Mine Automation and Data Analytics

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Week-1

Lecture-1

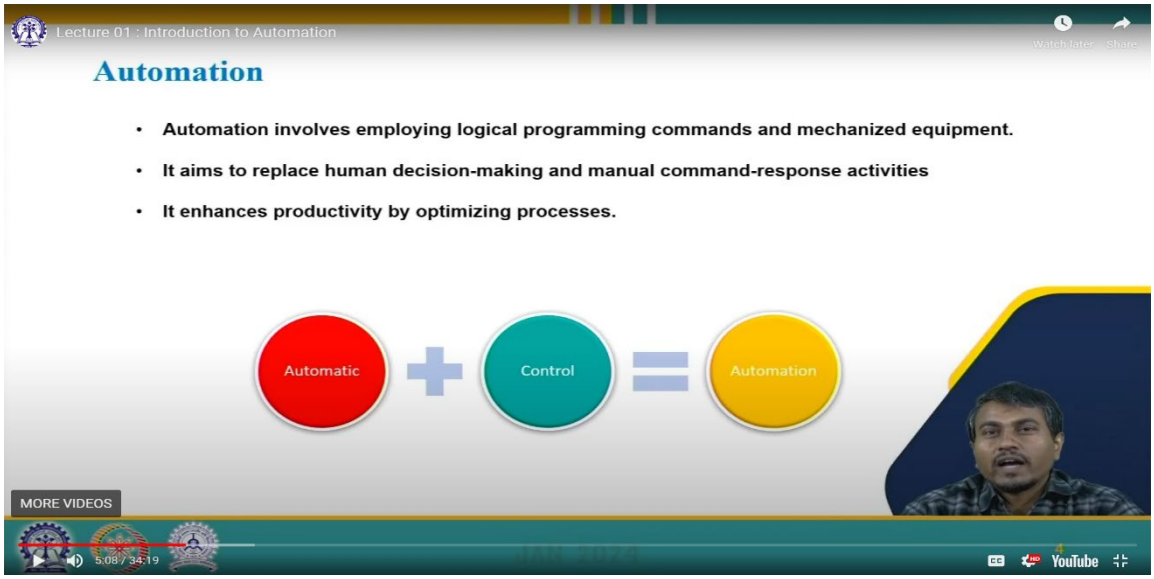
Introduction to Automation

Welcome to my course, Mine Automation and Data Analytics. This course is aimed at giving you exposure to the different technologies adopted in different mines to automate a part of the process or the whole process to achieve higher efficiency in the operation. So, this course, we have subdivided it into three components. The first component that we will focus on in this course is the aspect of mine automation with different case studies and the different sensing technologies adopted for making this automation successful and effective. In the second part of this course, we have included the application of descriptive statistics as well as inferential statistics for my automation. The third part of this course is all about the application of data analytics in the mine automation process.

So, with data analytics and the application of artificial intelligence, we aim to get higher and higher efficiency in the mine automation process. So, in this lecture, we are going to discuss the introduction to automation. So, in this lecture, we will cover the basics of automation and what automation means to us. Then, we will cover the advantages of automation and what advantages this automation is going to give us in the whole mining process chain. Then, we will discuss the disadvantages of automation.

Then, we will discuss some real-world examples of the mine automation which is running in the mines. Then, we will discuss the mining automation maturity model and the different levels of automation practices globally. Then, we will concentrate on the types of automation; principally, here, we will discuss the three types of automation. Then, we will discuss the implementation approach for automation. In the end, we will discuss the role of automation in the mining industry.

what is automation? Automation basically it involves employing logical programming commands and mechanized equipment. So, these automations are basically establishing some automatic control over the process. So automatic means a process or a machine operates with a fixed or defined rule and objectives. So, it aims to replace the human decision-making process as well as reduce the manual common response activities by doing so, it optimizes different parts of the process and also enhances productivity.



So, this automatic is a set of rules operated by a machine or by a process, and establishing control over the process in a defined area or a designated area is basically automation. So, automation is basically a method or technique that is adopted for enriching the system with sensing technology with control established on the system to get higher efficiency. So, what are the advantages of automation? Automation basically reduces the task of human labour in areas like monotonous activities, and it also reduces the fatigue of labour in these kinds of sectors. It is also aiming at replacing human labour in extreme conditions because mining is all about working against nature. So here, extreme temperatures, toxicity, and radiation are exposed to human labour when people are working in that particular environment.

