MINERAL ECONOMICS AND BUSINESS

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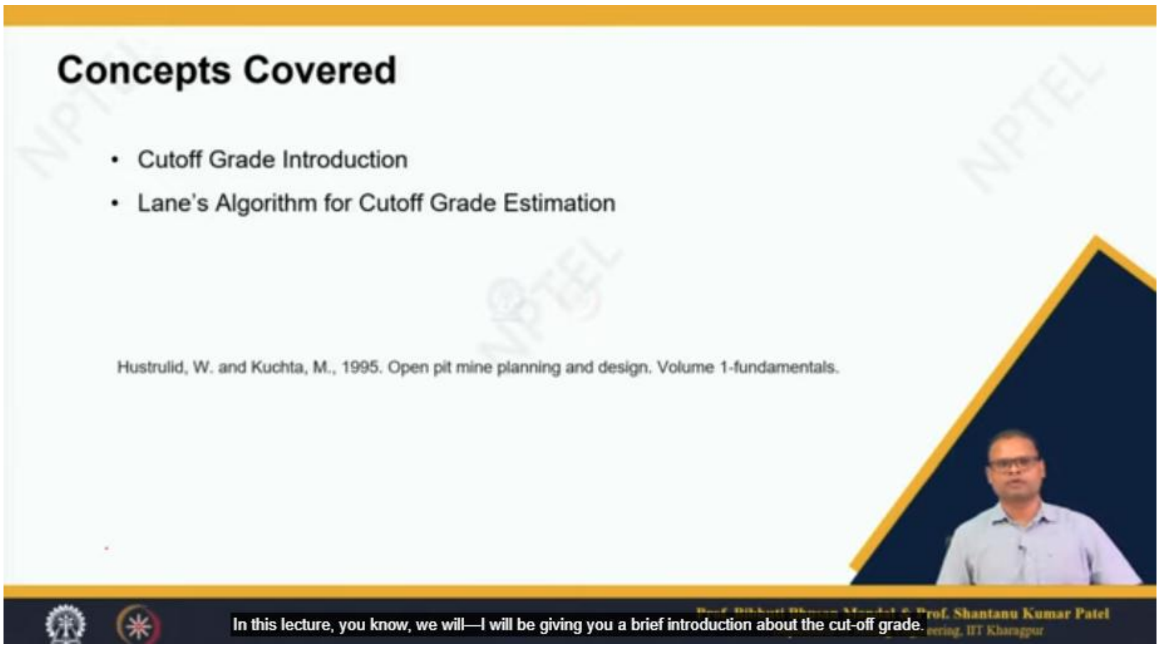
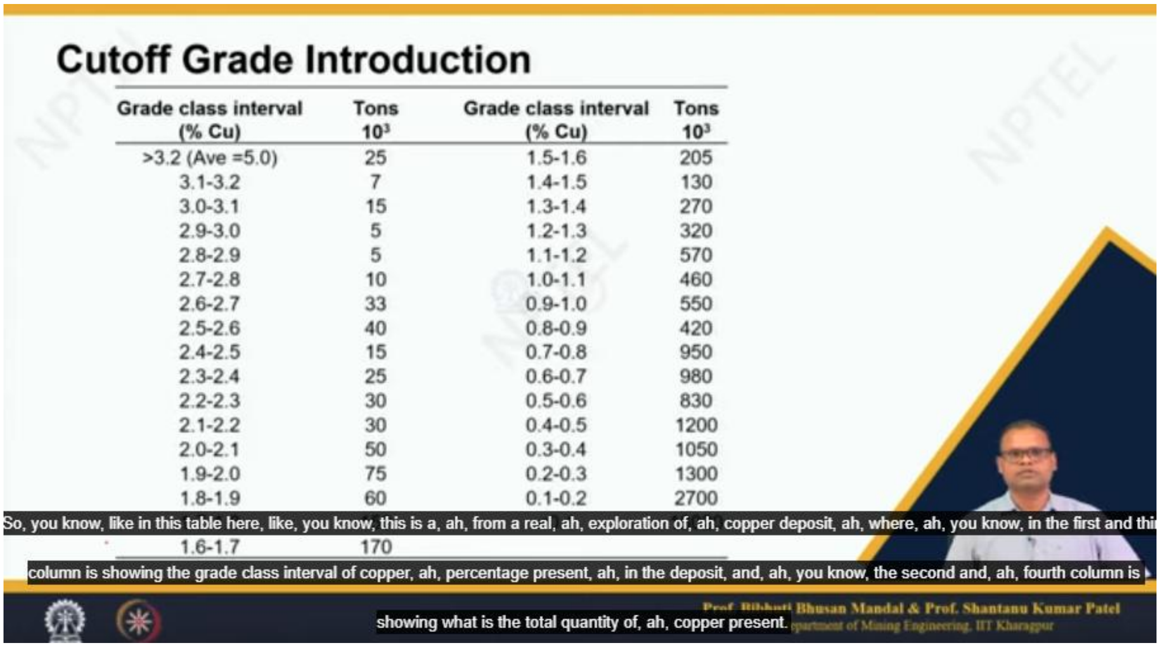
Lecture 12: Cutoff Grade - 1



