, the capital cost works out to be ₹986.88 lakhs for an increase of 25 per cent. In this case, the IRR is reduced to 12.25 per cent and the payback period increases to 9.64 years. On the other hand, for the case of decrease 25 per cent, the IRR increases to
25 per cent and the payback period is reduced to 5.79 years. Results of the sensitivity analysis showed that the profitability of ilmenite mining venture is not affected by the capital cost decreased by 25 per cent but the capital cost increased by 25 per cent is the profitability of ilmenite mining venture is affected.

The results of the sensitivity analysis of operating cost for plus or minus10 per cent, is that for 10 per cent upward shift in operating cost, IRR declines to 11.25 per cent from 17.75 per cent of the base case. It affects the profitability of the ilmenite mining venture. A 10 per cent downward shift in the operating cost improves the rate to 23 per cent. The payback periods for the respective cases are calculated to be around 10.34 and 6.15 years.

Similarly, the influence of 25 per cent variation in the operating costs is attempted here. The estimation shows that a 25 per cent increase in operating cost reduces IRR to 11.25 per cent and a 25 per cent decline in operating cost raises the internal rate of return to 31 per cent from the base case IRR of 17.75 per cent. The payback periods for the 25 per cent up and down cases are 14.10 years and 4.78 years respectively. Therefore the 25 per cent increase in operating cost is affecting the profitability of the ilmenite mining industry.

For the case of 10 per cent increase in the labour cost, the IRR stands at 10.25 per cent and for a decrease of 10 per cent the IRR increases considerably to 20.10 per cent. The payback periods for the 10 per cent upward and downward changes in the labour cost are 10.91 years and 6.84 years respectively.
The labour cost is raised by 25 per cent, the internal rate of return is calculated to be at 9.50 per cent with a payback period of 11.30 years. If labour cost is decreased by 25 per cent, the internal rate of return and the payback period are worked out to be at 24 per cent and 5.85 years respectively. Here, the profitability of the project is found to be considerably affected by the increase in labour cost by 25 per cent.

The results of the sensitivity analysis, for the case of 10 per cent increase in the annual revenue shows that the IRR stands at 25.50 per cent and for a decrease of 10 per cent the IRR declines considerably to 8.25 per cent and it is affected by the profit of the ilmenite mining venture. The payback periods for the 10 per cent upward and downward changes in the annual revenue are 5.70 years and 8.94 years respectively.

The risk impact analysis shows that is the annual revenue is raised by 25 per cent, that is, from `362.10 lakhs to `452.63 lakhs, then the cash flow works out to be at `192.88 lakhs. For this case, IRR is calculated to be at 35.25 per cent with a payback period of 4.09 years. Hence, the third hypothesis is valid. When, annual revenue is decreased by 25 per cent, that is, from `362.10 lakhs to `271.57 lakhs, then the cash flow decreases to `81.82 lakhs. In this analysis the internal rate of return and the payback period are estimated to be at 12.25 per cent and 9.65 years, respectively. Therefore, the profitability of the project is found to be affected and hence the third hypothesis is invalid.
The capital cost and operating cost of ilmenite have a marginal increase over years. The results of sensitivity analysis also proved that the ilmenite mining is more profitable. The significant change in the capital cost, operating cost and annual revenue also influence the profit of the industry which indicates that the viability of the ilmenite mining venture is not affected by 10 per cent changes in capital cost, 25 per cent decrease in capital cost, 10 per cent and 25 per cent decrease in operating cost, 10 per cent increase in annual revenue and 25 per cent increase in annual revenue. Hence, the third hypothesis is proved correct in the above reported conditions.

But the viability of the ilmenite mining venture is affected by 25 per cent increase in capital cost, 10 per cent and 25 per cent increase in operating cost and 10 and 25 per cent decrease in annual revenue. Hence, the third hypothesis of the present research is disproved in the above stated situations.

India has been producing ilmenite and rutile for a very long period but it has been conspicuous only after 1980’s. The production of ilmenite and rutile has increased from 188,828 tonnes and 8,752 tonnes respectively in 1980-81 to 678,772 tonnes and 20,518 tonnes in 2007-08.

In forecasting the ilmenite production, among the various models applied, a simple linear model estimated India’s ilmenite production to be at 7,00,238.6 tonnes for the year 2013. The result shows that the annual and compound growth rates are 0.09 per cent and 10.07 per cent respectively.
The estimated linear growth model for India’s rutile production shows that the annual and compound growth rates are 0.05 per cent and 10.39 per cent respectively. Being a titanium mineral, rutile production also has grown like ilmenite. This model estimated India’s rutile production to be at 22,038.37 tonnes for the year 2013.

