MINERAL ECONOMICS AND BUSINESS

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Week 4

Lecture 18 : Greenfield projects and Surface mine cost models

Welcome everybody. Today we will be discussing about the green field mining projects in the context of cost models. And we will be taking examples of surface mine cost model and we will try to give ideas about how a cost model is developed. It is not that the entire cost model will be presented in this lecture, but the approach towards ah developing the cost building of the cost model will be explained to give you an idea how to develop this models and how to contribute effectively in the preparation of ah detailed project reports feasibility studies. Now what the concept that we will cover today are the definitions and the basics of the cost model related to a greenfield project, the cost estimation for surface mines with some examples.

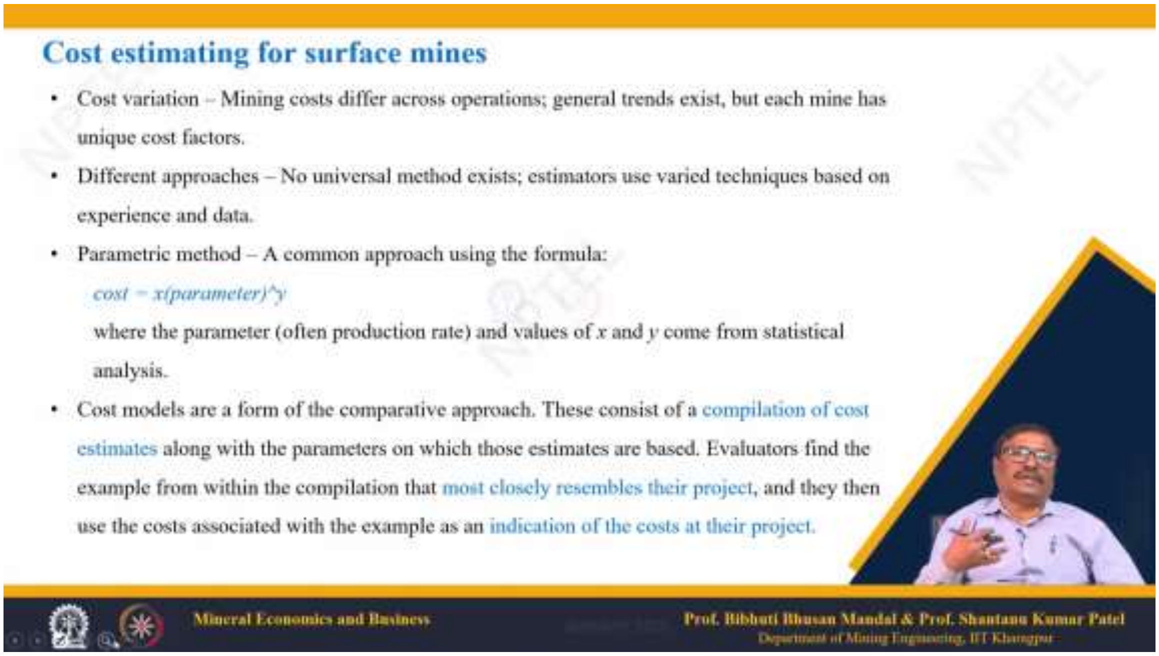
And, what are the key considerations in mining cost estimation once again? We will take examples from the drill and blast drilling and blasting cost estimation, excavation and hauling which is measured in open cost mines. There will be some points that I will touch about the ancillary systems ah that ah and the cost estimation of that and ah an example of the of the of the cost model. Now, in greenfield projects as right from the name it appears as maybe that these are completely new development. There is no infrastructure there, no operations, no facilities.

So, everything has to be built right from scratch without any prior mining activity in that area we call them greenfield project. This is an undeveloped area untouched by the industrial or mining activities. So, the significance of this green field mining projects are you are basically unlocking new mineral reserves. And that will definitely contribute to the economic growth, it will contribute to the gross domestic product and create employment, it will also cause lead to the local economic development. Since, you have no bias, so if you have the fund and the know how, then you can go for the latest mining technologies available, if you have the money and if the the deposit and other things permit.

and the best environmental practices can be adopted freshly. And substantial sustainability potential is better here because that since this is a green field project. So, environmental planning can be fresh which is compared to older mines is definitely new and then advanced. So, we can think of a better sustainable mining practices. Now in the ah financial aspects the related to the green field, we have the high capital ah initial capital investment which is typical of mining, land acquisition, infrastructure, equipment and the feasibility studies to be ah done.

And then you have to estimate this operating expenditure by calculating the labour required, energy required, transportation that will be required and the environmental compliance cost all these things. Return on investment will depend on the mineral grade and extraction efficiency, how we quickly you can develop that area. So, that you can go to the production phase and of course, the demand and the market prices. Long payback period sometimes due to extended exploration if you go on exploring and developing the mine. So, the payback period will be usually low.

Sometimes getting permissions and concessions approvals different kind of licenses all these things may take time. So, you need to be very professional in these things and getting all those and then getting all the studied studies completed beforehand. It will definitely boost the GDP cause as I said it will create local employment which is very important and overall industrial growth will be there. For the surface mines for example, we are going for an opencast green field mine this project. So, the mining cost if you try to estimate then it has to be some prior experience is required otherwise you have to do something which will be very difficult.



So, general trends are already available. So, studying that trend So, we can adopt certain or assume certain cost, but for this cannot be duplicated from one mine to the other. So, it could be unique cost factors related to different mines. There is no universal method as it is said.

So, estimators will use different approaches and techniques based on the experience and based on the data that is available for that project. So, when you decide that where to start from, so we can take for example, a determining parameter, often we take the production rate and from there we start building up the entire cost model. So, the cost of any related to parameter is related to something x is presented as x into the parameter raised to the power y. So, cost is a function of this, this is a generic statement. So, the values of x and y the values of this particular x and y parameters will come from the statistical analysis based on the data that is available. So, this is basically comparative approach that is we have the statistical data how we differ from the situation.

on the basis of that data available, can we predict our own cases or how much we differ from there. So, this is basically a selection of the databases which are abundantly available nowadays, which most closely resembles their your the project that we are handling now. Then the cost associated can be taken as an example. And as an indication of or the starting point of the cost estimate. So, the itemized cost estimate is usually in 3 steps.

Step 1 is the design you design the mine conceptually design the mine and then with available data you build up the mine models nowadays you can develop that pit outline, depth, routes to processing, waste stockpiles where the stockpiles will be there. Then you go for estimate all cost related parameters. For example, for a particular particular area, particular job you can go for estimating the number of workers required, the equipment required, the consumables required. So, here it is much more detailed and we need to be cautious about this part. And the ah last part is apply known unit cost.

So, when you are using certain figure, so you try to when you when you first find out the parameters ah all those parameters that is leading to the give us the the final cost estimate of the particular part, then we need to Start from available data like the labour wages, the equipment cost in the market, the supplies consumable those figures can be used for the purpose of estimating all cost related parameters. Now in this case what happens that you develop a model that means, that you have designed the mine and you have part by part you have further fragmented all these ah activities and there you have given the labour cost, equipment cost, supply cost all these things. What happens that it can be easily first thing computerized nowadays. And it becomes a dynamic cost model that means, if you want to change certain parameter if you think no no this cost is not realistic.