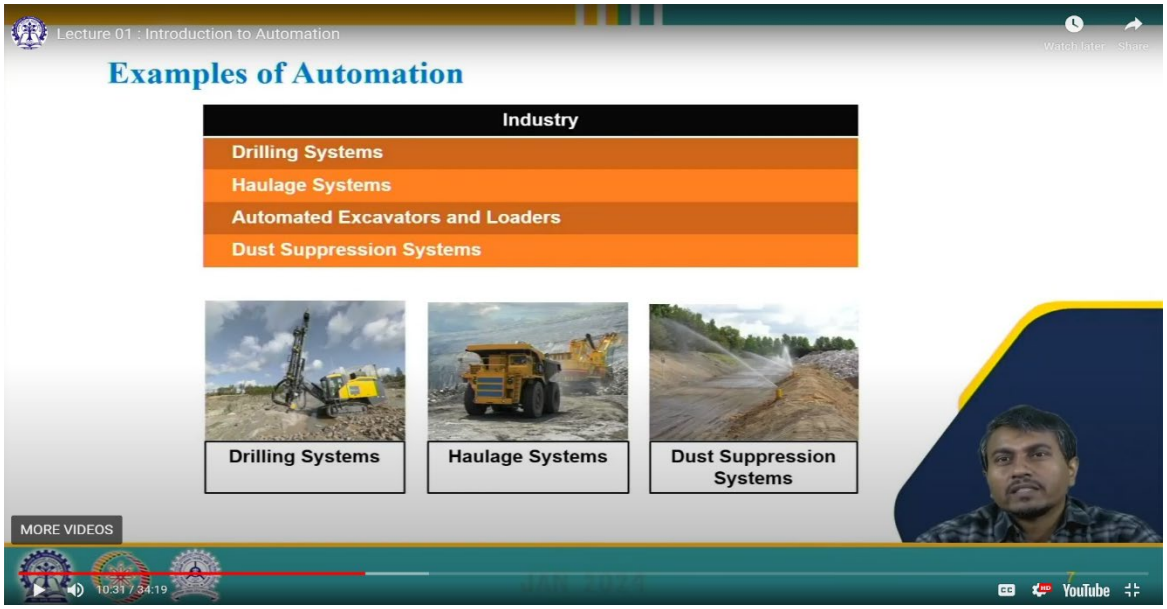
So, we are looking at replacing human labour in these sectors so that we can reduce the hazards in the mining process. The automation is also going to simplify the task, and it is also going to take on tasks that are beyond human capability. So those tasks that are not achievable or that are not possible for human labour can be performed very well and with very high efficiency. It also increases the speed of production, and by doing so, it basically reduces the running cost of the mining operation. It can also check the quality automatically in the process, and by doing so, it can reduce the production of out-of-tolerance parts and ensure consistency in the overall process chain.

What are the disadvantages of this automation? There are some tasks in the mines that are not possible in the current state of advancement of technology to automate that process. So, in those cases, automation or automatic control over the process might not be feasible at the current state of technology. There are some processes and some work that involves varying component size and complexity and that requires the experience of human labour and knowledge dexterity. So, in these challenging conditions, automation might not be applicable or might not be feasible. Automation is very much cost-effective where the task is repeatable and it handles high volumes.

