

Introduction to Industry 4.0 and Industrial Internet of Things
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Lecture – 07

Industry 4.0: Sustainability Assessment of Manufacturing Industry

In this lecture, we are going to go through some of the very important concepts for sustaining the Industry 4.0 revolution. So, basically what is required is not just the development, development in terms of introduction of new technologies, new types of services, and so on, but what is also required is to be able to sustain the newer systems, newer methodologies, newer techniques that are introduced. So, what is required essentially is to ensure that the sustainability of the newly introduced concepts, technologies, methods.

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The slide is titled "Introduction to Sustainable Industry" and contains the following content:

- Sustainability: means to continue at a fixed rate*
- Sustainable Industry provides**:
 - Energy efficiency
 - Conservation of resource
 - Low-waste production
- Example: Sustainable Manufacturing Industries

Source*: "Google Definition"
Source **: "Wikipedia"

The slide footer includes the IIT Kharagpur logo, NPTEL ONLINE CERTIFICATION COURSES logo, and the text "Industry 4.0 and Industrial Internet of Things".

The term sustainability means to continue at a fixed rate. A sustainable industry provides energy efficiency, conservation of resources, and low waste production. So, the last one particularly is very important. Energy efficiency is very important because there is a global concern about saving energy and thereby saving the environment. So, energy efficiency is definitely very important to reduce carbon footprint on the environment. But what is also very important is to ensure that the amount of resources that are used are all conserved and the amount of waste that is produced should be reduced significantly.

So, that will be a sustainable method of manufacturing, sustainable method of production or development. So, let us consider the context of sustainable manufacturing industries.

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The slide is titled "Sustainability in Industry 4.0" in a bold, dark red font. It contains three bullet points: the first states that Industry 4.0 proposes including characteristics of previous industry revolutions in a more sustainable way; the second identifies Industry 4.0 as the fourth industrial revolution, which is a comprehensive industrial revolution; the third notes that it incorporates globalization and emerging issues. The source is cited as Garbie, I., 2016. The footer includes the IIT Khharagpur logo, NPTEL Online Certification Courses logo, and the course title "Industry 4.0 and Industrial Internet of Things".

Sustainability in Industry 4.0

- Industry 4.0 proposes inclusion of the characteristics of the previous industry revolution in more sustainable way.
- Industry 4.0 or the fourth industrial revolution
 - A comprehensive industrial revolution
 - It incorporates globalization and emerging issues.

Source Garbie, I., 2016. Sustainability in manufacturing industries: Concepts, analyses and assessments for industry 4.0. Springer

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In the context of Industry 4.0, the proposition is to include the characteristics of previous industry revolution in a much more sustainable way. So, not only that we want to introduce newer things, we have to ensure that whatever has been existing from the previous industrial revolutions continue in the same form that it was before. To introduce newer techniques methods and continue the same things in a much more consistent, sustainable manner, so that it does not become a one-time kind affair.

Industry 4.0 or the fourth industrial revolution is a comprehensive industrial revolution, which takes into account this sustainability issue because it introduces newer concepts, newer technologies, but also to ensure that there is sustainability in the long run. Industry 4.0 incorporates globalization and emerging issues as well.

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Sustainability Assessment

- Manufacturing industry is considered as
 - Base of modern industrialized society
 - Corner stone of world economy
- Strong manufacturing base stimulates other aspects of the economy of any country
- Evaluation of S/SD or sustainability assessment of manufacturing industry in Industry 4.0 incorporates evaluation of relevant issues and performance metrics

Source Garbie, I., 2016. Sustainability in manufacturing industries: Concepts, analyses and assessments for industry 4.0. Springer

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So, when we talk about sustainability first, what is required is to consider some industry in our case, the manufacturing industry and assess the sustainability issues. First of all you have to assess, how much sustainable that is in particular industry, in terms of the processes, that are existing or the processes or the product, that is being manufactured.

A manufacturing industry is considered as a base of modern industrial society and is the cornerstone of the world economy. In order to estimate this sustainability and assess it, it is required to evaluate this term S over SD.

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Introduction to Globalization Issues

- Globalization is one of the drivers of sustainable industries
- Globalization issues affect the sustainability of any development/manufacturing
- These issues are one of the most fundamental requirements

Source Garbie, I., 2016. Sustainability in manufacturing industries: Concepts, analyses and assessments for industry 4.0. Springer

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The diagram illustrates the 'Elements of Globalization' as a central hub connected to five surrounding boxes: Energy Price, Information & Communication technology, Supply Chain Management, Emerging Market, and Business Models. Blue checkmarks are placed above each box, and a blue circle highlights the 'Supply Chain Management' box.

This S over SD considers different issues, different parameters, which are linked to the issue of globalization, are considered as one of the important drivers of sustainable industries, globalization issues affect the sustainability of any development or any manufacturing or any production system.

There are five different elements of globalization that are depicted. So, the first one is the business models, the next one is the energy price, information and communication technology adoption, supply chain management, which is a very important thing, particularly, in the manufacturing context, and the inclusion of emerging markets. So, these are some of the important issues or the cornerstones behind globalization.