So, this is realistic we change that immediately the effect will be reflected. So, we can go for the different operational alternatives that if I do not do this what will happen? Throughout the mine slide it will be reflected easily through computerization. Now, what are the key considerations that define others like if you find out the truck numbers from the amount to be dispatched, then it will determine the driver and the say maintenance requirement, it will also lead to the driver wages or salaries.

Also, when you have a large number of tracks, what other essential infrastructure is required, such as shops, workshops, parking lots, living quarters for the people, and changing houses. All these things can be calculated based on certain key parameters. For example, four key factors can be used to estimate surface mine cost. Target production rate is very important.

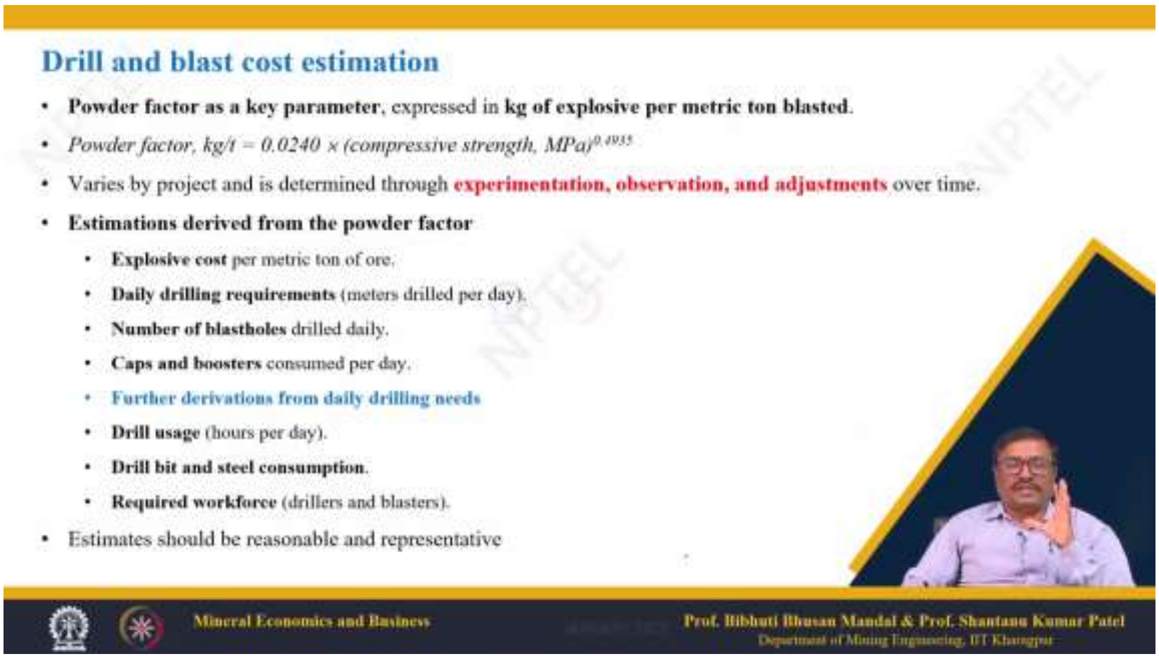
What is the stripping ratio? So, if you are mining out one ton of ore or valuable mineral, in that case, what will be the overburden that you are removing? So, the stripping ratio will also give us an idea of how much you have to remove, not only the ore but also the overburden or waste material. So, the amount to be excavated, and then the track required, drilling, and blasting, everything can be calculated based on the target production rate and stripping ratio. Now, if you are designing the mine, knowing how the ore body is oriented, then based on these data—the target production rate and the stripping ratio—you can now design your

haul profile: how you will be moving from one place to the other, where you will dump, what the hauling distance will be, all these things, and also the estimated powder factor. So, that will come because it will give us many derived parameters. So, in the case of overburden and waste haul profile, you have the choice of how you design it. And based on the powder factor, also, how much drilling will be required, how much explosive will be needed, everything can be calculated from there. For example, the resource size and the operator's financial assets—we can first see in the beginning that most feasibility studies have this formula.

So, many people used to ah utilize the Taylor's rule which is very famous well known nowadays and ah since in those days when around 1970 it was first proposed. So, the ah so, what happened now the situation has changed. that means, the production rate per day or per year that has gone up very high. So, in 1977 itself Hoskin revised this thing. So, the capacity in terms per year as you can see can be estimated by the metric terms of resource and raise to the power 0.75 whole divided by 70 whole divided by 70.

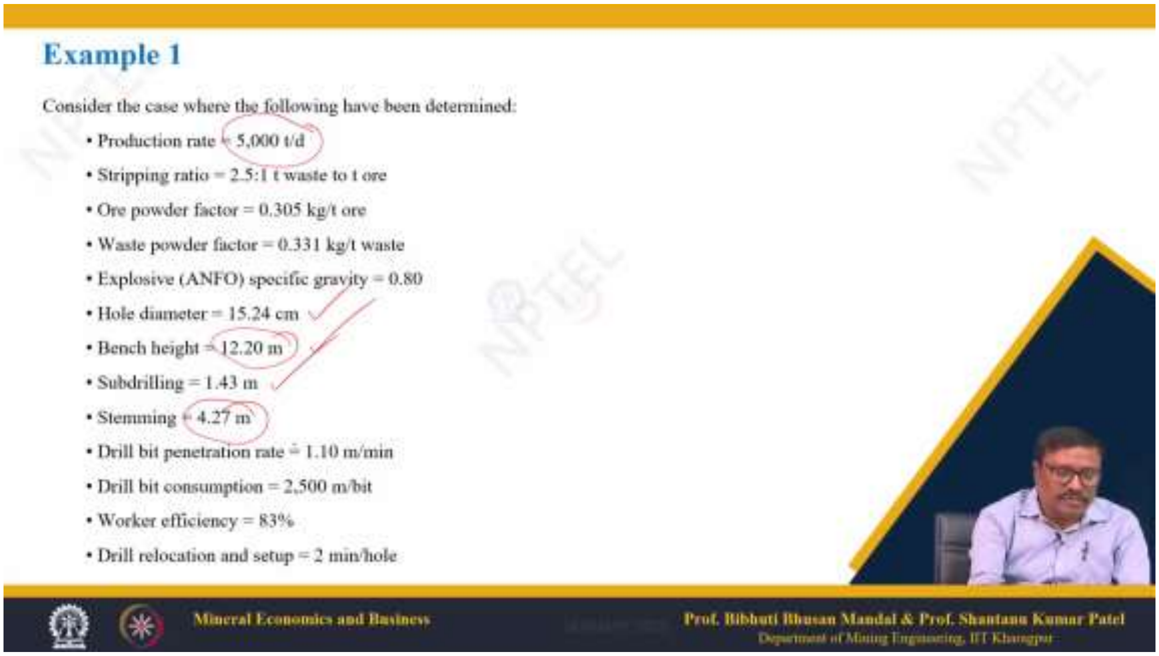
Previously the Taylor's rule was different. Now, further with further mechanization we have even increase the capacity in tons per year. So, now, we are saying that more or less this part is same ah it is 0.69 then we divide by 20.12. So, the capacity in tons per year can be further increased. So, from here we can estimate the capacity tons per year and depending on the resource that we have divided by the capacity tons per year you can estimate the roughly estimate the life of the mine.