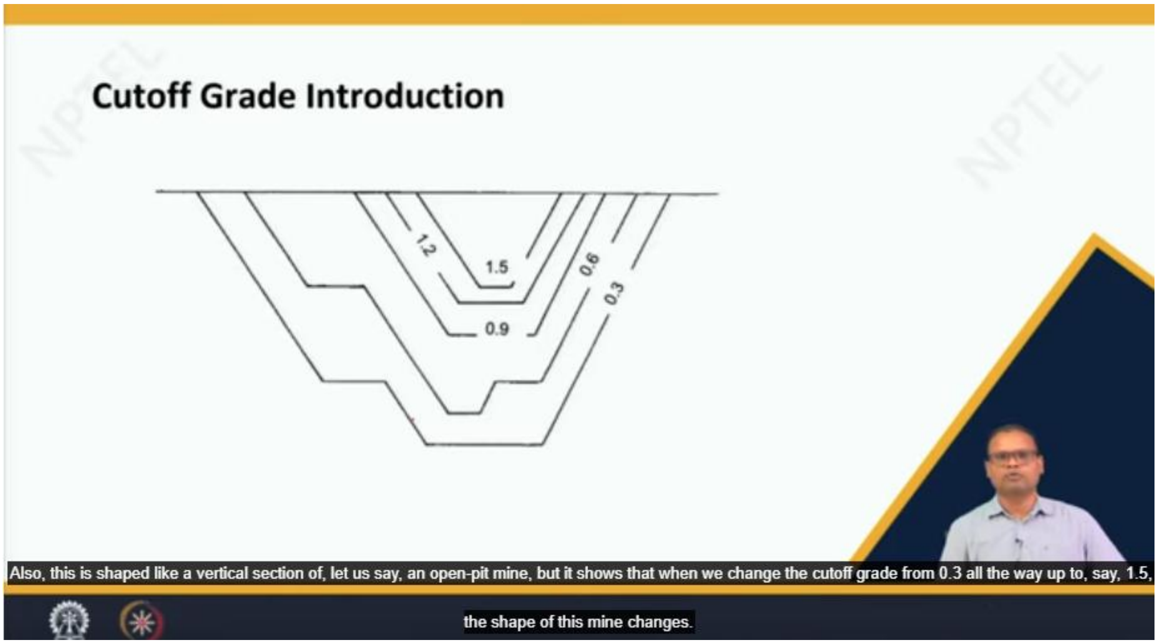
Hello everyone, and welcome again to this course on Mineral Economics and Business. So, this is our lecture number 12, and this is the first part of the lecture on cut-off grade. In this lecture, you know, I will be giving you a brief introduction about the cut-off grade. And then, ah, you know, the next part of the lecture will be, ah, towards, ah, Lane's algorithm, ah, for cut-off grade estimation, which will be covered in, ah, lecture number 2 and lecture number 3. So, most part of this, ah, you know, the, ah, data presented in this, ah, lecture is taken from this book, ah, by Foster, Lidd, and, ah, Kucita, ah, is a book named Open Pit, ah, Mine Planning and Design. And it was published in 1995.