India’s ilmenite consumption is stated to have increased from 50,818 tonnes to 92,800 tonnes and to 244,967 tonnes during 1980-81, 1990-91 and 2007-08 respectively.

In this study linear, quadratic, cubic, logarithmic and exponential trend models are attempted to forecast different important economic parameters of the India’s ilmenite consumption. The trend curves fits well and the $R^2$ value is 0.884, 0.640, 0.926, 0.933 and 0.883 respectively. Hence, among the five models cubic model has the best fit with the high $R^2$ value of 0.933. Linear, quadratic, cubic, logarithmic and exponential models estimated India’s ilmenite consumption to be at 251770.4 tonnes, 179376.7 tonnes, 315161.7 tonnes, 366261.4 tonnes and 375297.2 tonnes for the year 2013 respectively. The ARIMA (1,1,1) model projected this production to 282,868 tonnes in the year 2013, which is more than 15 per cent of the year 2007-08.

According to the trend models applied on the rutile consumption in India, it is expected to rise to the level of 23,046.50 tonnes as estimated by the cubic model. The linear trend, logarithmic trend, quadratic trend, exponential trend and
ARIMA (0,1,1) models have anticipated India’s rutile consumption to be of 24,047.92 tonnes, 16,357.25 tonnes, 29,342.04 tonnes, 38,408.45 tonnes and 19,300.29 tonnes for the year 2013 respectively.

The export of ilmenite in 1980-81 is 112,017 tonnes and it is 254,805 tonnes in 2007-08. Actually there is a wide fluctuation in the exports of ilmenite and a steady growth of exports which is needed by the country is absent here. According to the trend models applied on the export of Indian ilmenite, quadratic and cubic models are found significant in terms of their respective values of ‘F’ statistic and the ‘F’ value is 16.26 and 11.17 respectively. The ARIMA model analysis has shown that the export of ilmenite from India will decrease to 190,217.8 tonnes in the year 2013. Therefore necessary policy measures have to be initiated especially to the export of ilmenite.

The export of rutile in 1980-81 is 300 tonnes and it is 521 tonnes in 2007-08. During 1981-82 to 1993-94 there is no export of rutile and in the remaining study period the export of rutile is very low.

The price of ilmenite in 1981-82 is `1,000 per tonne and it is `3,550 per tonnes in 2007-08. The price of rutile in 1981-82 is `2,800 per tonne and it is `27,500 per tonnes in 2007-08. The cubic model has estimated the price of ilmenite for the year 2013 to be at `6,771.75 per tonne. The trend models fit with poor co-efficient of determination. The \( R^2 \) values for the linear, logarithmic and quadratic models are 0.282, 0.436 and 0.323 respectively. ARIMA (1,0,0) model has projected ilmenite price in India to `2,726.87 per tonne in the year 2013 which
is the least forecast when compared to the other forecasts of the trend models. Therefore necessary policy measures have to be initiated especially to the price of ilmenite.

Rutile price in 1981-82 is `2,800 per tonne and this has increased to `28,722 per tonne in 2007-08. The estimated cubic trend model explains about 93 per cent of the variations in India’s rutile price. Both the estimated regression co-efficients are significant at 5 per cent level. This model has estimated India’s rutile price at `18404.89 per tonne for the year 2013. ARIMA (1,1,1) model has projected rutile price in India to `33,398.07 per tonne in the year 2013 which is the highest forecast when compared to the other forecasts of the trend models.

The world reserve base for ilmenite is estimated at 1,400 million tonnes in terms of TiO₂ content. Major resources occur in China (25%), South Africa (16%), India (15%), Australia (11%), Brazil (6%), Norway and USA (4% each) Mozambique (2%) and Ukraine (1%). The various trend models do not forecast the world ilmenite production revealed by the low R² value, ARIMA model is estimated for world ilmenite production. The estimated ARIMA (1,0,1) model forecasted world ilmenite production for the year 2013 to be at 9982.35 tonnes, which is lower than the production in the year 2006-07.

This study disclosed that the world rutile production, the co-efficients of the ARIMA (1,0,0) model are found significant and the results showed a decrease to the level of 514.11 thousand tonnes in the year 2013 from 638 thousand tonnes of
the year 2006-07. According to this estimate, it is found here that the world rutile production would decrease by 19.42 per cent during 2013 than the year 2007.