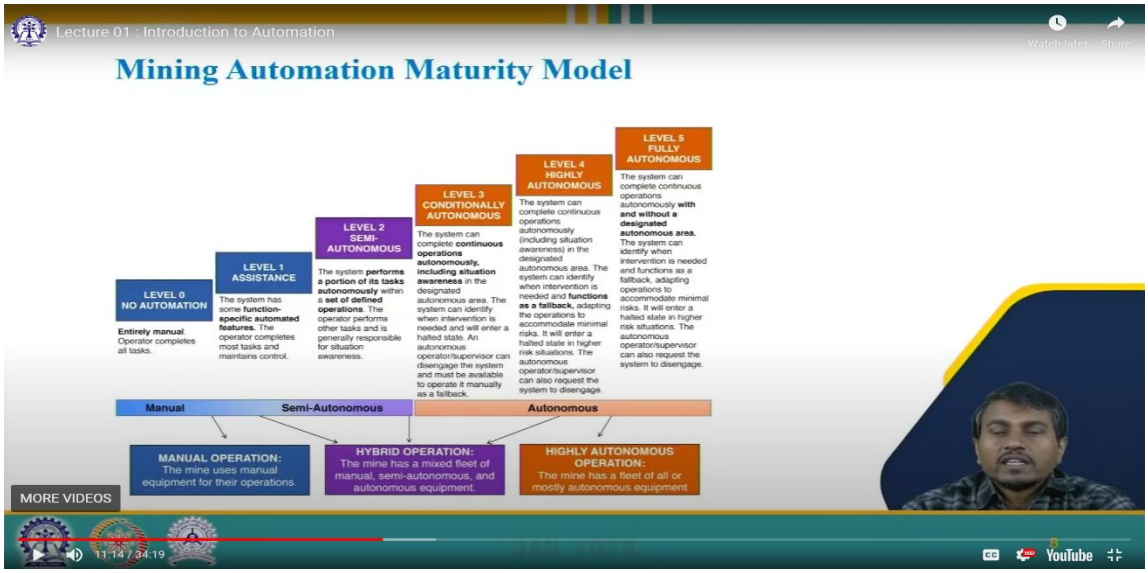
Some of the tasks, some of the processes, or some of the mines can be operated in a cost-effective way rather than automatizing the process for a number of reasons. A skilled maintenance department is required to smoothly run the automation system or autonomous system in the mines because regularly the maintenance ensures the system running smoothly, and without this support, there would be a problem, and loss of production, and it would also

produce some defective parts. So, these are the areas that we need to give more attention to in the future.

So let us see some of the examples that are now working at the mine site in different parts of the world. So, the drilling system is now automated to some extent, and the haulage system, an automated excavator, and loaders are also working in the mines. There are some setups for suppressing the dust in open-cast mines, and we know that there are some issues with the dust. So, these are the areas where the process has been automatize, or some part of it has been working automatically. So, this is one example of the drilling system that is operating in many parts of the world, and it is basically working on programmable logic. Another example is the haulage system, and this kind of haulage system is working in some mines around the world without any human labour on the cabin or operator in the cabin. It can autonomously navigate its path; it can autonomously navigate in dynamic terrain; and in real time, it basically chooses the path to take so that optimum fuel consumption is achieved. This is a dust suppression system in open-pit mines. On the haulage road, there are issues with the dust. So, with the help of an automatic dust suppression system, this process is very well optimized.



So let us see the mining automation maturity model. This figure shows the different levels of automation practice that are feasible or can be thought of from the perspective of a specific mine or mine site. So, level 0 is basically the no-automation part of it. The entire operation is operated by the operator. The operator controls all the tasks. So, there is no role for automation level 0 at the bottom. Level 1 assistance: here the system has some function-specific automated features, but principally the operator completes most of the tasks and maintains control over the system.



So, it is the next higher level than level 0; it is level 1. The next higher level is level 2, semi-autonomous. Here, the system performs a portion of the task; all tasks continuously, in a sustained manner, autonomously within a set of defined operations. The operator performs other tasks, and it is generally responsible for situation awareness. So the operator is basically responsible for situational awareness.

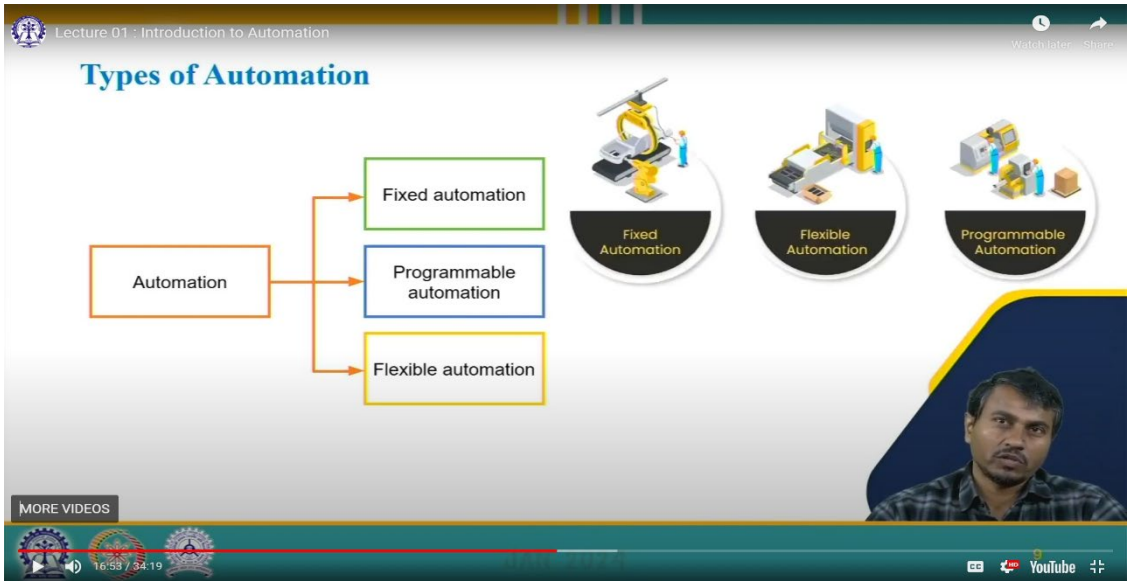
Situational awareness is about getting data about the environment and also comprehending the data based on necessity, and in some cases, it can predict or project the future status of these parameters. Then the next level is level 3, which is conditionally autonomous. Here, the system completes the sustained operation automatically, including situation awareness, in the designated autonomous area. The system can identify when intervention is needed and will enter a halted state. An autonomous operation, autonomous operator, or supervisor can disengage the system and must be available to operate it manually as a fallback when it is required.