So, that gives us the starting point. Another key factor for example, in drilling and blasting cost estimation powder factor is a key parameter. powder factor is a key parameter. You can take it from ah similar projects and ah experimented ah project, but when the mining starts we can go for further scientific studies and validate whether what whatever we are assuming the powder factor is correct or not whether it can be further adjusted. That means, it can be determined ah correctly very closely to with experimentation, observation and adjustment over time later on. But in the beginning where to start, how to start? So, we can use a comparative empirical formula like this one 0.0240 into the compressive strength in mega Pascal of the rock that we are blasting this to the power 0.49. So, that gives you the powder factor it it has got lot of ah lot of utilities in this. So, it can vary from project to project and ah from here what we can do we can we can calculate the explosive cost for metric ton of ore because we know the powder factor.



So, from there you can find out this one, then when this ah this figure then we can go to find out the meters drilled per day, number of blast holes drilled daily, then the if the number of blast hose from there the detonator and the boosters that will be consumed per day. Now, further derivations based on this will be the drill uses hours per day. drill bit and steel consumption and required workforce. See we start or started from the mine of the lab that we know the resources and we have taken a key factor powder factor as a key factor and how many things we have calculated from there.

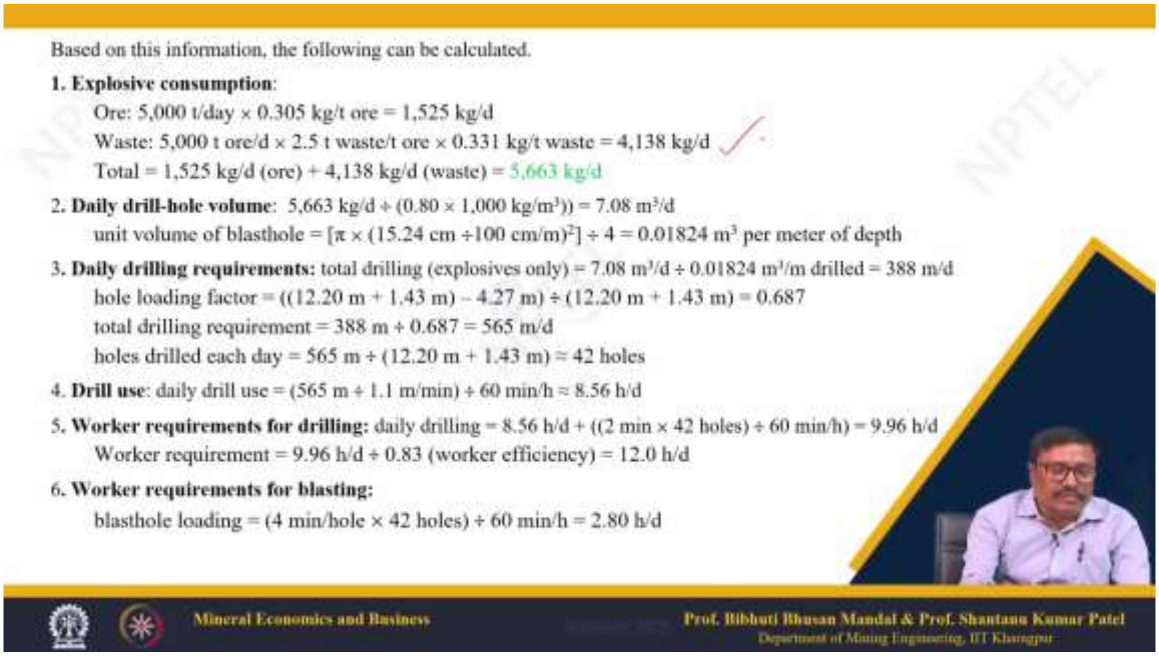
But every time whenever estimated something it should be representative and reasonable assumption. We will take an example here. For example, we take an assume production rate 5000 tons per day. Calculated starting from some Hoskins rule or Taylor's or others and then adjusting depending on your capacity to expand because you need to develop the mine that way. So, say we assume that that mine is producing about 5000 tons per day.



Stripping ratio is 2.5 that means, you need to remove 2.5 waste on it overburden for every 1 ton that you mine out average this. powder factor is given 0.3, waste powder factor is given 0.331 kg per ton and here ah ah the the explosive is specific gravity is say known as 0.80. your the whole diameter we are taking 15.24 centimeter or almost 150 say millimeter. Our design is 12.20 meter bain site sub drilling sub grade drilling will be say 1.43 meter. A stemming we are keeping as 4.27 this is the part of the blast design.

So, you can find out this thing depending on what what are the parameters that you are using in the blasting software itself in the design software itself. So, the drill if the from the manufacturers that the drill bit penetration rate in that kind of rock is approximately 1.10 meter per minute and the drill bit consumption is 2500 meter per bit. The worker efficiency is assumed to be say 83 percent which is quite high and the drill relocation and set up time is 2 minutes from 1 hole. to another whole location.

So, how we are I mean benefited with this data? So, based on the information the following can be calculated. For example, ore is 5000 tons per day that we assume and we know that powder factor 0.3. So, we will be requiring 1525 kg per day for XO 6. In in in a similar way for waste also will be requiring 4138 kg per day.



It means the total requirement will be 5663 kg per day. So, daily drill hole volume will be this kg per day is the explosive and then 0.80 will be the volume. your density in that case we can from there we can find out the 7.08 meter cube per day 7.08 meter cube per day. This is the drill hole volume because we will be charging explosive we know the density of that. So, from there we can find out the drill hole

So, now we can find out unit volume of blast hole also by using the pi d square by 4 and the simple calculation from there that means, per meter it has a volume of 0.01824 meter cube this is helpful in further calculation. So, the daily drilling requirements is total for explosives only is 7.08 meter cube per day that we have seen earlier plus this mass 0.01824 meter cube per divided by this will give us the length 388 meters per day. So, if that from there we can find out the length of the drill hole that we want to that we need to drill. Now, see hole loading factor is the length of the drill hole and then the subgrade drill minus the stemming.

So, the rest of the part will be loaded and this part the subgrade or the additional volume we have added minus the stemming. Now, this will give us the volume that will be loaded. And, since we know that this part this is the length of the hole and this is the subgrade if you divide then we get the hole loading factor that means, actually 60 about 69 percent of the hole is loaded rest is either streaming or not being charged. So, the total drilling requirement will be the 388 meters per day divided by 0.687 because we will be loading only 68 percent. So, that is if I divide by that then we get a higher figure 565 out of which only 69 percent will be loaded.

So, 565 meters per day will be our drilling requirement. So now, if I know the length of the drill hole is 12.20 meters plus 1.43 meters subgrade, then this is the total drill length. This is our total requirement. If I divide this, we get 42 holes. See how we are serially calculating one by one. Now, for drill use, the daily drill use is 565 meters divided by 1.1 meters per minute, which is the penetration rate. And then we are using 60 minutes per hour, meaning we are converting that into hours.