Tamil Nadu ilmenite production has increased from 72,887 tonnes in 1980-81 to 73,961 tonnes in 1989-90 and further to 314,789 tonnes in 2007-08 with an increase of 1.47 per cent in 1989-90 and 331.88 per cent in 2007-08 when compared to 1980-81. The regression co-efficients of the estimated trend models are found significant at 5 per cent level. Quadratic and cubic models have estimated Tamil Nadu ilmenite production which would increase to 493,865.5 tonnes and 718,546.8 tonnes respectively for the year 2013.

The production of rutile at 20,518 tonnes in 2007-08 has increased by 27 per cent as compared to 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. Quadratic and cubic models have estimated Tamil Nadu’s rutile production that it would increase to 6,527.27 tonnes and 7188.28 tonnes respectively in the year 2013.

The end use of ilmenite mineral in India is consumed for manufacturing synthetic rutile. It is followed by paint and others such as electrode, ferro-alloys, iron and steels industries. And bulk of rutile is consumed for the manufacturing of electrodes and it is followed by paint industries.

This study discloses that to know the major factors affecting the production of ilmenite in India, various explanatory variables of the global and Indian markets
such as Indian ilmenite price, Indian ilmenite export, Indian ilmenite consumption and world ilmenite production are considered. The multiple regression analysis pointed out that there is an increasing trend in the production of ilmenite in India. The results of the multiple regression have identified that the ilmenite consumption and ilmenite export are the most important economic determinants of the ilmenite production. Hence, it is suggested that suitable policies may be formulated as regards the development of ilmenite mineral production and export.

In this study an attempt is made to find out the impact of Indian ilmenite production, exports, consumption such as end use of synthetic of rutile, paint and electrode on ilmenite production. For this purpose a regression considering ilmenite production as dependent factor and other variables as independent factor has been applied. The results indicates these variables significantly influence the ilmenite production ($R^2 = 0.978$). The value of ‘F’ (198.309) indicates that the fitted regression model has been significant.

Another regression for determining the importance of ilmenite price is tried and the results point out that the ilmenite price has being greatly depending upon ilmenite production. The $R^2$ value is 0.431 and the co-efficient of the ilmenite production is also significant at 5% level.

The major determining factor affecting the rutile price in India is analysed through regression analysis. The model is found significant in terms of the ‘F’ value (31.286) and the model explained over 83 per cent of the variations in the dependent variable. The co-efficients are all significant in terms of their ‘t’ values.
Among the independent variables, the world rutile production and Indian rutile production are found to have influences on the rutile price in India.

According to the estimated model, an additional unit of variables like Indian rutile production, Indian rutile consumption and world rutile production could increase Indian rutile price by 0.689 unit, 3.343 unit and 1.444 unit respectively.

Major deposits of titanium minerals are found in Australia, Canada, India, Norway, South Africa, Ukraine, and the United States. Metallic titanium is imported from Russia (36%), Japan (36%), Kazakhstan (25%), and other nations (3%). TiO₂ pigment for paint is imported from Canada (33%), Germany (12%), France (8%), Spain (6%), and other nations (36%).

The processing technologies need the estimation of capital and operating costs of the titanium mining plant in Tamil Nadu. The capital cost is estimated under three heads, viz., mining sector (godown), processing sector and transport sector. Here, the plant capacity is assumed to be 3,000 tonnes throughput per year. Total capital cost is estimated at ₹1,757.94 lakhs and the total operating cost works out to be ₹1,033.53 lakhs. Annual revenue of the titanium mining venture is estimated to be equal to ₹1,365 lakhs.

To analyse the economics of value addition of titanium minerals in Tamil Nadu as well as India, there are three measures of economic return viz. Net Present Value (NPV), Internal Rate of Return (IRR) and simple payback period analysis are used in these estimation.
The economic return analysis explained that the titanium mining plant, with a capital cost, operating cost and annual revenue of `1,747.94 lakhs, `1,033.53 lakhs and `1,365 lakhs respectively, generates an internal rate of return of 26.75 per cent which is observed to be well above the present market rate of interest in India. When export of ilmenite brings `5,500 per tonne, the value added ‘titanium’ fetches `45,500 per tonne on export, it proves that the value addition increases the economic returns and thus the second hypothesis is proved.

The risk impact analysis has been worked out with respect to the unforeseen changes expected to occur greatly in capital cost, operating cost, and annual revenue.