So, the next higher level is basically the highly autonomous system level 4. Here, the system can complete, according to necessity, all the tasks in the designated area, but there are some functions of the fallback when it is required to engage the supervisor in the process. It can tolerate low or minimal risk conditions as and when it is required, it will reach the halted condition, and the operator can disengage the system whenever required. Level 5 is basically a fully autonomous system. Here the system operates continuously autonomously with and without a designated autonomous area, and situation control or situation awareness is also automatically alerted when required. Minimal intervention by the supervisor is required in this process, but it will enter a halted state when it enters a higher-risk situation, and here the operator or supervisor can request the system to disengage when required.

So principally, we can see in this mining automation maturity model the three levels. One is the manual one, the second is the semi-autonomous one, and the third is basically the autonomous one. So, level 3, level 4, and level 5 are autonomous, or partly autonomous in some cases, and complete autonomous in the fully autonomous system, and so we can subdivide this into three major operations: manual operation, hybrid operation, or highly autonomous operation. So, hybrid operation is basically a mixed fleet system with manual semi-autonomous as well as autonomous equipment. Manual operation is all about the manual

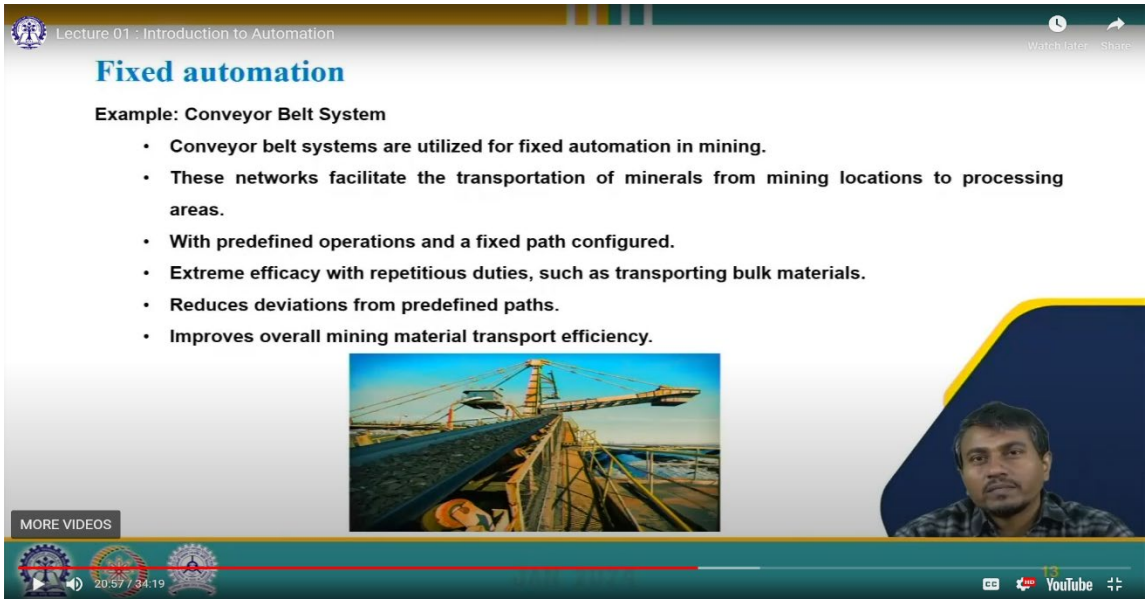
work of the system; it is from 0 to 1, level 2 is basically semi-autonomous, and levels 3, 4, and 5 are basically highly autonomous operations. So, we can define this level in an increasing way, as this kind of pyramid can be represented. At the bottom, the automation level is 0, and the highest level is 5, fully autonomous. So, as we go up in the pyramid, the degree of automation, or the degree of automatic control over the process, increases.