Grade class interval (% Cu)	Tons 10^3	Grade class interval (% Cu)	Tons 10^3
>3.2 (Ave =5.0)	25	1.5-1.6	205
3.1-3.2	7	1.4-1.5	130
3.0-3.1	15	1.3-1.4	270
2.9-3.0	5	1.2-1.3	320
2.8-2.9	5	1.1-1.2	570
2.7-2.8	10	1.0-1.1	460
2.6-2.7	33	0.9-1.0	550
2.5-2.6	40	0.8-0.9	420
2.4-2.5	15	0.7-0.8	950
2.3-2.4	25	0.6-0.7	980
2.2-2.3	30	0.5-0.6	830
2.1-2.2	30	0.4-0.5	1200
2.0-2.1	50	0.3-0.4	1050
1.9-2.0	75	0.2-0.3	1300
1.8-1.9	60	0.1-0.2	2700
1.6-1.7	170		

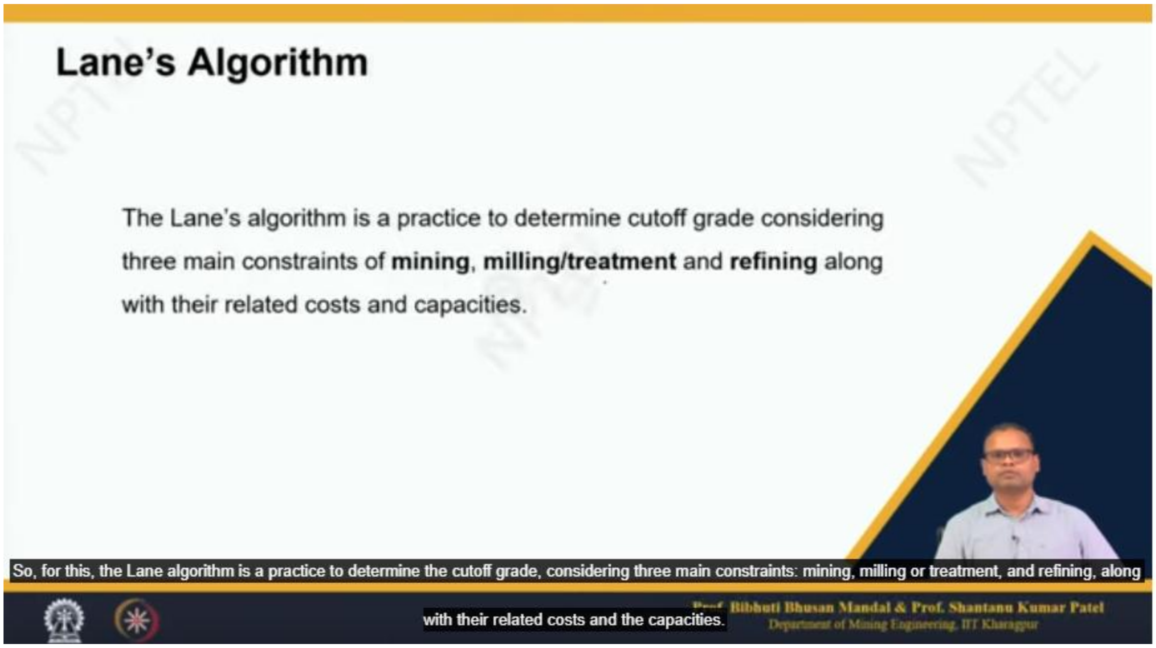
So, you know, like in this table here, like, you know, this is a, ah, from a real, ah, exploration of, ah, copper deposit, ah, where, ah, you know, in the first and third column is showing the grade class interval of copper, ah, percentage present, ah, in the deposit, and, ah, you know, the second and, ah, fourth column is showing what is the total quantity of, ah, copper present. Or in this, ah, you know, in other terms, let us say, you know, this is a top view of the deposit, and, ah, you know, the deposit, ah, has some concentration, let us say here, ah, this grade is, ah, let us say, example, ah, let us say, you know, changing from 3 or the control of this grade is 3.0 here, and, ah, let us say it is ah, 3.1 here. So, whatever, ah, the amount of mineral present here or the, you know, the quantity of the ore present is, ah, represented in the, ah, ah, table here: 3.0 to 3.1 is, ah, 15 into 10 to the power 3 tons.