In applying the sensitivity analysis, a high risk is attached to the capital cost. So, capital cost is moved up and down by 10 and 25 per cent. The IRR for the case of 10 per cent increase in capital cost is 24.10 per cent and the payback is 5.80 years. For the 10 per cent decrease, the IRR increases to 29.80 per cent and the payback period decreases to 4.75 years. It is here observed that an unexpected rise of capital cost by 10 per cent does not significantly affect the profitability of the titanium mining unit in the study area.

In the case of increasing capital cost by 25 per cent from the base case, the capital cost works out to be `2,184.93 lakhs for an increase 25 per cent case. In this case, the IRR reduces to 22.20 per cent and the payback period increases to 6.59 years. On the other hand, for the case of decrease of 25 per cent, the IRR increases to 36.30 per cent and the payback period reduces to 3.95 years.
The results of the sensitivity analysis of operating cost for 10 per cent upward shift in operating cost, IRR declines to 18.10 per cent from 26.75 per cent of the base case. A 10 per cent downward shift in the operating cost improves the rate to 36.10 per cent. The payback periods for the respective cases are calculated to be around 7.66 and 4.02 years.

If the operating cost is increased by 25 per cent, it reduces IRR to 17.20 per cent and a 25 per cent decline in operating cost raises the internal rate of return to 46.10 per cent from the base case IRR of 26.75 per cent. The payback periods for the 25 per cent up and down cases are 7.83 years and 2.96 years respectively.

The results of the sensitivity analysis of escalation of electricity cost by 10 per cent upward shift, IRR declines to 26.50 per cent from 26.75 per cent of the base case. A 10 per cent downward shift in the electricity cost improves the rate to 29.25 per cent. The payback periods for the respective cases are calculated to be around 5.55 and 5.03 years.

Regarding the electricity cost, an increase by 25 per cent, the IRR decreases to 23.50 per cent and the payback period increases to 6.01 years and a 25 per cent decline in electricity cost raises the internal rate of return to 30.25 per cent from the base case IRR of 26.75 per cent. The payback period for the 25 per cent fall is 4.70 years. Hence, the variations of electricity cost by both 10 and 25 per cent, had not significantly affect the profitability of the titanium mining venture.
The risk impact analysis shows that at a 10 per cent increase in the annual revenue, the IRR stands at 38.25 per cent and for a decrease of 10 per cent the IRR declines considerably to 14.50 per cent. The payback period for the 10 per cent upward and downward changes in the annual revenue are 3.74 years and 8.97 years respectively.

The results of the sensitivity analysis showed that if the annual revenue is raised by 25 per cent, that is, from `1,365 lakhs to `1,706.25 lakhs, then the cash flow works out to be at `672.72 lakhs. For this case, IRR is calculated to be at 50 per cent with a payback period of 2.60 years. If annual revenue is decreased by 25 per cent, that is, from `1,365 lakhs to `1,023.75 lakhs, then cash flow decreases to `209.78 lakhs. In this analysis the internal rate of return and the payback period are estimated to be at 16.10 per cent and 8.33 years respectively. Here, the profitability of the project is found to be considerably affected by the decrease in annual revenue by 25 per cent.

The researcher concluded that instead of exporting ilmenite mineral as concentrates, if they are exported in the form of value added products such as titanium dioxide which will fetch comparatively more earnings. For example, the export of ilmenite concentrates brings a maximum export price of `5,500 per tonne whereas, its value added product titanium pigment brings a price of `45,500 per tonne. Therefore the value addition is the most important factor determines the profitability of titanium processing. Hence, the second hypothesis is held true.
The risk impact analysis has been worked out with respect to the unforeseen changes expected to occur greatly in capital cost, operating cost, and annual revenue. Hence, a 10 per cent and 25 per cent variation in the important parameters that is, capital cost, operating cost and annual revenue except 25 per cent decrease in annual revenue do not affect the economic feasibility of both the ventures and the third hypothesis is held true.

Moreover, the development of the titanium mining industry designed in tune with environment may also bring the valuable foreign exchange to our country since most of the heavy minerals produced are exported. In addition, the titanium industrial development may go a long way in narrowing down the income inequality found between the villages and cities of the coastal and other regions.