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Supply Chain Management (SCM)

- Strategic function in manufacturing industry
 - Many different stages including supplier, production system, and customer
 - Sequencing the stages for the whole system
- The most important stage in SCM is selection for outsourcing components/parts or raw material
- SCM must have environmental concerns: Climate change, contamination and resource consumption

Source Garbie, I., 2016. Sustainability in manufacturing industries: Concepts, analyses and assessments for industry 4.0. Springer

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We will start with the supply chain management. So, supply chain management talks about consideration of the different stages through which the production system starting from the production till the supply goes through. In these manufacturing industries, there are different suppliers, the production system as a whole and different customer. Each of these together go through different stages. The sequencing of the stages for the whole system is what SCM basically talks about, supply chain management.

The most important stage in SCM is the selection for outsourcing components or parts of raw material. So, supply chain management has many additional environmental concerns as well. So, these are the issues that basically contribute to the overall sustainability. Issues of climate change, contamination – contamination of through the introduction of

different wastes to the environment, contamination resource consumption, how much resources are consumed, different human resources, non-human resources. It is required basically to optimize the resource consumption. These are the different supply chain management issues.

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The slide is titled "Information and Communication Technology (ICT)" in a bold, dark red font. Below the title, there are four main bullet points, each preceded by a right-pointing arrowhead. The first bullet point is "Main nervous system of any manufacturing industry", with a sub-bullet "In absence of ICT, no communication within the enterprise". The second bullet point is "Share information between customer, producer, and supplier". The third bullet point is "Examples of ICT", with sub-bullets for "Enterprise Resource Planning (ERP)", "Wireless Communication Technology", "Global Positioning System (GPS)", and "Radio Frequency Identification (RFID) system". A small text box on the right side of the slide cites the source: "Source Garbie, I., 2016. Sustainability in manufacturing industries: Concepts, analyses and assessments for industry 4.0. Springer". The slide footer contains the logos for IIT KHARAGPUR and NPTEL ONLINE CERTIFICATION COURSES, along with the text "Industry 4.0 and Industrial Internet of Things".

Information and Communication Technology (ICT)

- Main nervous system of any manufacturing industry
 - In absence of ICT, no communication within the enterprise
- Share information between customer, producer, and supplier
- Examples of ICT
 - Enterprise Resource Planning (ERP)
 - Wireless Communication Technology
 - Global Positioning System (GPS)
 - Radio Frequency Identification (RFID) system

Source Garbie, I., 2016. Sustainability in manufacturing industries: Concepts, analyses and assessments for industry 4.0. Springer

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The second thing is the introduction of ICT -- Information and Communication Technology. As we know that ICT overall is the backbone of most of the modern manufacturing industries today. So, if there is no information technology or communication technology there is no communication within the enterprise and across enterprises. This communication technology is required even to distribute we have distributed communication between different people, distributed communication between different people, distributed communication between the different labs of the same organization, across the different locations, or different campuses of the same organization or even it is also required for having proper communication between the different partners of a particular organization, who contribute to the manufacturing of the products or the services.

So, overall ICT is very important and we are talking about ICT, as a whole, in the bigger context, not just the introduction of computers and communication technologies, but also different other things that we talk about in the industry 4.0 context like sensors, actuators

and the connectivity between them and the different other things. So, it is very required to have communication between the customers, the producers, and the suppliers.

They need to be able to share the information between themselves and with the help of these computers, computing technology, and communication technology. It is required to enable Enterprise Resource Planning, ERP-based systems, then wireless communication technology, which is sort of like why wireless is; wireless is something that makes portability a reality, portability of different equipment, then mobility across different parts of the company, that are being used in the manufacturing process.

Wireless communication technology is very important thing, a third one is the GPS and the fourth one is the radio frequency identification system. With the help of RFIDs we have gone through in the introduction. You need to tag the different parts in a production system or different equipments that need to be tracked or different items or elements or agents that need to be tracked and that basically helps to have a complete and efficient monitoring, of the mobility and portability of these different parts and constituents of the whole production system.

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Energy Prices

Energy → Created → Transferred → Transformed → Consumed

- For enterprise, less energy consumption brings significant economic advantages
- Main issues: Energy supply at reasonable price
- Increase in energy price affects sustainability
- Reduction in energy consumption form non-renewable sources and increase in energy consumption form renewable will have significant positive effect in sustainability.

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The second, the third one is the energy prices. If you are talking about large-scale enterprises there is a consideration of the energy consumption as a whole. So, larger enterprise means larger energy consumption, but that is sustainable and beneficial for the environment more energy consumption basically leads to bigger impact on the

environment and which is not very desirable. So, for enterprises it is very important to ensure that there is reduced energy consumption, through the introduction of these newer technologies.

Energy has to be first created, then transferred, transformed into a different form, and then gets consumed. For instance, if you are talking about electricity; electricity gets generated in the generating power plant, then it is transferred through different grids and transmission lines it is transferred from one location from the generation station to elsewhere to this station to the electricity substations and different other points. So, one form of energy is transformed to another form of energy.