So, what are the types of automation? Here we will discuss three types of automation. First is the fixed automation system; second is the programmable automation system; and third is the flexible automation system.



So, in a fixed automation system, we will basically look at the fixed system-supervised and specialized operations in the system. So, let's discuss the questions. Question 1: What is the primary objective of automation in mining, considering its aim to replace human decision-making and manual command-response activities? We are basically aiming to improve efficiency by replacing human decision-making and manual command-response activities with automated systems, and this system is going to reduce errors. It is going to enhance safety, and it will increase the operational effectiveness of the mine process chain. So let us see an example of a fixed automation system.

So, this fixed automation refers to the use of special-purpose equipment to automate a fixed sequence of processing or assembly operations. It is typically associated with high production rates, and it is relatively difficult to accommodate changes in the product design. That is why this is also called hard automation. So, conveyor weld systems working in open pit mines conveying material from the pit bottom to the pit top are a kind of example of a fixed automation system. So, what are the advantages of the fixed automation system? Its main advantage is its maximum efficiency. It operates with very high efficiency.

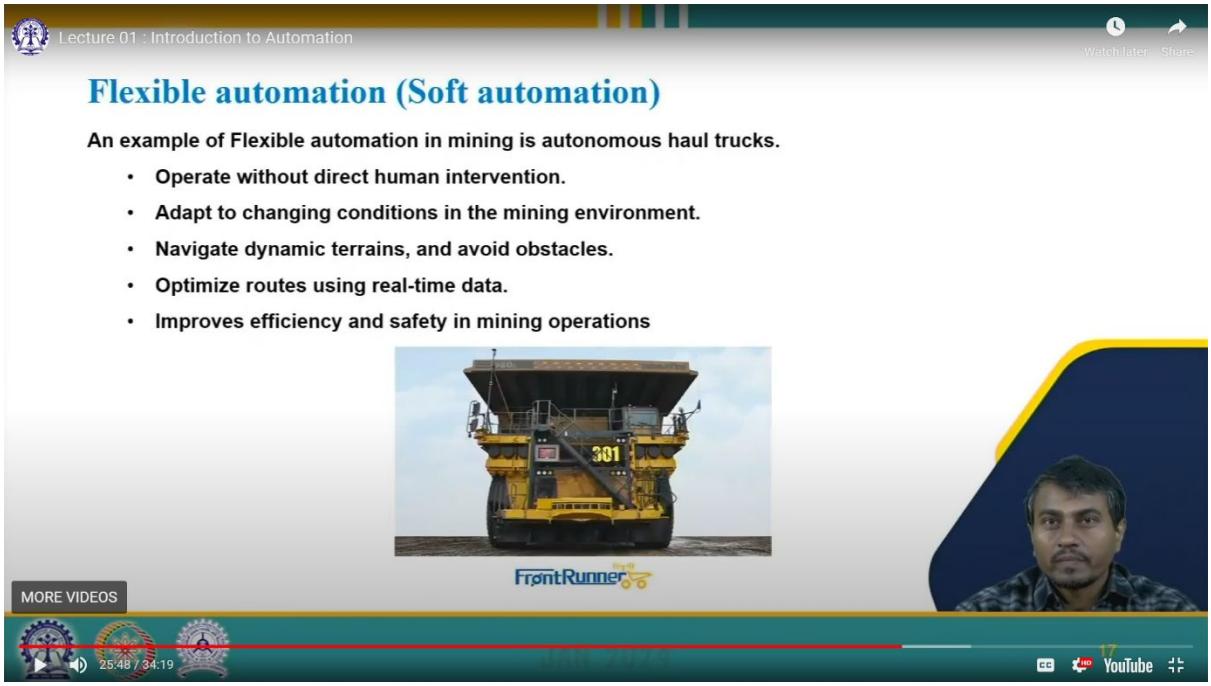


It operates with a very low unit cost, and it enables automated material handling capability. By that, it basically conveys the material very quickly from one location to another, and it can handle the material very efficiently with very little waste in the process. So, what are the disadvantages? A large initial investment is required for this system to be set up. It is inflexible in accommodating product variety, and the example of the conveyor weld system in the mines is basically a kind of example of a fixed automation system, and this network, the conveyor belt network, basically enables the mines to convey the material and transport it from one location to another seamlessly and smoothly without any loss in the production process or any wastage in the process. It basically works in a predefined way to determine what is to be conveyed at what speed based on the situation, and it also works on the configured fixed path. It is very efficient, and it can handle the large transportation of bulk materials. It basically reduces the deviation from the predefined path. It improves the overall mining material transport efficiency. So, this is one of the example of fixed automation.