### 8.3 Suggestions

Mineral Concession Rules (MCR), framed in the late fifties, state that only GSI, AMD and Indian Bureau of Mines are authorized to assess the reserves and report about the occurrence of placer deposits. It could have been valid under the then existing conditions. Now, there are many National Laboratories and Marine Research Centers in Universities of coastal regions and they contribute considerably in the evaluation and exploration of placers. Many a times, entrepreneurs, including the foreign investors, approach them but regretfully the State Geology and Mining Departments, the mine-lease awarding authorities did not accept their reports as authentic. Specialized institutions in the field of marine
sciences, like NIO, CMRI, RRL (Bhubaneswar, Trivandrum), OSTC centers of DOD, and Coastal Marine Geology Departments should be included in the section of 2A (MCR). Such a provision will give support to strengthen R&D institutions and it will also stimulate the industry to choose and spend money to support R&D programmes in universities.

It is suggested that mining industry may come forward through sponsorship to strengthen the infrastructural facilities of the R&D Institutions and Universities like CMRI, Indian School of Mines, RRL (Bhubaneswar), RRL (Bhopal), RRL (Trivandrum), CESS, Trivandrum, NML, Jamshedpur, academic institutions and Government agencies such as Indian Rare Earths, BARC & AMD, Indian Bureau of Mines etc.

Government of India is requested to strongly emphasise the getting of any analytical or testing work certificates from the private industries only through Indian Institutions/ Universities before clearing the necessary permit/ lease.

As the exploitation of construction sands from river bed and mining of placer sands or of similar nature occur very often, the government is urged to consider both the operations with the same yardstick. The placer mineral exploration has to be placed under lease, like quarrying of construction sand from river beds without insisting EIA & EMP.

The research and development (R&D) in heavy minerals should be more emphasized in the exploitation aspects-effectively, economically and in eco-friendly framework, while sustaining mineral exploration aspects.
Mining industry and R&D institutes interaction through Brain Storming Sessions to be organized, which would be oriented to encourage transfer of modern eco-friendly technology in the field of mineral beneficiation and evolve such technology to solve problems of existing operating plants.

The royalty for mining may be revised considering the mined products. The part of the royalty can be / should be utilized in rehabilitation programmes for society and sponsoring some of the R&D activity.

The world demand of titanium dioxide is recovering slowly. The feedstock markets (Viz, ilmenite, rutile, titanium, etc.) are in deficit supply. Global TiO$_2$ pigment consumption is on the rise in countries like USA and China. New capacities are adding up through expansion/ restoration. Feedstock prices rose modestly during 2006 while in 2007 prices rose more rapidly worldover.

Indian heavy-mineral resources (for titanium) are one of the largest in the world. Moreover, ilmenites of higher grades are available in the world in large quantities. With the steady industrial growth in the country, domestic titania sector is also expected to grow suitably.

In India, there exists a peculiar situation wherein imports of many final products take place even though it has rich resources of the respective raw materials. This situation also persists in the case of titanium metal (India Infoline Ltd., 2001), abrasive ilmenite, rutile and zircon. The titanium mineral industry’s capability of producing export surplus can be improved by a proper R&D effort and this will make the economy self-reliant in this field.
The setting up of an ilmenite mineral industry or an industry concentrating on the value addition processes is highly capital intensive. Due to financial crunch, the government finds it difficult to start new public sector undertakings in this field. Therefore, it is necessary to allow private sectors individually or in collaboration with the Public Sector Units through a judicious mix as emphasized by the Government of India’s Industrial Policy Act 1991. The private entrepreneurs may be permitted to start their own units for titanium minerals mainly for the purpose of the overall development of the heavy mineral industry. It is also recommended that favourable, promotional and supportive financial, industrial and trade policies should necessarily be introduced to have a strong export oriented mineral industry to reign and lead the future world titanium mineral market.

The researcher also concluded that value added know-how is the driving force that makes the titanium industry viable.

The researcher also suggests that as this industry is capital intensive in nature and therefore government funding at reasonable interest rate is necessary to induce private players to undertake such industries. A public-private model is very much welcome.

As the ilmenite industry is also labour intensive, the researcher suggests that, to cater to the requirement of employment opportunities, the government should reform the tax procedures with tax holidays and tax concessions.
As the application of titanium and ilmenite is rapidly growing in the world, these industries can be made viable by infusing the value added technology and thus render sustainable growth to overall economy of the nation.

Thus the researcher concludes that value added ilmenite not only realises a better price in the international market but generates more employment opportunities of direct and indirect nature as these industries are labour intensive. Generally its contribution to the growth of economy is encouraging value added know-how, when used effectively in the ilmenite processing will surely increase the profit margin and thus many more new entrepreneurs may enter into the field.