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BEYOND SMART SUSTAINABLE MANUFACTURING - BSSM
ONLINE TRAINING
KRISHNAJI PAWAR - CEO & FOUNDER



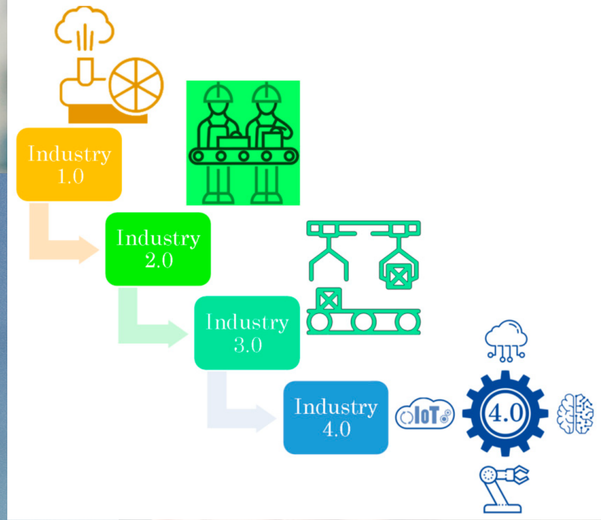
06. SUSTAINABLE-SMART MANUFACTURING APPROACH: INDUSTRY 4.0 AND SUSTAINABILITY ASPECTS

SECTION - SMART SUSTAINABLE MANUFACTURING

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Overview

- Industry 4.0, the fourth industrial revolution, is projected to change society and industry. Figure 7 shows four key industrial changes throughout history.
- This starts with the utilization of steam power and mechanical mechanisms in production in 1784, which represents the first industrial revolution. In 1870, Henry Ford popularized mass manufacturing and assembly lines, launching the second industrial revolution. In 1969, PLCs and robotics were introduced in various manufacturing stages to automate and digitize the third industrial revolution.
- Currently, and since 2001, the industry has been experiencing the fourth industrial revolution. This revolution is based on emergent technologies such as big data analytics and the Internet of Things (IoT), enabling the development of an intelligent network that permeates all production stages and completely changes the relationship between companies and society.



> While our society is promoting exponential technological growth, human activities and many resources (e.g., energy, materials, and water) are increasingly resulting in climate change. The modern industry is facing two significant changes that will affect all perspectives of consumption and production in the 21st century: the fourth industrial revolution and the implementation of the sustainable manufacturing approach.