So, similarly, if we draw, ah, contours all around the deposit, ah, for different, ah, class intervals, we have different, ah, quantities of mineral present. Now, if we say that, you know, for my mine, you know, this the cut-off rate is, let us say, 0.4. So, for that case, what we are doing is, you know, we will leave everything below 0.4 ah, from this, this 1050 into 10 to the power 3, ah, tons, ah. So, we are not going to take it out, and, ah, what we are going to take out is, ah, you know, all the way from 0.4 to 0.5 interval all the way up to, ah, this greater than 3.2 percentage of, ah, grade.

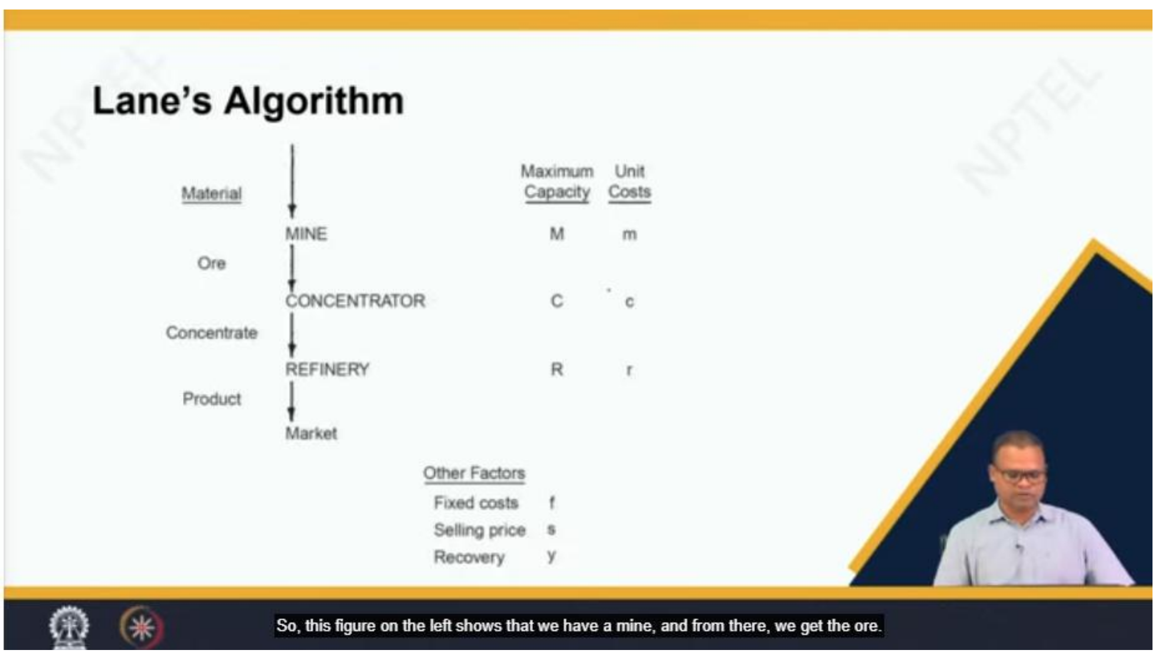


So, in this figure here, the x-axis represents the cutoff grade, and the y-axis shows the tonnage that we are going to extract, in 10 to the power of 6 tons. For example, if we keep a cutoff grade of, let us say, 0.4 here, the corresponding amount that we are going to extract, or the tonnage, is around 7 into 10 to the power of 6. So, if we change this cutoff grade, or maybe increase it, the tonnage for our case will decrease. For example, for 1, it is less than what we get for a cutoff grade of 0.4. Also, this is shaped like a vertical section of, let us say, an open-pit mine, but it shows that when we change the cutoff grade from 0.3 all the way up to, say, 1.5, the shape of this mine changes.

And if we change the cutoff grade, the quantity of mineral that we are going to extract also changes. And we have the total profit that we are going to get from, say, a cutoff grade of 0.9, which will be different from that of 0.6 and 0.3. So, we have to find what is the maximum profit that we are going to get from the mine. So, and to decide our cutoff grade.