The programmable automation it involves equipment designed to adapt to specific product changes, and when required, it can modify and adapt. Processing or assembly operations can be altered by modifying the control program, which means some degree of flexibility is added to the system. It is well suited for batch production, typically manufacturing products in medium lot sizes at a regular interval. The advantages are flexibility to deal with variations and changes in product, low unit cost for large batches. Then disadvantages are new product requires a long period of time and high unit costs related to a fixed automation system. The programmable automation example is a drilling machine with programmable control.

This drilling machine operates in mines with some program logic and a program-driven control. It can accommodate different kinds of drilling patterns as required at the mine site at different levels, and it can adjust parameters like depth, angle, and other parameters as well. So, it is very flexible to allow miners to adapt the equipment to different geological and ore body conditions, and even in a metal mine, the ore body's geologies differ at different levels and at different depths. So, this kind of drilling machine is very well adapted to execute the command for the required kind of drilling pattern efficiently.

The flexible automation, or as many people say it, soft automation. In flexible automation, the equipment is designed to manufacture a variety of products or parts, and very little time is spent changing from one product to another. Thus, a flexible manufacturing system can be used to manufacture various combinations of products according to any specified schedule.



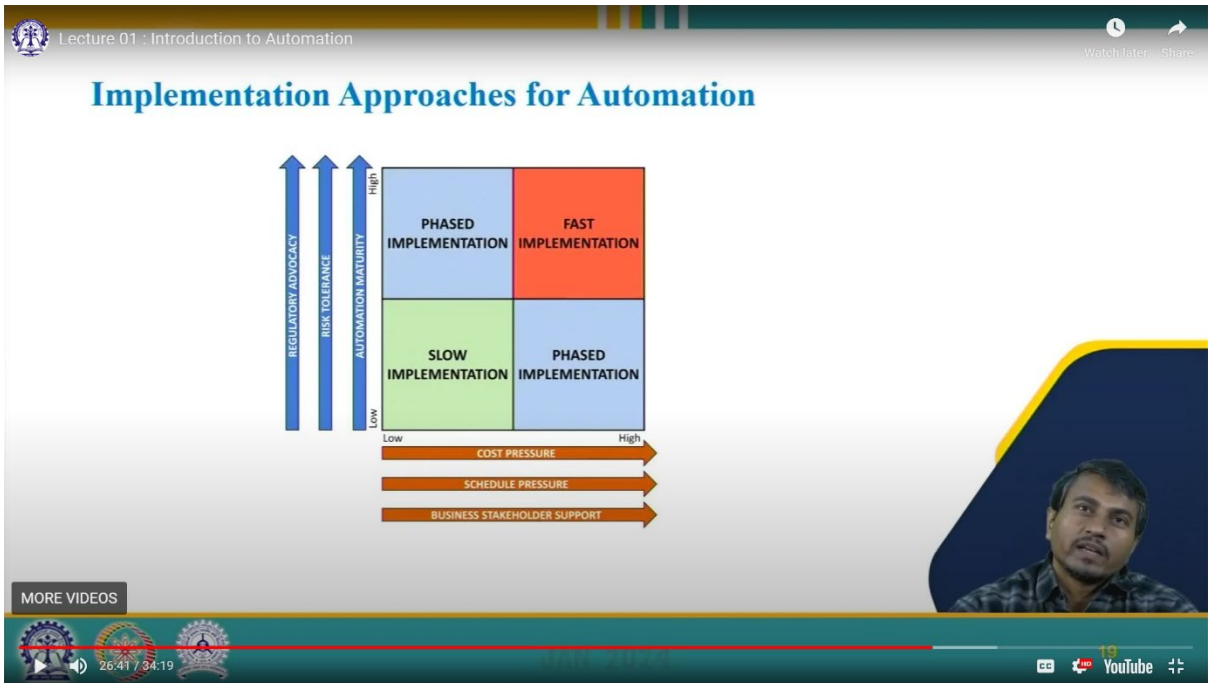
With a flexible automation system, it is possible to quickly incorporate changes in the product or introduce a new product line. The advantages are flexibility in dealing with product design variations and customized products. The disadvantages are the large initial investment and the high unit cost relative to fixed or programmable automation. The example of a flexible automation system. The mining autonomous haul truck is an example of a flexible automation system.