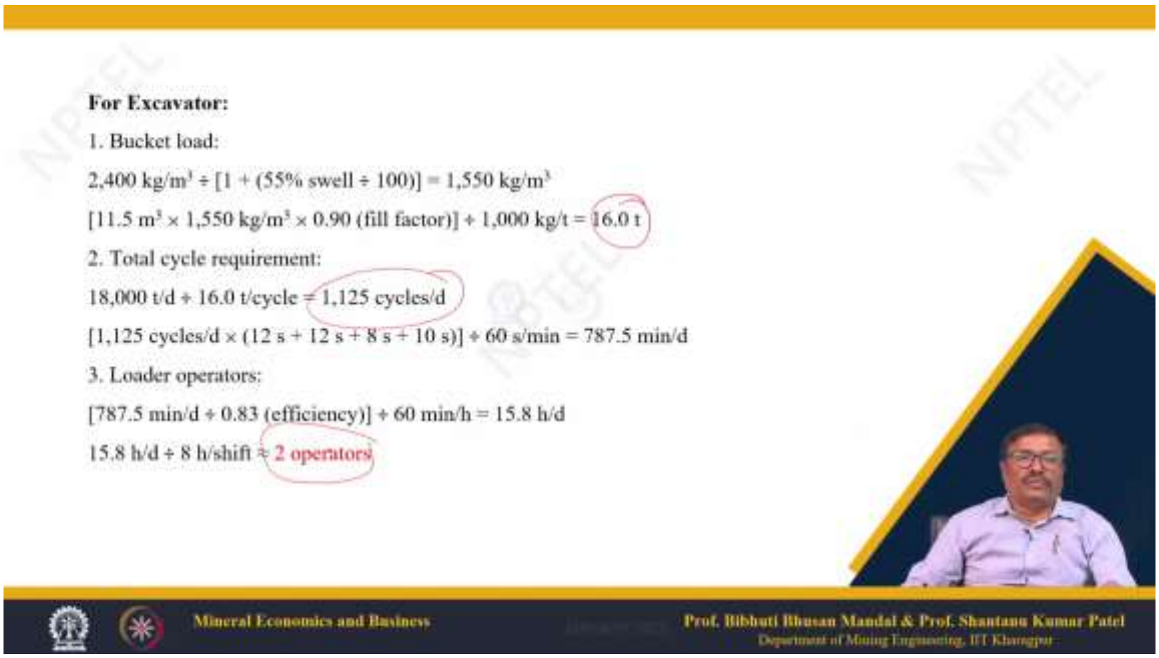
So, the drill will be used 8.56 hours per day. Now, 8.56 hours per day is for drilling only. Then we use 42 holes multiplied by 2 minutes for relocating. So, the total time divided by 60 again gives us hours. So, the total engagement will be 9.96, almost 10 hours per day. Since the worker is assumed to have an 83 percent efficiency overall.

So, utilizing that figure, we get 12.0 hours per day as the worker requirement because they will be working at 83 percent efficiency. Now, the worker requirements for blasting will be blast hole loading, say 4 minutes per hole, as we have given earlier, multiplied by 42 holes again divided by 60. So, this will be 2.80 hours per day. Now, you see these are the figures. From the basic figures, we are now deriving one by one the figures where the cost can be.

For example, we will take another example excavation and all which is hauling which is very important. This is highest expense we say in surface mining. So, what are the things? One is the excavation of the rock, loading it on the conveyance, hauling it for processing plant or stockpile or and then dumping it. So, we need to have reliable cost estimate depending on accurate excavation and hauling cost calculation.

So, the cost are based on the haul routes distance and gradient, how you design that is another science. And high stripping ratio will make waste haul distance and gradient crucial factor, because amount of waste that is to be handled per unit ton of your ah ore produced will be ah much more. So, for key design goals for excavators and hauler operation hauling operation. So, we ah we we assume here say 3 to 6 ah loader cycle should fill a truck completely, it should not take much more time these are assumptions and reasonable assumptions. Loader bucket capacity should match.

So, there is a lot of match factor problems in in mining that we study. And, then your number of trucks and loaders should minimize the waiting time for both. So, unnecessary wastage of time will not be there. Utilizing this ah ah we can do another estimate like the ah the Delhi ah excavator and track use for a situation where we have the ship length of 8 hours, production is 2 ship per day, waste production capacity is 18000 tons per day, front end loader bucket capacity is given. and average bucket fill factor is given these are from the experiences or known factor.

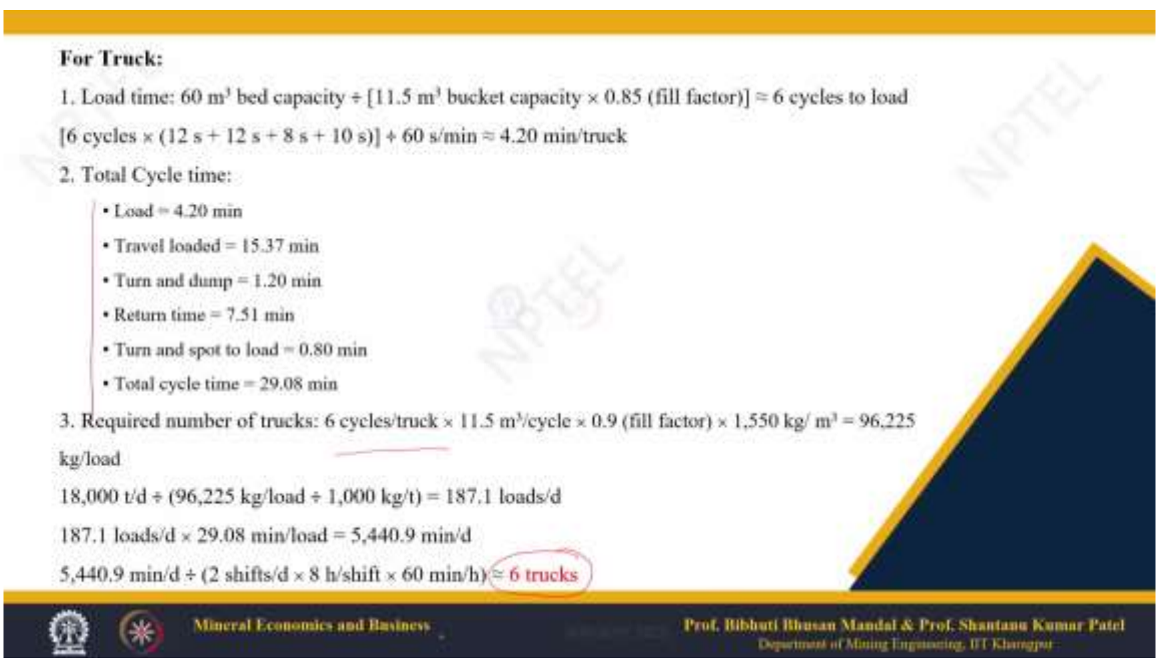


These are known from the particular project and the swelling factor is approximately say 55 percent. Now, from the data available for usually the excavators, we know from the previous projects that the loading time is 12 second, lift and swing 12 second again, dump time is 8 second, return and load time is 10 second, operator efficiency is taken at 83 percent. for the truck which is taking this material. So, we have the bed capacity or the volume 60 meter cube and by weight it can take say 90 ton material weight is given. All these figures are say is known from the previous project and certain part is now calculated from here.