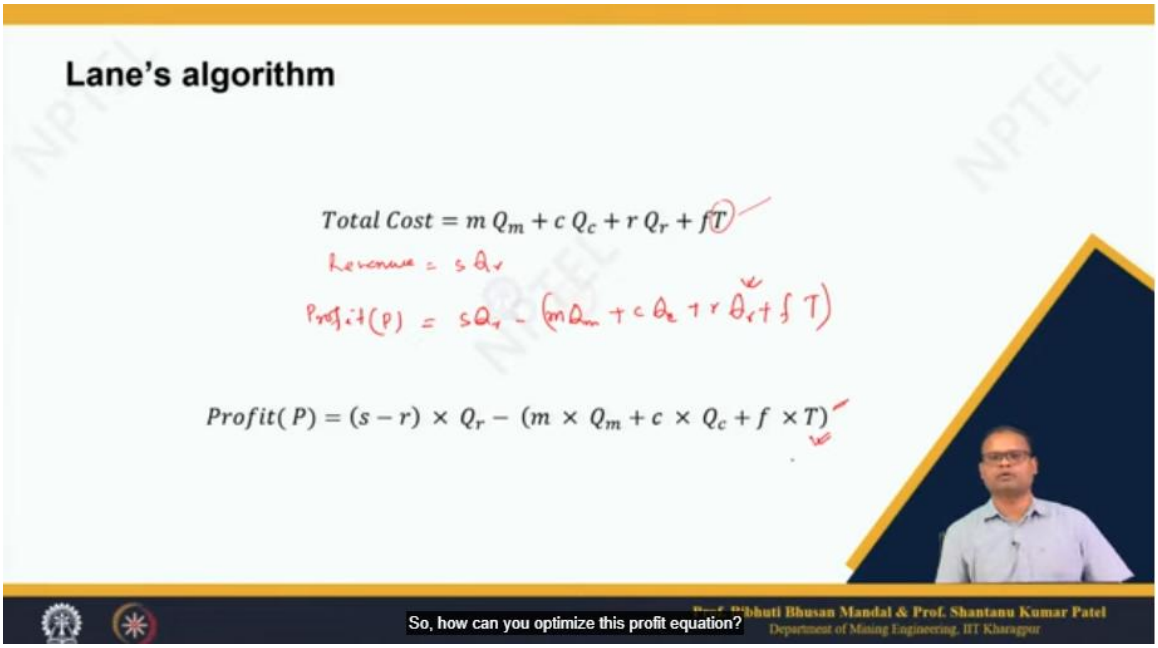
So, for this, the Lane algorithm is a practice to determine the cutoff grade, considering three main constraints: mining, milling or treatment, and refining, along with their related costs and the capacities.



So, which we will see in our next slide. So, this figure on the left shows that we have a mine, and from there, we get the ore. The ore is sent to the concentrator, and the concentrator produces concentrate, which goes to the refinery, and the refinery produces the product, which goes to the market. So, this is how it works.

So, now if you see, the mine has a maximum capacity, which is called M here. So, if we have resources of, let us say, 100 people. Or 1000 people, along with the respective machinery, the capacity of this mine will change—how many million tons of ore we can produce will change. So, for a particular set of resources that we have, we have a capacity for the mine. Similarly, if we have a concentrator, which can be a smaller one or

let us say, a bigger one, both will have different capacities to process this ore. So, we have a concentrator maximum capacity. Similarly, the refinery has a capacity to produce the final product, which depends on what resources we have for the refinery. Ah. Similarly, we have costs involved—unit costs involved for mining—which can be, to produce 1 ton of ore, what is that amount (Rs per ton) that we need. So, that is our unit cost for mining. Similarly, to process 1 ton of ore in the concentrator, the unit cost is small c, and we call the refinery cost to produce the final product from the refinery r. Similarly, we have fixed costs, which we call small f, and there is a selling price for this product that we are producing from the refinery. And there is recovery because 100 percent recovery may not happen or will not happen during this entire process. So, it can be, let us say, 80 percent recovery or whatever it is, based on our resources that we have.