In our example, electricity is transformed, let us say that if we are talking about lighting lamps and bulbs in the warehouses, then electricity is getting transformed into light energy.

So, what is required is whatever be the cycle, however, the energy consumption and this transformation takes place, whatever be it what is important is to ensure that there is reduced energy consumption overall and that basically we will also have an impact on the economy and the environment as I said earlier.

So, it is required to have energy supply also at reasonable price. The increase in the price of energy is not good, because if you are increasing the price of energy then that will affect the overall price of the product or the service that is being created and that is not going to be sustainable over all from another perspective.

Increasing energy price effects sustainability and we have seen that different ways it is affecting, it is not sustainability has different facets. So, what is also not desirable is to increase the cost of the product or the service that is being generated or being developed and also it is also the cost of energy, if it increases, it is not very useful from the environment point of view as well.

The reduction in energy consumption is also required and energy consumption, energy production can be done not only from the non-renewable sources of energy, but also from the renewable ones like solar, wind.

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Emerging Markets

Dictatorship Period → Emerging Market → Free market and Free Economy

- Markets: able to meet the standards of newly developed, innovative product
- Issue: difficult to identify all of the world's emerging markets
- Emerging markets are expected to be found in developing countries

Source Garbie, I., 2016. Sustainability in manufacturing industries: Concepts, analyses and assessments for

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The next one the next globalization issue is the emerging markets and its consideration. So, markets are able to meet the standards of newly developed innovative products. If you think about the emerging markets, whenever a particular product is being introduced. So, it goes through typically a phase of dictatorship; dictatorship means like it is a monopoly kind of thing. The company which introduced the product basically has monopoly. And, then gradually it has to transform towards the free market and free economy where it will be made accessible to the greater part of the world. So, the consideration of emerging markets is very important, particularly for developing countries.

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Business Models

- **Mass Customization:** incorporates the knowledge including international and local cultures
- Business Models \cong Mass Customization
- Business Model:
 - Strategic approach
 - Maximizing economic profits for an enterprises
 - Taking into account competitive benefits, promoting product value

Source Garbie, I., 2016. Sustainability in manufacturing industries: Concepts, analyses and assessments for industry 4.0. Springer

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Business models: we need to think about business models which will be helpful for the greater society. So, it is required to have mass customization, which will incorporate the knowledge including the consideration of international culture across different countries, different societies, and so on and also the local culture where things have been introduced and produced first. So, business models basically have direct linkage with the mass customization. So, what is required is from the globalization point of view the product that is manufactured should not only cater to the needs of the local community, but also to the international community.

So, business models are to be developed which should take the strategic approach by considering the bigger issues the strategic issues; that means, high level issues for a particular organization business and the greater issues overall. It is also required to have the business model, which will maximize the economic profits for an enterprise by taking into account the competitive benefits and promoting the product value.

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Introduction to Emerging Issues

- **Emerging Issues:** changes in manufacturing industries based on the world-wide aggressive competition
- Major aspects in case of sustainable development in designing manufacturing industry.

Source: Garbie, I.H., 2013. DFSME: Design for sustainable manufacturing industries (an economic viewpoint). International Journal of Production Research, 51(2), pp.479-503

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Emerging issues are also there like the globalization issues which also contribute to the sustainability factor. There are many of these emerging issues which contribute to such sustainability. One is technology, growth of population, government regulation, consumption of natural resources, and consideration of crisis, recession, and depression. These are the five different contributors to the sustainability factor from an emerging issue viewpoint.

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Technology

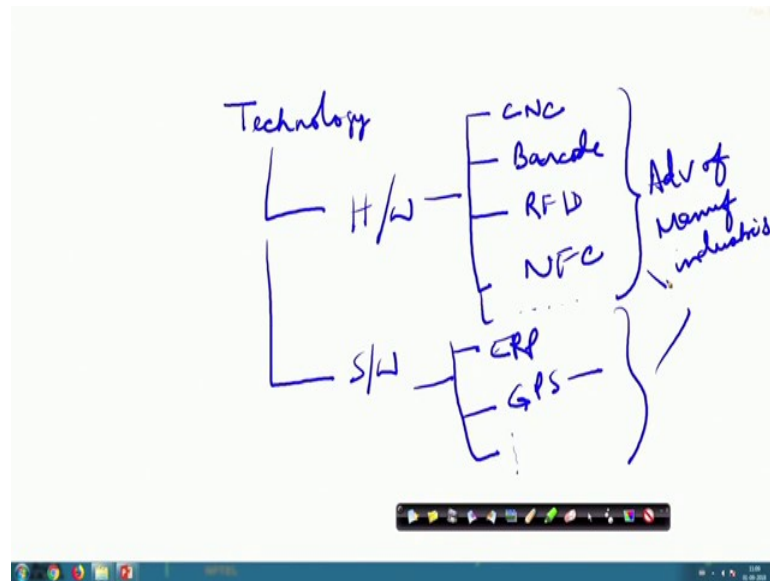
- One of the important issues in sustainability.
- Advancement in technology facilitates manufacturing with
 - High quality products
 - Low-cost products
 - Reduces manufacturing time
- Role of technology advancement in global market
 - Converting from traditional system to automated system
 - Introducing more agility and flexibility