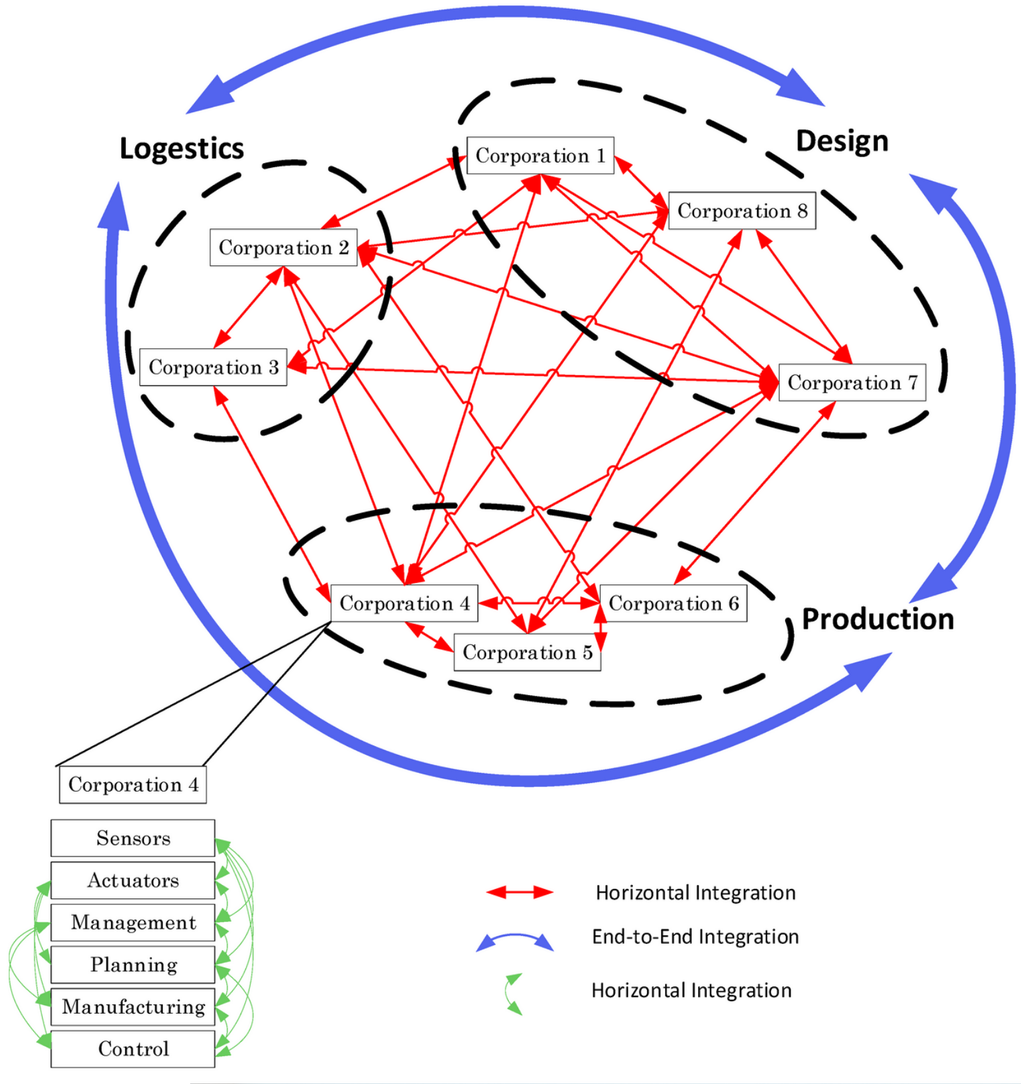


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Interoperability in factory 4.0

- This new holistic approach to manufacturing links equipment to the network and facilitates safe, real-time communication between divisions, corporations, and consumers.
- To enable flexible manufacturing, devices and machines may prioritize production orders, job optimization, and maintenance.
- Factory 4.0 networks machines and processes to gather, share, and analyze data to forecast future behaviors and find effective solutions to issues.
- This network lets robots interact and make small choices without human involvement.
- Figure 8 shows three types of interoperability: vertical, horizontal, and end-to-end [28].
- Horizontal integration connects businesses to share financial and material information.
- This ensures fresh, updated business models.
- Vertical integration links corporate subsystems such sensors, actuator control, management, production, and planning.
- Allowing smart devices to self-organize will increase production flexibility.
- Finally, end-to-end integration links consumer demands, product design, maintenance, and recycling across the product life cycle.