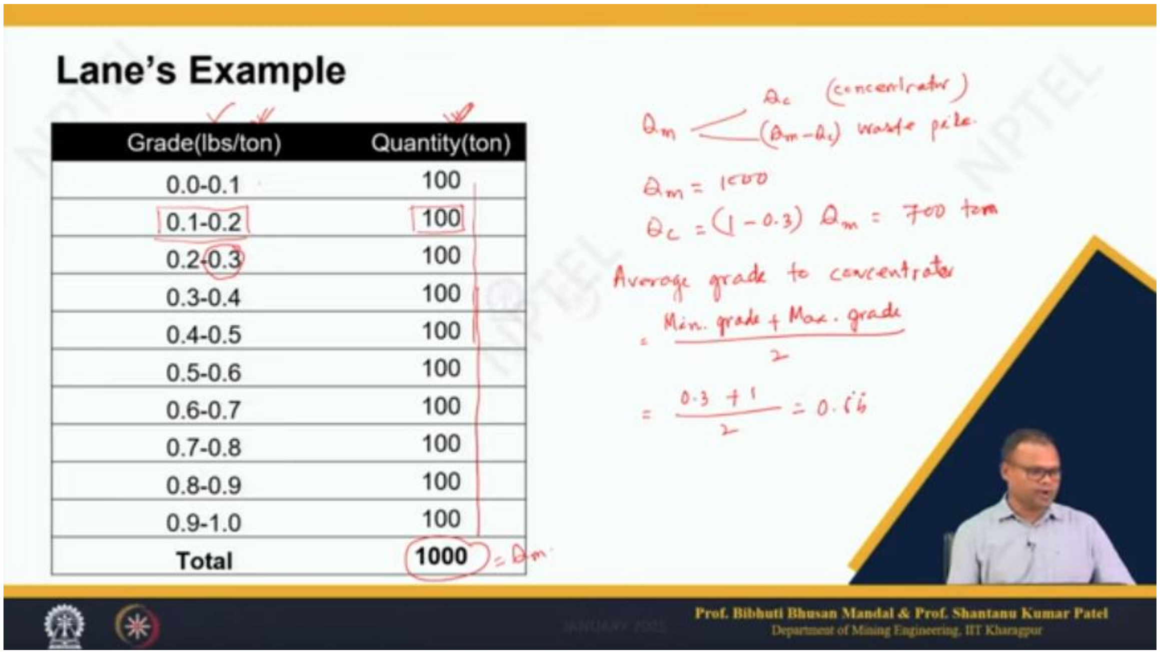


So, here we, for this Lenz algorithm, we use a few more terms along with the terms we saw in our previous slide. So, the next term is Qm. Qm is the total quantity of the ore mined, and Qc is the total quantity sent to the concentrator. And Qr is the amount produced from the refinery. It can be in tons, pounds, kg, or any unit. So, based on that, if m is the unit cost for mining and you are producing some Qm amount of ore, the mining cost becomes m times Qm. Similarly, the processing cost is c times Qc, and the refinery cost is r times Qr because the refinery is producing Qr amount of product. So, that is what we are selling, and the revenue becomes s times Qr.