Source: Garbie, I.H., 2013. DFSME: Design for sustainable manufacturing industries (an economic viewpoint). International Journal of Production Research, 51(2), pp.479-503

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So, the first one is the technology. Technology considerations are very important. So, if we are talking about technology, let us say, technology broadly can be classified as hardware and software. Within hardware we have different types of technologies that are used commonly technologies such as computer. When we are talking about technology, we have the hardware technology and the software technologies.

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Within hardware we have different technologies in the manufacturing industries such as the computer numeric control machines, we have the barcodes, barcode base technology barcode, we have different technologies such as RFID, NFC, all of these are used quite widely and these are the technologies that have also contributed to the overall advancement of the manufacturing industries.

In terms of software, we have technologies such as ERP, the GPS-based software technologies. GPS itself is hardware, but the GPS-based software technologies and like this there are many other software technologies that have emerged and contributed to the advancement of manufacturing industries.

These are very important and what we need to ensure is that all these different newer technologies should be included in order to have better sustainability. Advancement in technology facilitates manufacturing with higher quality products, lower cost products and products which are manufactured in reduced time. So, these are very important. So, the quality of the product that is developed should be improved with the introduction of

these newer technologies, then the cost of the production should be less, so that the overall product comes to the market at a reduced price and comes faster to the market, the production lifecycle should be reduced. So, there is reduced manufacturing time.

The role of technology advancement in the global market is about converting from the traditional system of manufacturing to the automated system. Technology can help in having greater agility, faster development, and flexible, changeable, maintainable products.

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Government Regulation

- Necessary to protect public and private sector
- It consists of Enterprise Requirements for achieving government purpose such as demands for better services and low cost goods
- Government Regulation
 - Prevents the manufacturing industry from unfair competition
 - Enact laws to provide suitable environments for the employees

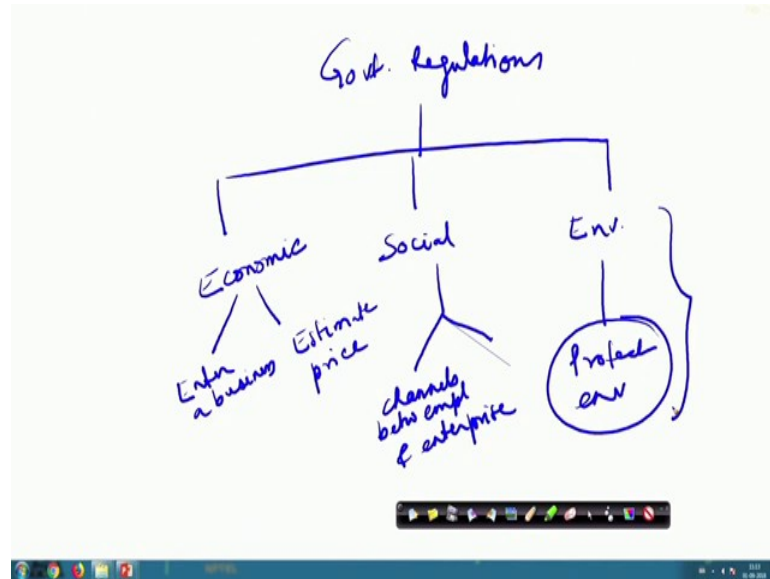
Source: Garbie, I.H., 2013. DFSME: Design for sustainable manufacturing industries (an economic viewpoint). International Journal of Production Research, 51(2), pp.479-503

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In terms of government regulation, it is also required to be able to protect the public and the private sectors. It is required to protect the enterprises. So, for protecting the enterprises, different enterprises have their own different requirements, and those will have to be taken into consideration while arriving at different regulations and rules, which can help these organizations these enterprises to offer better services and low cost goods.

So, government regulation will help in basically avoiding unfair competition and also to promote sustainable environment considered development for everyone including the employees of the organization or the industry. Therefore, government regulations are very important.

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We are talking about government regulations, there are different considerations or the different types of regulations. Some of these regulations are basically having direct impact on the economic issues, some of them have considerations of the social issues, and some the environmental issues.

Economic issues talk about some of these regulations, when a business will enter, when an institution basically enters a business. Price estimations, there are government regulations typically, which will help in this price estimation. Then social issues, which will essentially help in opening channels between channels of communication, maybe between employees and the enterprise or the management and environmental issues will concern the protection of the environment.

Environmental issues are very important in the manufacturing process. Government regulations should be there to protect the environment, because if there is some kind of production process, which produces lot of waste and in turn harms the environment the water, the land, are full of different industrial wastes. There are government regulations, which talk about how to reduce these wastes and also the wastes that are produced will have to be handled properly.