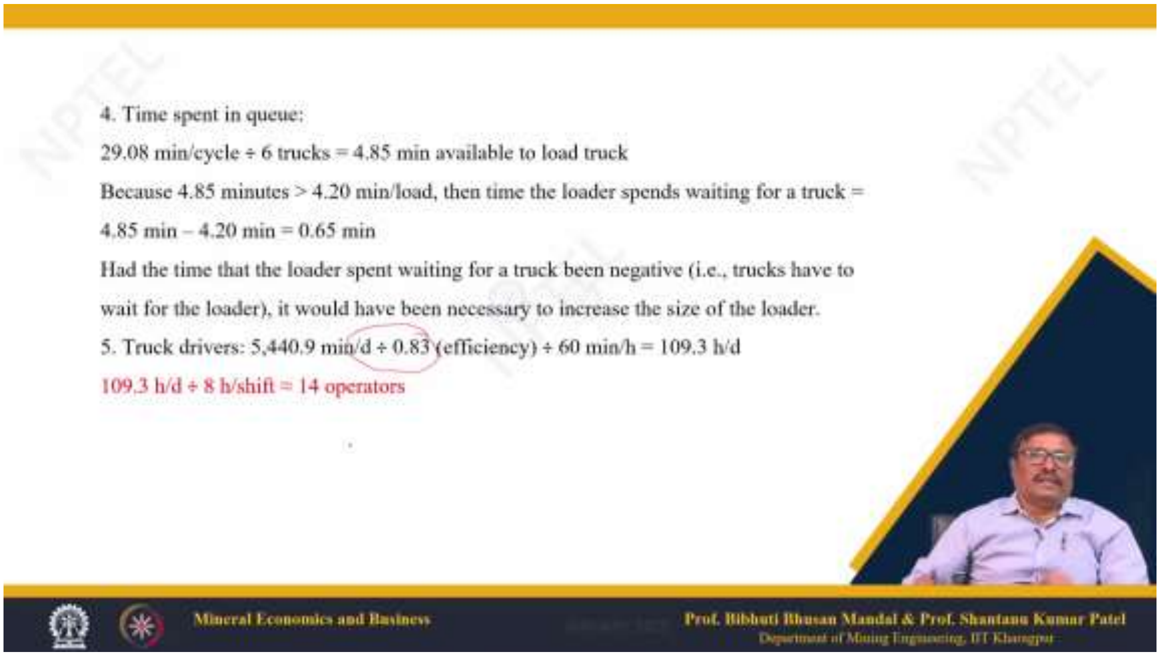
So, you see that for the bucket load since we know the swell factor is 55 percent. So, from there from the given factor 2400 kg per meter cube, we can find out 1550 is the bucket load per meter cube and we know the fill factor also. So, from there we can find out that it is 16.0 ton. total cycle requirement can be calculated by 18000 tons per day divided by 16 tons. So, it will be requiring 1125 cycles per day.

For loader operator also we can we we can similarly calculate and by doing this we can also find out that this ah for the loader we need 2 operators. I will not go into details here the calculations can be available ah through ah this your ah your transcript also this will be provided. So, you can calculate check the calculations from here. The idea is to say that from the data and the derived parameters from there we can ultimately find out that we need to operators for that where we know the capacity of the ah the bucket capacity of the loader to operate or provide the load on to the tracks.

For the track here, we also use the same similar data that we have provided earlier. The required number of tracks is calculated as 6 cycles per track into 11.5 meter cube per cycle, and we have a 90 percent fill factor. So, from there, we can find out it is 96,225 kg per load. Now, from there, we can also find out that we will be calculating loading time and all these things. So, from there, we can find out that we will be requiring 6 tracks, and previously we found out that 2 loaders with 6 tracks will be sufficient for the design.

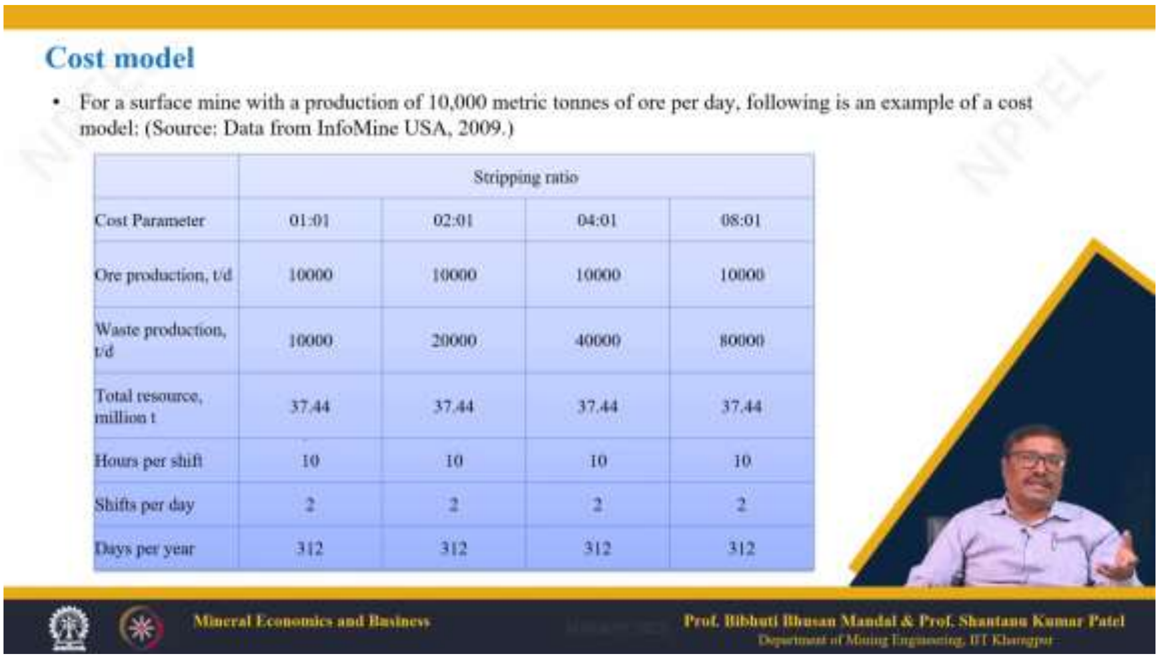


Now, from here, further calculations show that we will be requiring a total of operators for this job, considering 83 percent efficiency and the number of tracks and loaders. Now, this is how we calculate derived parameters from certain given figures. And from there, if the 14 parameters are known, you can now calculate the wage or salary easily based on



the number of operators, people, or the rate of absenteeism. So, you have 14 operators, and you assume that you have 25 percent absenteeism. So, then you have to calculate how many extra operators you require.