$$Total\ Cost = m\,Q_m + c\,Q_c + r\,Q_r + fT$$

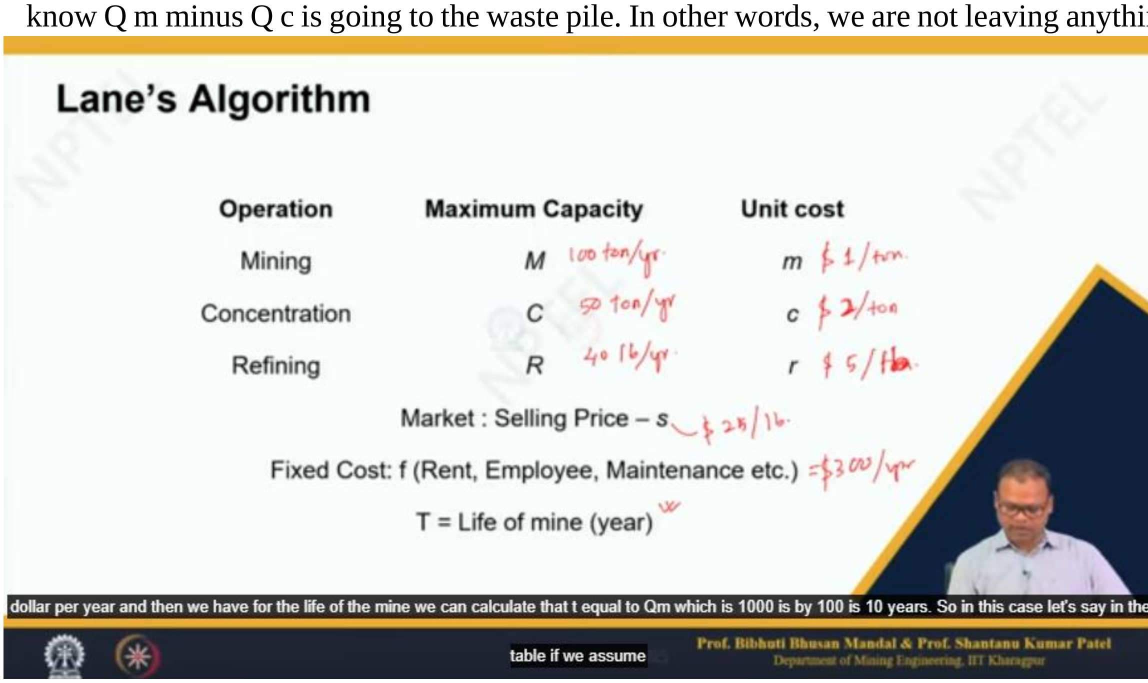
$$Profit(\,P) = \big((s - r)\times Q_r\big) - (c \times Q_c + m \times Q_m + f \times T)$$

The main objective of this Lenz algorithm is how we can get maximum profit from the mine. So, how can you optimize this profit equation? For that, Lane took a simple example, not like a random distribution of this quantity present in the different grades, but constant.



So, for example, you can see here if the grade from 0.1 to 0.2 is Similarly, for all these grades, here on the left side column, the quantity is almost the same. This is what Lane's assumption is, to take a simple case.

So, here you can see that the total quantity of ore present is 1000. So, this becomes our Qm, but as you know in this case, Lane assumed that you know is going to take the entire material out, and Q m out of this entire material, Qc will go to the concentrator. and you know Q m minus Q c is going to the waste pile. In other words, we are not leaving anything