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Government Regulation

- Employment
- Advertising
- Labor
- Environmental
- Safety And Health
- Privacy

Source: Garbie, I.H., 2013. DFSME: Design for sustainable manufacturing industries (an economic viewpoint). International Journal of Production Research, 51(2), pp.479-503

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There are government regulations concerning employment, advertisement, labor – labor laws are there, environmental regulations are there, regulations concerning the safety of the workers, safety of everyone, health regulations are there, and privacy protection of individuals.

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Government Regulation

- Employment & Labor rules represents laws
 - Concerning wages/salaries
 - Benefits (e.g. retirement plans)
 - Compliance with health and safety issue
 - Proper working condition
 - Expatriate employee issue (e.g. Visas)
 - Equal opportunity in employment (including promotion)
 - Provisioning of Authority or High ranking position


Source: Garbie, I.H., 2013. DFSME: Design for sustainable manufacturing industries (an economic viewpoint). International Journal of Production Research, 51(2), pp.479-503

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Basically, the employment and labor rules represent laws concerning wages and salaries, things such as benefits to the workers in terms of retirement plans, compliance with health and safety issues, proper working conditions, issues of expatriate employees such

as visas and so on. Equal opportunity in employment in terms of promotion and consideration of all workers from different ethnicity in the equal platform, provisioning of authority or higher ranking position; these are different types of classes of regulations that are typically there in any industry.

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Government Regulation

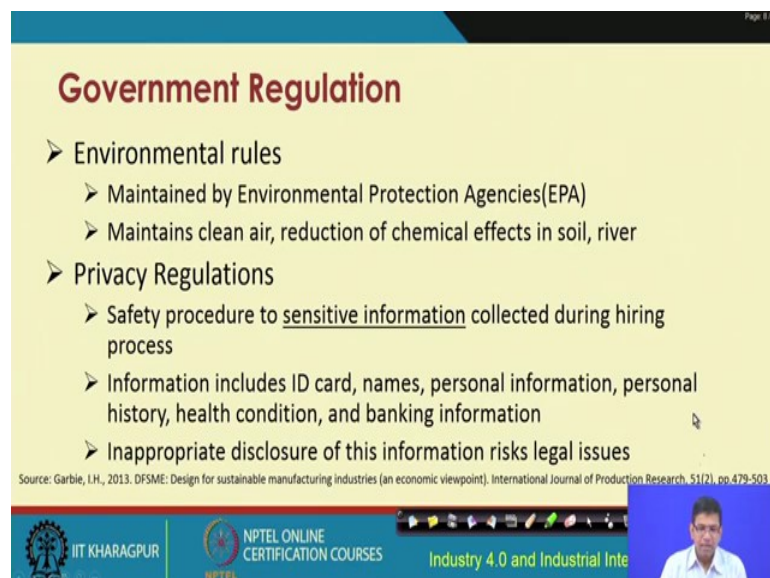
- Advertisement Regulation focuses on
 - Protection of customers
 - Firm honesty about a product
 - Information regulation publicly
 - Transparency on distribution and manufacturing process

Source: Garbie, I.H., 2013. DFSME: Design for sustainable manufacturing industries (an economic viewpoint). International Journal of Production Research, 51(2), pp.479-503

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In terms of advertisement – advertisement regulations protect customers, firm honesty about a product, information regulation publicly, then transparency on distribution and manufacturing process.

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Government Regulation

- Environmental rules
 - Maintained by Environmental Protection Agencies(EPA)
 - Maintains clean air, reduction of chemical effects in soil, river
- Privacy Regulations
 - Safety procedure to sensitive information collected during hiring process
 - Information includes ID card, names, personal information, personal history, health condition, and banking information
 - Inappropriate disclosure of this information risks legal issues

Source: Garbie, I.H., 2013. DFSME: Design for sustainable manufacturing industries (an economic viewpoint). International Journal of Production Research, 51(2), pp.479-503

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Environmental regulations or rules meant, are maintained by different acts, different agencies such as the environmental protection agency. Maintaining clean air, reduction of chemical effects in soil, river water of different water bodies, then privacy regulations concerned with the information of safety and security, particularly the sensitive information, that is collected about the different employees and the other stakeholders by a particular enterprise.

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The slide is titled "Government Regulation" in a bold, dark red font. Below the title, there are three bullet points, each preceded by a right-pointing arrowhead. The first bullet point is "Safety and Health regulations", which is further broken down into three sub-bullets: "Ensures healthy working environment", "Enterprise must distribute information on maintaining a healthy workplace to avoid dangerous events", and "Need to update safety regulation information due to yearly changes in Governments". At the bottom of the slide, there is a small line of text: "Source: Garbie, I.H., 2013. DFSME: Design for sustainable manufacturing industries (an economic viewpoint). International Journal of Production Research, 51(2), pp.479-503". The slide is part of a presentation, as indicated by the navigation icons and the speaker's video feed at the bottom.