So, the total operators on roll can be easily found out, and from there, you can calculate the wage, salary, and other benefits of the operators. Now, other than these typical measures like what we found out in drilling, blasting, excavating, and hauling, there are also pumping and bulldozing operations. Another in the process when we add up all these things. So, in the final cost calculation, we will try to find out rupees per day used for a particular ancillary cost, for example, road grader or dozer. And divided by total tons mined.

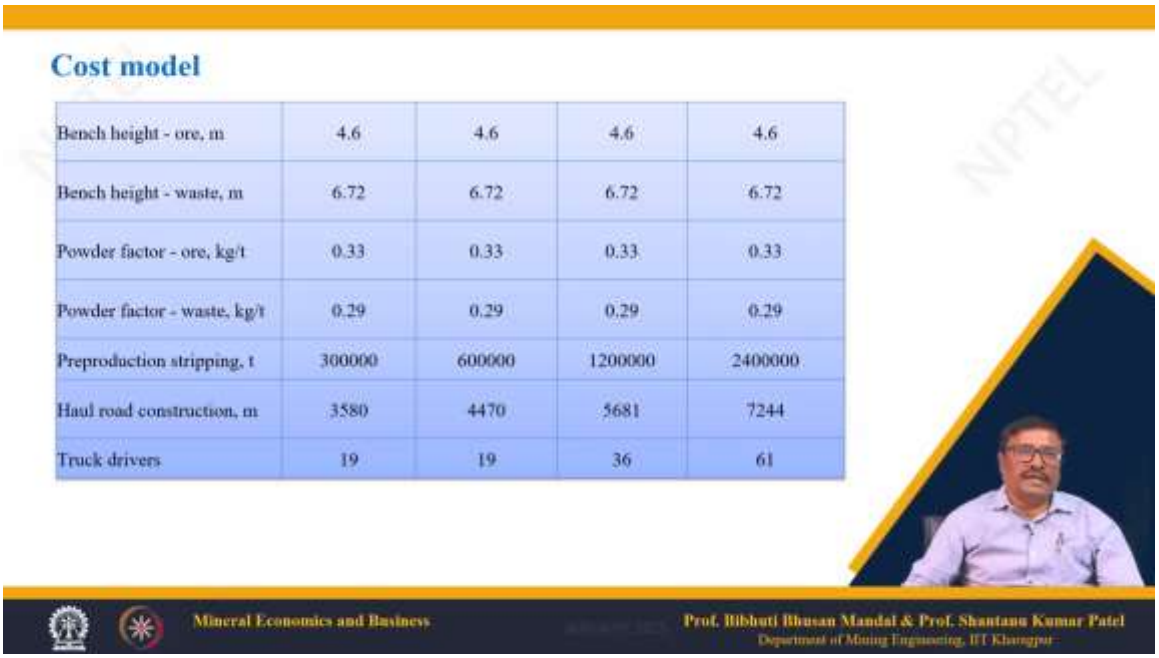


	Stripping ratio			
Cost Parameter	01:01	02:01	04:01	08:01
Ore production, t/d	10000	10000	10000	10000
Waste production, t/d	10000	20000	40000	80000
Total resource, million t	37.44	37.44	37.44	37.44
Hours per shift	10	10	10	10
Shifts per day	2	2	2	2
Days per year	312	312	312	312

So, that will give us tons mined per day. So, that figure will be universal for all these measures and the ancillary costs. Now, this is, for example, we are just showing how it is done by InfoMine USA in 2009. So, we are taking this from the SME handbook, where you can see that what we have discussed now.

So, they have just presented a 10,000 metric-ton ore-per-day mine cost model, where we see that the cost parameters are given for different stripping ratios. Because if you are thinking that your ore is about 1 ton, then and the stripping ratio varies, in that case, your total load for drilling, blasting, excavating, and hauling will change. So, there are four kinds of scenarios which have been explained here: 1, then 2:1, 4:1, 8:1—8 times, say, for 1 8 tons of waste has to be mined out.

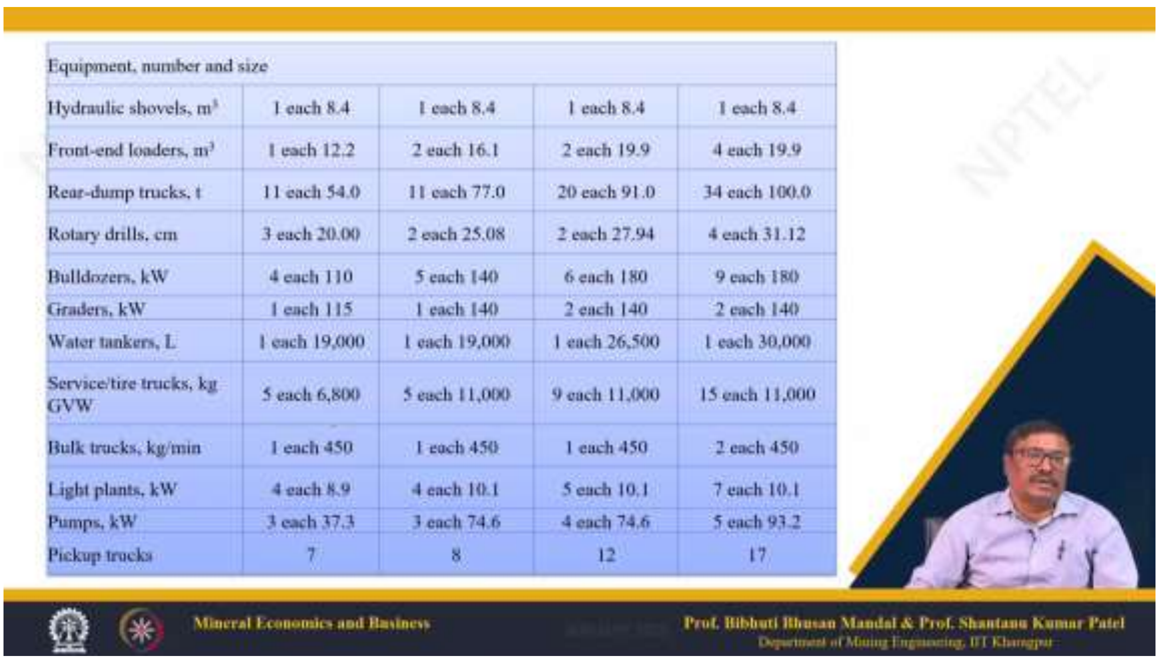
So, now you see the ore production is given here in the next row, and since the stripping ratio is varying, so this is also increasing. So, the total resource in million tons will now be added. This is known—say, we know that it is 37.44 million tons for all figures—this remains the same because we have the we have the data from the geological and geostatistical modeling.



Now, hours per shift here are assumed as 10 hours per shift, and per day we have 2 shifts. And days per year for all calculations are 312 working days that have been assumed for the model. Now, the bench height is given, bench height in waste is also given; these are design parameters. Powder factor assumed—powder factor in waste and ore are different, as you can see. Here, which is common for all stripping ratio scenarios. Then, the production stripping—how much overburden you are generating.