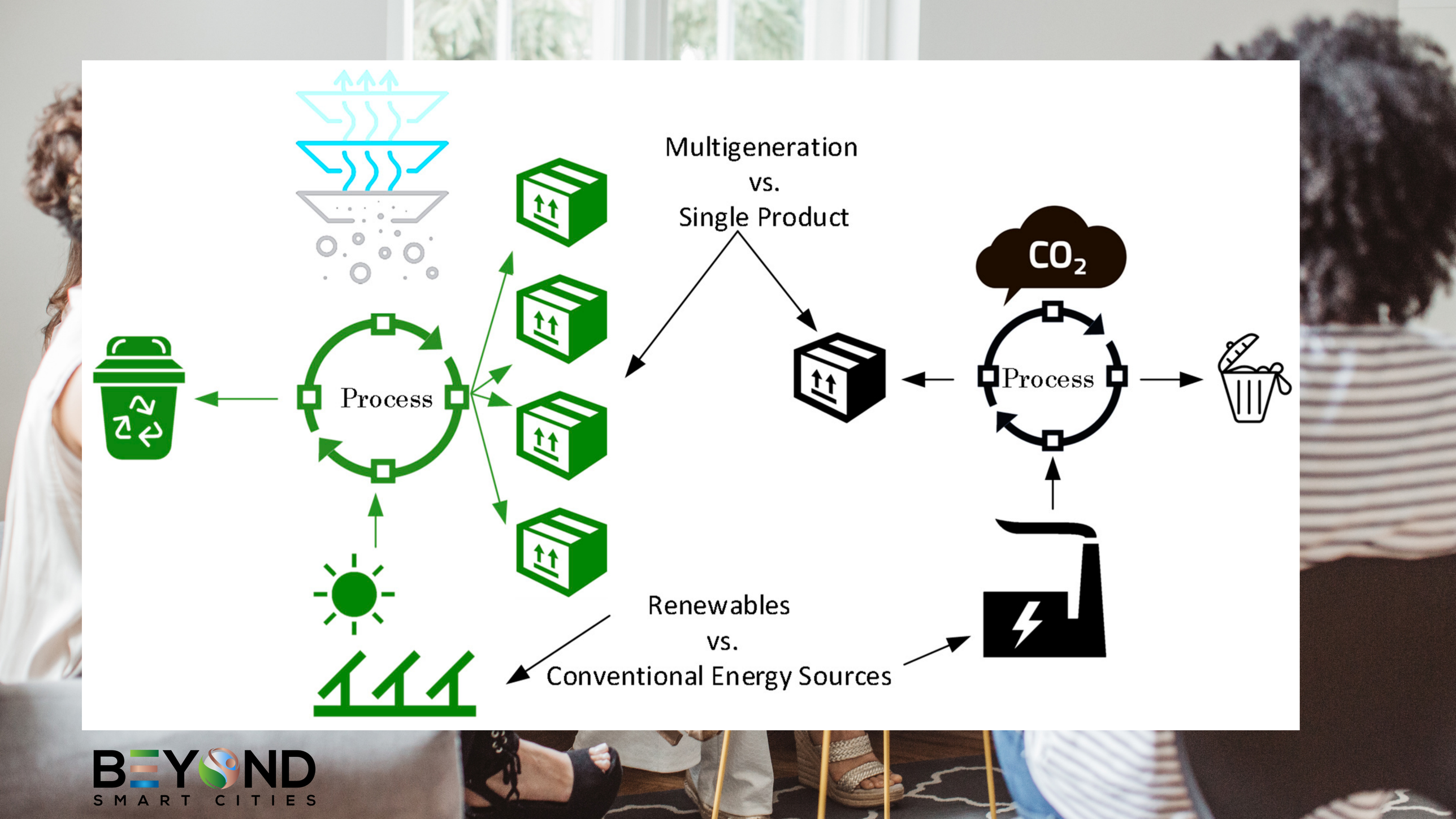
This integration allows investigate and anticipate the interaction impact between various processes, allowing product customisation at different life cycle phases.



PROGRESS TOWARD SUSTAINABILITY THROUGH THE 3S ROUTE

- Industry 4.0 is emerging at a time when sustainability and sustainable development are at their peak, yet much study has been technical.
- Few of these studies explore how this transition affects economic, ecological, and social outcomes , which are the foundations of sustainable production.
- Industry 4.0 may improve sustainable production by promoting the Source System Service (3S) pathway .
- The first S in this concept is using environmentally friendly, abundant, and locally available sources like renewables to achieve sustainability goals.
- The second S optimizes system resource consumption (renewable or not).
- Increase system efficiency, multigeneration, or waste recovery.
- Finally, the final S focuses on recycling and limiting waste and irreversibility.
- Figure 9 depicts the effect and possible benefit of applying the 3S approach on a specific process.
- Industry 4.0 contributes primarily to the system phase.
- Factory 4.0 uses new manufacturing technologies to improve system efficiency.
- System efficiency improvements reduce waste and losses without slowing output.
- Thus, it will also aid in minimizing resource usage.
- The three sustainability pillars—economical, environmental, and social—require fewer losses, waste, and resource depletion.
- Factory 4.0 affects these three pillars in the next section.