Government Regulation

- Safety and Health regulations
 - Ensures healthy working environment
 - Enterprise must distribute information on maintaining a healthy workplace to avoid dangerous events
 - Need to update safety regulation information due to yearly changes in Governments

Source: Garbie, I.H., 2013. DFSME: Design for sustainable manufacturing industries (an economic viewpoint). International Journal of Production Research, 51(2), pp.479-503

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Safety and health regulations will concern the health issues providing healthy and working environment, overall safety, and workplace safety. These are the different types of government regulations.

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Population Growth

- Monitoring population growth is important for manufacturing industry
- It affects
 - Industry growth
 - Food supplies
 - Fertility
 - Sociology
 - Economics
 - Politics
 - Industry Location
 - Use of Available lands

Source: Garble, I.H., 2013. DFSME: Design for sustainable manufacturing industries (an economic viewpoint). International Journal of Production Research, 51(2), pp.479-503

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Population growth: monitoring population growth is important for manufacturing industry. It affects the industry growth, food supplies, fertility, sociology, economics politics, industry locations, and use of available lands.

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Population Growth

- Three different category of countries based on population growth
 - Developed
 - Emerging
 - Developing
- Population growth of countries (developing and disadvantaged) > Population growth of countries (developed and advantaged)

Source: Garble, I.H., 2013. DFSME: Design for sustainable manufacturing industries (an economic viewpoint). International Journal of Production Research, 51(2), pp.479-503

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There are three different types of countries based on the population growth, developed countries then emerging countries, and developing economies.

So, the population growth of countries developing and disadvantage is typically greater than the population growth of the developed and advantaged countries.

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Population Growth

- Based on the United Nations (UN) report, population growth from 1950 to 2050
 - Reduced between 32 to 13 % in developed countries
 - Increased between 8 to 20 % in emerging and developing countries
- Economic view on population growth
 - Pessimistic
 - Optimistic

Source: Garbie, I.H., 2013. DFSME: Design for sustainable manufacturing industries (an economic viewpoint). International Journal of Production Research, 51(7), pp.479-503

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Based on the United Nations report the population growth is from 1950 to 2050, reduced between 32 percent to 13 percent in developed countries, increased between 8 to 20 percent in emerging and developing countries.

So, economic view on the population growth can be of two types: pessimistic view and optimistic view.

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Population Growth

- Pessimistic view of population growth
 - Hinders the economic growth
 - Consumes most of the economic investments in safety, need for schools, hospitals, universities
- Optimistic view of population growth
 - Dissemination of knowledge and information
 - Increases globalization issue such as trade and commerce

Source: Garbie, I.H., 2013. DFSME: Design for sustainable manufacturing industries (an economic viewpoint). International Journal of Production Research, 51(7), pp.479-503

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The pessimistic view of population growth basically effects the economic growth and the optimistic view basically on the contrary talks about increase of the globalization issues

such as trade and commerce due to the growth of population. So, pessimistic view basically effects, hinders the overall economic growth, on the other hand, and the optimistic view on the other hand, basically, increases the globalization issues such as trade and commerce.

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Population Growth

- Despite the advantages of population growth, if there is no plan to control it, it would turn out to be disaster for any developing country
- Human capital and respective skills are one of the most important aspects of manufacturing industries.
- Example: A location of manufacturing industry requires politics and skill level provided by the local population

Source: Garbie, I.H., 2013. DFSME: Design for sustainable manufacturing industries (an economic viewpoint). International Journal of Production Research, 51(2), pp.479-503

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The slide features a video inset of a man in a white shirt and blue background in the bottom right corner. The footer includes logos for IIT Khharagpur and NPTEL, along with the course title 'Industry 4.0 and Industrial Inte'.

Population growth is a very important consideration in terms of sustainability. So, basically, if the growth is not conformant with the overall growth of the economy then that will become a disaster for that particular economy.

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Economic Crisis/Recession and Depression

- Economic crisis takes place over a duration not more than a few months
- Recession: exponential decline in economic activity
 - Commence after economic crisis arrives at the activity peak
 - Completion after economy arrives at its trough
 - Duration: more than few months but not more than two years
 - Observable on gross domestic product (GDP), actual income, employment, industrial production, and wholesale-retail sales

Source: Garbie, I.H., 2013. DFSME: Design for sustainable manufacturing industries (an economic viewpoint). International Journal of Production Research, 51(2), pp.479-503

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Then the last one is basically the consideration of economic crisis recession and depression. So, economic crisis basically takes place over a duration not more than a few months, so that is the crisis. Recession on the other hand, talks about the decline in the economic activity recession; that means slowdown of the economy, exponential decline happens.

When the economic activities again increase, then there will be commencement or the rise of the economy. So, basically from the recession, then there will be some kind of acceleration in terms of the growth.