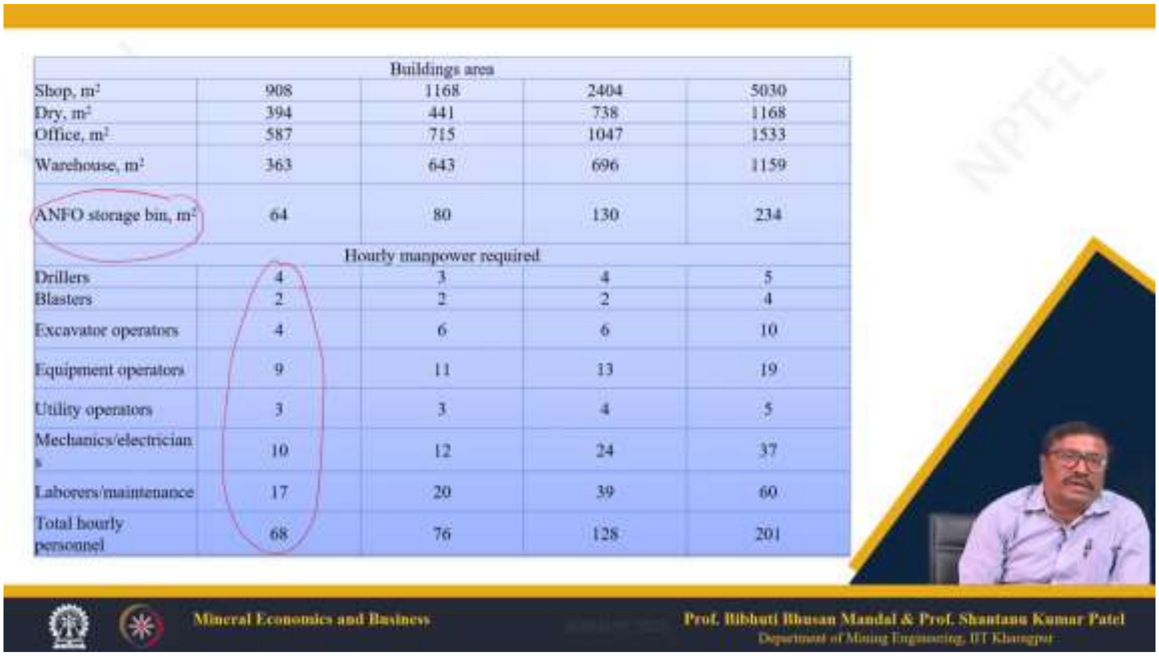
Now, here, haul road construction in meters—this has been calculated by planning; you can use software also. From there, as we have shown earlier, we have calculated that, depending on the workload and the machines we are using, we need truck drivers. Similarly, for equipment like hydraulic shovels, front-end loaders, rear-dump trucks, rotary drills, bulldozers, graders, water tankers—all are scheduled. This is only to show you the parameters or the items that you must not miss when you design or develop a cost model. All the factors are to be there in the model.

So, the light plants—even the moving lights or when you are working at night. So, those light plants are also included; pumps required for dewatering from the pit bottom—all these things. From here also, we can find out, depending on the facilities, equipment, and the people, now we can find out the shop area, workshop area, then office—how big is the office, warehouse, your taxpayers—ah, many other things to be stored, and then we also need explosive storage facility. Now, the manpower required is estimated like this: drillers, blasters, excavators, equipment operators, utility operators, mechanics, electricians. Then, for maintenance, the total hourly is 68 for the minimum, and for 8 to 1, where the production plus overburden is very—I mean, stripping ratio is very high—we will be requiring 201 people to produce that much.



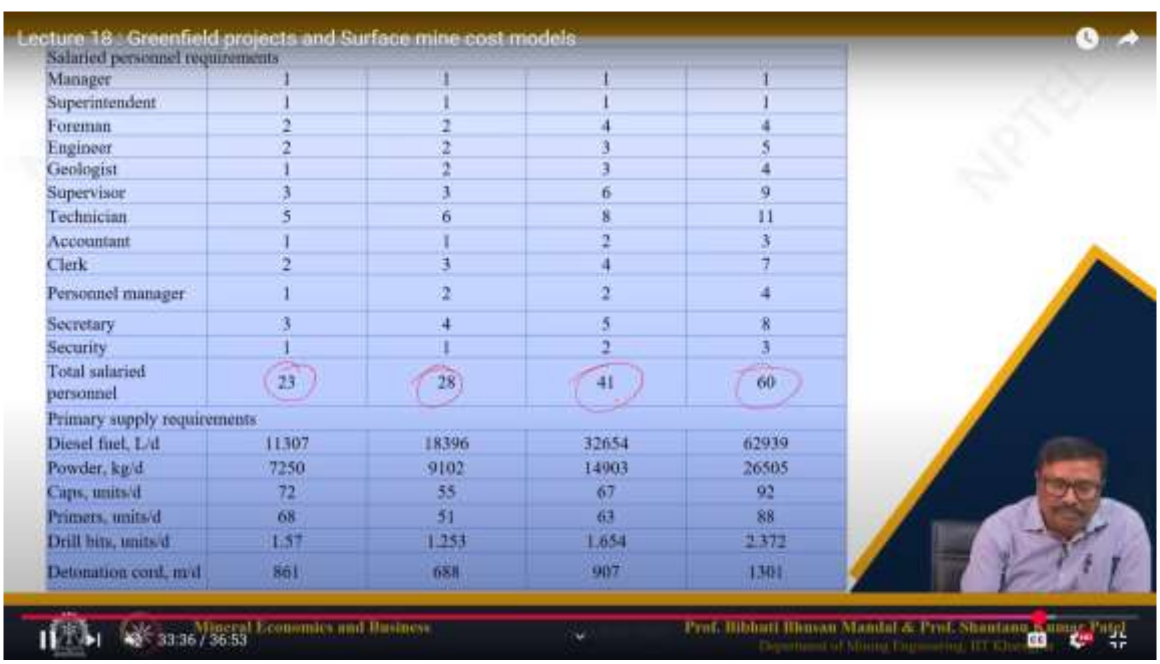
Equipment, number and size				
Hydraulic shovels, m^3	1 each 8.4	1 each 8.4	1 each 8.4	1 each 8.4
Front-end loaders, m^3	1 each 12.2	2 each 16.1	2 each 19.9	4 each 19.9
Rear-dump trucks, t	11 each 54.0	11 each 77.0	20 each 91.0	34 each 100.0
Rotary drills, cm	3 each 20.00	2 each 25.08	2 each 27.94	4 each 31.12
Bulldozers, kW	4 each 110	5 each 140	6 each 180	9 each 180
Graders, kW	1 each 115	1 each 140	2 each 140	2 each 140
Water tankers, L	1 each 19,000	1 each 19,000	1 each 26,500	1 each 30,000
Service/tire trucks, kg GVW	5 each 6,800	5 each 11,000	9 each 11,000	15 each 11,000
Bulk trucks, kg/min	1 each 450	1 each 450	1 each 450	2 each 450
Light plants, kW	4 each 8.9	4 each 10.1	5 each 10.1	7 each 10.1
Pumps, kW	3 each 37.3	3 each 74.6	4 each 74.6	5 each 93.2
Pickup trucks	7	8	12	17

So, the salaried personnel requirement like the manager, superintendent, foreman, engineer, geologist, supervisor, technician, accountant all these people are salaried and then we can of course, hire people on contract on wages also. So, the number of secretary security people. So, total salaried person we can find out from here estimated figures for different volume of or rather depending on the stripping ratio amount that is being produced or handle is changing. So, the number of people are also changing. Now for the primary supply requirement we need the diesel these are operating expenses, then powder ah this that means, the explosive, then detonator, primers, drill bit, detonation cord all can be calculated by step by step as we have seen earlier during the ah previous discussion.