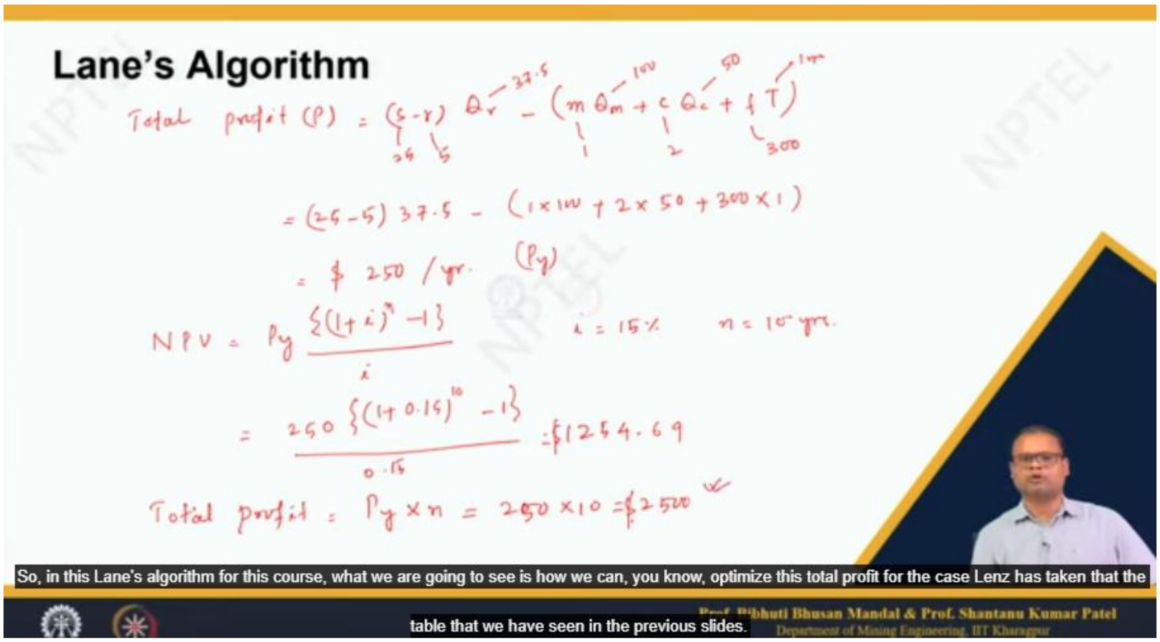


in the ground and are mining everything out. So, this is the assumption you know Lane has considered. For now, let us say the cutoff rate is 0.3. So, what we are going to do is take everything from 0.3 to 1.0 and send it to the concentrator. So, Qm or Qm is 1000 But Q c in this case becomes you know 0.1 minus 0.3 because the cutoff grade is 0.3 into Q n is our 700 ton is going to the concentrator.

So, in this case, the average grade going to the concentrator rate to concentrator is the minimum grade plus maximum grade. by 2 because the distribution of you know different grade is uniform in this case. So, this becomes 0.3 plus 1 by 2 is 0.65. Also, what you know Lane assumed is the different capacity for example, you know M is 100 ton per year, C is 50 ton per year.

The refinery capacity is 40 pound per year. The m is 1 dollar because it was the example from US, 1 dollar per ton. To process 1 ton of ore in the processing plant, this is 2 dollar. So, c becomes 2 dollar per ton. R is 5 dollar per ton. So, he assumed a selling price of 25, sorry this is per pound. So, r is 5 dollar per pound because this product is you are getting it in pound.

So, the selling price is s equal to 25 dollar per pound. Also what he assumed was f equal dollar per year and then we have for the life of the mine we can calculate that t equal to Qm which is 1000 is by 100 is 10 years. So in this case let's say in the table if we assume or cutoff grade. 0.5. So, in that case what we are going to send to the concentrator is 0.5 to 0.6, 0.6 to 0.7, 0.7 to 0.8, 0.8 to 0.9 and from 0.9 to 1.0 and the respective quantities 100, 100, 100 and 100 and 100. So, in this case the total quantity that is being sent to the concentrator is 500 ton. So, in this case what we are doing is we are mining total amount of 1000 and what we are doing is sending 500 tons to the concentrator and sending 500 tons to the waste pipe. And what we are assuming here is the recovery is 100 percent for this lane's algorithm. So, like you know, if we are sending 500 to the concentrator, the per-year amount to amount sent to the concentrator equals 500, and the life of the mine is 10 years. So, 500 divided by 10 is 50 tons. So, and the average grade to the concentrator equals the minimum grade, which is 0.5, plus the maximum grade, which is 1.0, divided by 2 is 0.75. So, if and the amount or the product getting per year becomes the average grade into quantity sent per year. quantity sent per year, which is you know, 0.75 into 50. So, this becomes 0.75, you know, in lb per ton, and then this is 50 per 50 tons.



So, this becomes 37.5 So, and in here the total profit if you see the equation,

Total Profit (P):

$P = (S - R) \cdot Q - (m \cdot \theta m + c \cdot Qc + f \cdot T)$

Where: $S = 26$

R=5,

Q=37.5,

m=1,

θm=100

c=2,

Qc=50

f=300,

T=1

P = (26−5) · 37.5−(1·100+2·50+300·1)

P=$250/year

you know the NPV for the entire mine or for the life of the mine becomes the NPV is the net present value that you have, that we have already seen in our other classes.

Net Present Value (NPV):

$NPV = Py \cdot ((1+i)\ n - 1)/i$

Where:

i=15%=0.15

n=10 years

NPV = 250·((1+0.15)10−1)/0.15 = $1254.69

Total Profit=P y·n=250·10=$2500

So, in this Lane's algorithm for this course, what we are going to see is how we can, you know, optimize this total profit for the case Lenz has taken that the table that we have seen in the previous slides. So, that, you know, that algorithm we will discuss in our chapter number, or maybe the, you know, this lecture number 2 and lecture number 3.

So, this is the end of our lecture for today.