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The slide is titled "Economic Crisis/Recession and Depression" in a dark red font. It features a list of characteristics for depression on the left and a diagram on the right. The diagram consists of three concentric circles. The outermost circle is labeled "Economic Crisis", the middle circle is labeled "Recession", and the innermost circle is labeled "Depression". A blue bracket on the left side of the diagram groups the three circles together. Below the diagram, there is a source citation: "Source: Garbie, I.H., 2013. DFSME: Design for sustainable manufacturing industries (an economic viewpoint). International Journal of Production Research, 51(2), pp.479-503". At the bottom of the slide, there is a footer with the IIT Kharagpur logo, "NPTEL ONLINE CERTIFICATION COURSES", and "Industry 4.0 and Industrial Internet of Things".

Economic Crisis/Recession and Depression

- Depression: extremity of recession
 - Observed by exponential unemployment increase
 - Reduction in available credit
 - Significant reduction in trade and commerce
 - Huge number of bankruptcies
 - Volatility in currency value
 - Duration: more than two years

Source: Garbie, I.H., 2013. DFSME: Design for sustainable manufacturing industries (an economic viewpoint). International Journal of Production Research, 51(2), pp.479-503

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Depression is the extremity of recession, which is observed by exponential unemployment increase, reduction in available credit, significant reduction in trade and commerce and huge number of bankruptcies might also consequently happen and there is volatility in currency value and the duration is more than two years and this is basically the extreme case of recession.

So, we start with the economic crisis then that is that will take place for few months, then recession, a rapid slowdown of the economy and thereafter we have the depression. This depression basically is the extreme case of recession, where all of these things would happen.

So, let us now look at the view of each of these. So, basically if we talk about crisis so, let us say that this is the economic crisis. Then comes the recession phase, recession, and the next one is basically the depression. So, conceptually it would look like this.

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Economic Crisis/Recession and Depression

- An economic crisis and recession → observing reduction in prices of few major commodities
- Increasing productivity and reduction in cost is one of the solution
- Applying same solution, it takes more time to recover form depression
- Example of avoiding crisis → The main economy of manufacturing location should not be based only one resources

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If there is economic crisis on recession, then there will be reduction in prices of different major commodities and what is important is to increase the productivity and reduce the overall cost that becomes the solution in such a case. So, it is very important to ensure and avoid this kind of crisis and recession as much as possible.

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Consumption of Natural Resources

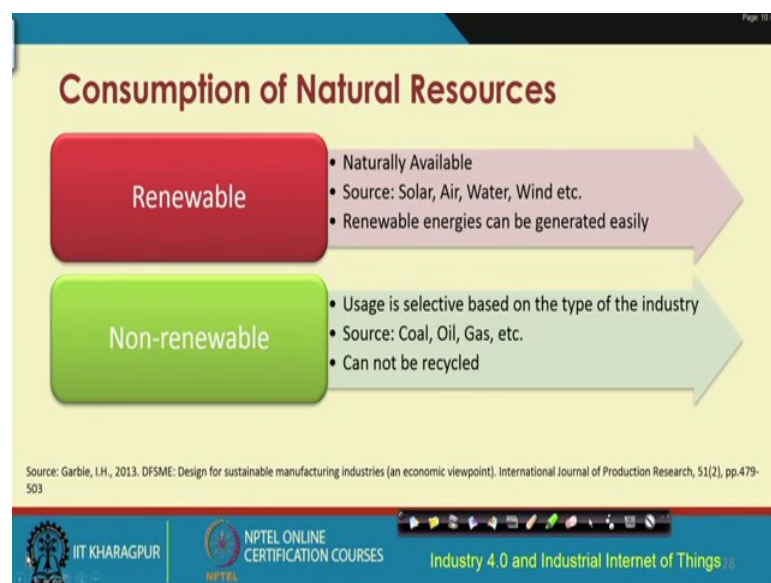
- One of the biggest issues in contrast of economically sustainable development
- As natural resources are main source of revenue in developing countries, it is one of the major source of social conflicts
 - Mining
 - Oil and Gas extraction
 - Demography shifts
 - Difficult economic situations
 - Negative societal behavior
 - Politics
 - Technology

Source: Garbie, L.H., 2013. DFSME: Design for sustainable manufacturing industries (an economic viewpoint). International Journal of Production Research, 51(2), pp.479-503

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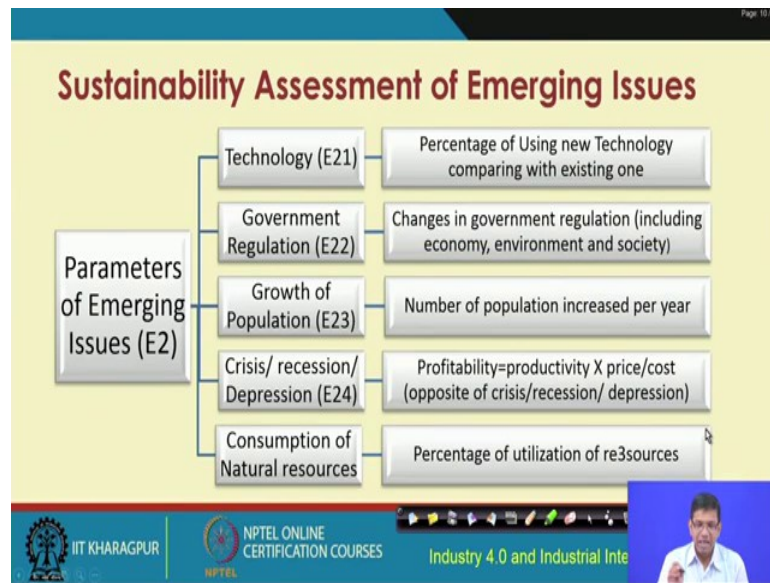
In terms of consumption of natural resources this is one of the very biggest concerns, because that has impact on the sustainable development which is environment friendly. So, this is one of the biggest issues, in contrast, to economically sustainable development as natural resources are the main source of revenue in developing countries. It is one of the major sources of social conflicts. So, basically concerns about mining, extraction of oil and gas, demographic shifts, societal behavior, politics, technology, economic situations, difficult economic situations all of these are major contributors in terms of the consideration of natural resources.