These haul trucks have operated in different mine sites for decades, and in many mines they've been offered very efficiently. There are some autonomous haul truck systems that operate without an operator in the cabin. So, it operates autonomously without any direct control from the human operator. It is very well adapted to changing mining conditions and mine environment conditions. It can navigate the dynamic terrain, and it has an obstacle avoidance system.

It can optimize the routes using real-time data. It has GPS facilities, and based on that, it designed the optimum route, which basically reduces fuel consumption. It improves efficiency and safety in the mine operation. There are some case studies showing that this kind of system has been operating at a mine site for the last 10 years without a single reportable accident. So, it enhances the safety of the mine operation. So, this is one example of an autonomous haul truck.

Let us discuss question number two. In the context of automation, what do logical programming commands refer to? human decision-making processes, mechanized equipment optimization, manual command response activities, and programmed instructions for an automated system. The right answer is the D program instruction for an automated system.

So let us see the implementation approach for automation. So, this particular figure outlines the implementation strategy of the automation for the mine site. This may change mine to mine based on different conditions, but this kind of representation is very well suited for the mining industry.



So, there are three principal blocks. One is the slow implementation, the second is the phase implementation, and the third is the fast implementation. This transition from slow implementation to phase implementation to the fast implementation, there are three stages, and these basically depend on the six identified parameters that we have identified. It is based on low- to high-level regulatory advocacy based on the regulations of different countries. The risk tolerance is how much risk we can perceive and take from low to high. The automation maturity model goes from low to high, as well as the cost pressure, the schedule pressure, and the business stakeholder support. So, these six parameters are basically influencing the implementation approach for the automation at the mine site.

So, what do we mean by the slow implementation strategy? It is basically associated with the low risk of the process. It involves a higher cost, and the implementation is extended over a long period of time because it requires a long time, and there are multiple checkpoints. That is basically the beauty of this system, starting with the concept trial and multiple releases that basically safeguard the success of this implementation strategy and allow the mine site to incorporate research and development. So, these are the features we have in the slow implementation strategy.

Then the phase implementation strategy involves medium risk associated with the approach, medium cost involved in the process, implementation completed in phase stages with two or three checkpoints included, and a mixture of mature and agile solutions.

Then the fast implementation strategy involves involving higher risk in the approach and lower cost in the process, and this new system aims to completely replace the old one and involves implementing mature commercial solutions. This is basically the strong point of the first implementation strategy. So, let us see the role of automation in the mining industry. So, the major role played by automation in the mining industry is its higher operational efficiency. When a part of the process or a part of the system is automated or an automation system is adopted, the system performs with very high operational efficiency, and that is basically the positive thing about automation in the mining industry.

The second positive thing about these automations in the mining industry is their cost reduction and unit operation as well as the running cost are reduced substantially, and that is why the companies operating in the mine are looking at implementing a higher and higher degree of automation in the system to reduce the production cost per unit. Another advantage of this automation is basically the improvement of safety and the improvement of safety notions. As I told you in the last slide, there are some mines operating with the autonomous haul truck system without a single reportable accident. That basically enhances the safety of the mines. So that basically enhances the notion of worker safety as well. So that is also why mining companies are looking at implementing a higher degree of automation.

Another important role played by automation in the mining industry is its adaptability to changing conditions. It is very adaptable to different changing environmental conditions and it has the facility to scale up the process as and when required based on necessity. That is also another big advantage of the automation system used in the mining industry.

So, these are the references: some books as well as some website references. So let us conclude in a few sentences. We have discussed in this lesson a comprehensive overview of automation, the basics, and the advantages and disadvantages of automation systems. We have illustrated with real-world examples what has been implemented in the mining industry.

And we have emphasized setting specific aims for different automation levels and their implementation. We have explored the various types of automation, and we have highlighted the versatility and adaptability of different automated systems. Thank you.