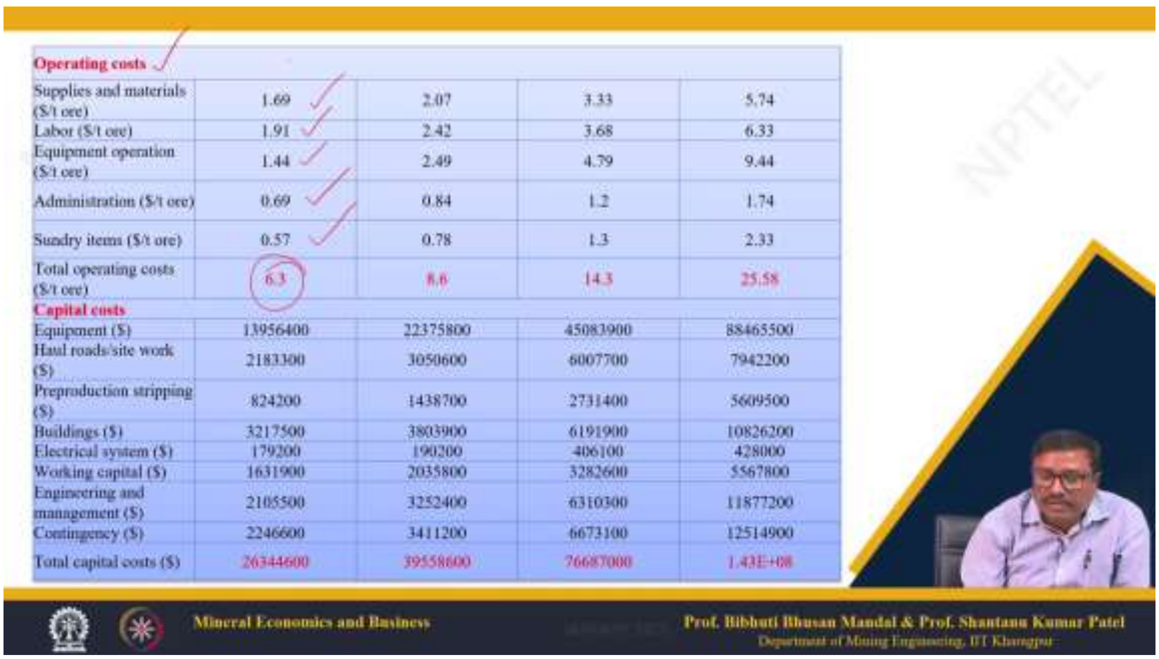
Buildings area				
Shop, m²	908	1168	2404	5030
Dry, m²	394	441	738	1168
Office, m²	587	715	1047	1533
Warehouse, m²	363	643	696	1159
ANFO storage bin, m²	64	80	130	234
Hourly manpower required				
Drillers	4	3	4	5
Blasters	2	2	2	4
Excavator operators	4	6	6	10
Equipment operators	9	11	13	19
Utility operators	3	3	4	5
Mechanics/electricians	10	12	24	37
Laborers/maintenance	17	20	39	60
Total hourly personnel	68	76	128	201

So, from there we find out the operating cost like this find out ultimately from the all now we are summing up things in the under the heads suppliers and materials, under labour, under equipment operation this is in dollar we have taken from that US that book S and E handbook. Administration Sunday item so, total it is coming say 6.3 dollar per ton of ore is the OPEX. which is increasing when the stripping ratio is more and that is why it is becoming 25.58 here. Now, the capital cost for the entire mine in the beginning equipment this much, then haul load for site work in dollars, then your pre-production stripping before the production starts.



Salaried personnel requirements				
Manager	1	1	1	1
Superintendent	1	1	1	1
Foreman	2	2	4	4
Engineer	2	2	3	5
Geologist	1	2	3	4
Supervisor	3	3	6	9
Technician	5	6	8	11
Accountant	1	1	2	3
Clerk	2	3	4	7
Personnel manager	1	2	2	4
Secretary	3	4	5	8
Security	1	1	2	3
Total salaried personnel	23	28	41	60
Primary supply requirements				
Diesel fuel, L/d	11307	18396	32654	62939
Powder, kg/d	7250	9102	14903	26505
Caps, units/d	72	55	67	92
Primers, units/d	68	51	63	88
Drill bits, units/d	1.57	1.253	1.654	2.372
Detonation cord, m/d	861	688	907	1301

buildings, electrical system installation, working capital in the beginning to start with engineering and management, contingency all this thing is coming to give you the total capital cost. And what we have seen operating cost per ton of ore. So, from here what we have seen, we know that the capital cost is this much. Now, we if you are distributing this capital cost over the life of the mine, we can find out the capital cost per year and from there if the ton is per year, you can find out the capital cost component capital cost component that is to be charged per ton of ore produced.



Operating costs				
Supplies and materials ($/t ore)	1.69	2.07	3.33	5.74
Labor ($/t ore)	1.91	2.42	3.68	6.33
Equipment operation ($/t ore)	1.44	2.49	4.79	9.44
Administration ($/t ore)	0.69	0.84	1.2	1.74
Sundry items ($/t ore)	0.57	0.78	1.3	2.33
Total operating costs ($/t ore)	6.3	8.6	14.3	25.58
Capital costs				
Equipment ($)	13956400	22375800	45083900	88465500
Haul roads/site work ($)	2183300	3050600	6007700	7942200
Preproduction stripping ($)	824200	1438700	2731400	5609500
Buildings ($)	3217500	3803900	6191900	10826200
Electrical system ($)	179200	190200	406100	428000
Working capital ($)	1631900	2035800	3282600	5567800
Engineering and management ($)	2105500	3252400	6310300	11877200
Contingency ($)	2246600	3411200	6673100	12514900
Total capital costs ($)	26344600	39558600	76687000	1.43E+08

If you add this operating cost and the capex cost, then you get the total cost per ton of ore. This only gives an idea of how you develop from scratch based on the available data, the engineering and scientific studies further conducted, and the analytical methods applied to develop a cost model. From there, you can estimate what the total cost will be. So, depending on the market price, you can also forecast the price in the market and, using the time value of money, compile everything to prepare the final feasibility study report. You can study in detail the SME Mining Engineering Handbook and also the InfoMine USA document, which can be referred to for further study.

Thank you very much.

REFERENCES

- SME Mining Engineering Handbook
- InfoMine USA, 2009