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So, natural resources can be of two types, the renewable ones and the non-renewable ones. Coal, oil, gas, are the non-renewable examples of non-renewable sources of natural in energy and then solar, water, wind, are the examples of renewable sources of energy.

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So, all of these things we have discussed because if you recall that we started with that formula S over SD .

So, for computing this S over SD , which is basically the sustainability factor we have gone through all of these different issues. Issues of technology, government regulation, growth of population, crisis, recession, depression, and consumption of natural resources, and they are corresponding things also we have understood that how these, what are these different issues and what are what is important for consideration of these different issues.

So, while we have understood all of these things we now need to basically look at this particular S over SD formula.

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Sustainability Assessment of Emerging Issues

- Sustainability/Sustainable development
 - $S/SD_{E2} = f(E21, E22, E23, E24, E25)$
 - $S/SD_{E2} = (I_{E21}^{Y_{E21}} \cdot I_{E22}^{Y_{E22}} \cdot I_{E23}^{Y_{E23}} \cdot I_{E24}^{Y_{E24}} \cdot I_{E25}^{Y_{E25}})$
 - Where $I_{E2i} = S_{E2i}/E2i$,
 - S_{E2i} = The change towards the sustainability
 - Y_{E2i} = Exponent of the change towards sustainability (S_{E2i}) of $E2i$

Handwritten notes: A bracket groups the first two formulas, pointing to a circle containing 'S' over 'SD'. A vertical line with an arrow points down from this circle to the word 'Sustainable' written in cursive.

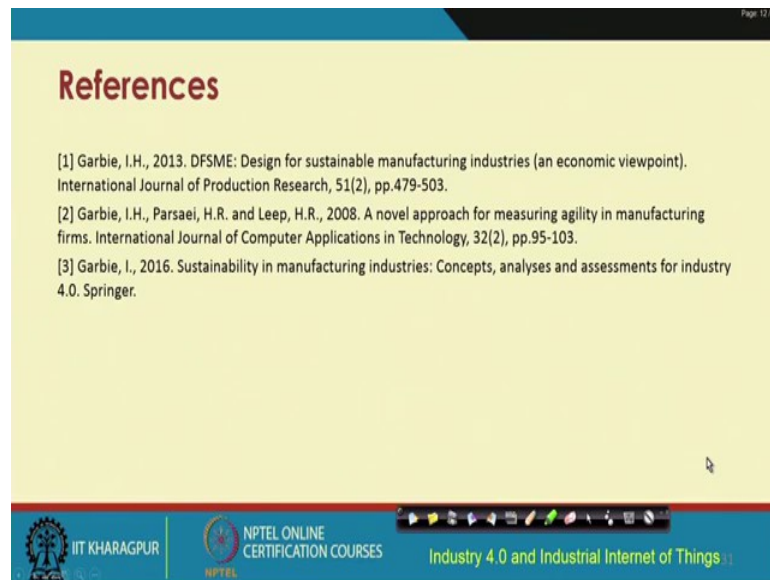
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S over SD is basically sustainability over sustainable development and for this S over SD has all of it is a function of all these parameters, right. So, all these parameters that we have seen in the previous slide and so, this basically can be again rewritten as a function of all these is and where I equal to S over E and S is basically the change towards the sustainability and Y is basically the exponent of the change towards sustainability S of E.

So, this is basically the overall formula that we wanted to arrive at to start with we have looked at this S over SD formula and these are these different contributors to the different parameters that contribute to this computation of S over SD and this factor basically talks about whether a particular effort is sustainable or not.

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References

- [1] Garbie, I.H., 2013. DFSME: Design for sustainable manufacturing industries (an economic viewpoint). International Journal of Production Research, 51(2), pp.479-503.
- [2] Garbie, I.H., Parsaei, H.R. and Leep, H.R., 2008. A novel approach for measuring agility in manufacturing firms. International Journal of Computer Applications in Technology, 32(2), pp.95-103.
- [3] Garbie, I., 2016. Sustainability in manufacturing industries: Concepts, analyses and assessments for industry 4.0. Springer.

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So, finally, these are some of these references that you could go through in order to understand these concepts, in greater detail.

Thank you.