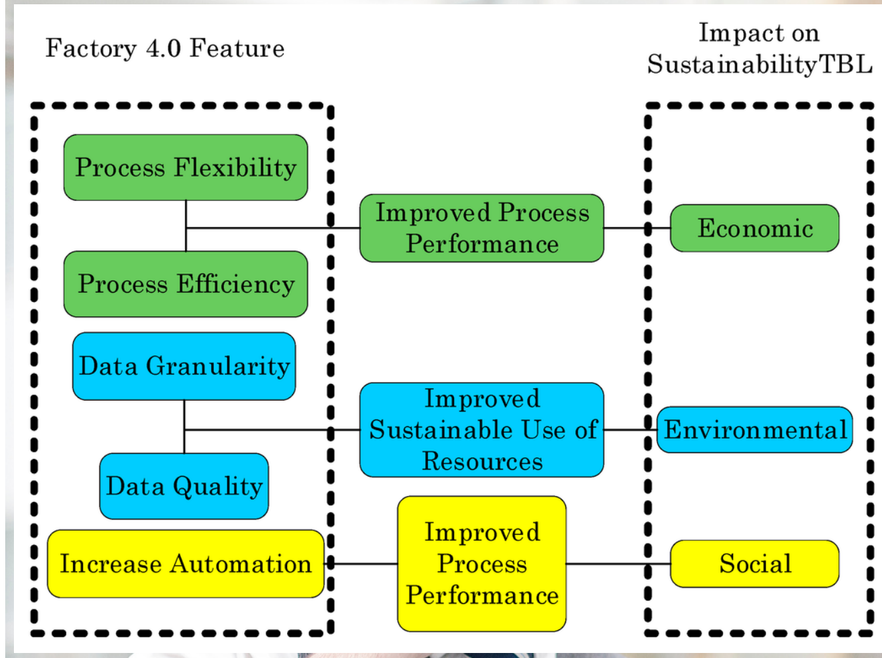
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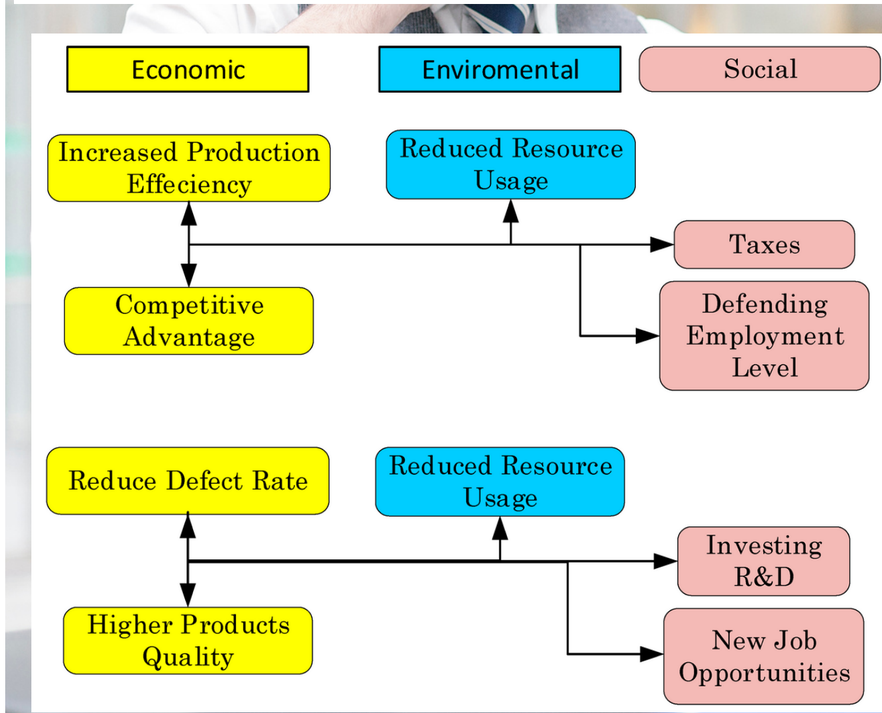


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Interoperability in factory 4.0

- Considering Industry 4.0 is shaping the future of industry and manufacturing, it is essential to understand how it can contribute to sustainable development. In the past, the term sustainable development (i.e., the traditional concept) had a mainly environmentally oriented definition; however, nowadays, sustainable development effectively includes three dimensions: environmental, social, and economic.
- Thus, achieving sustainable and smart development is required in order to build a society with the appropriate equilibrium that is shaped between the two perspectives (i.e., sustainability and industry 4.0). In a previous work, an attempt was made to summarize the positive impact on sustainability of the triple bottom line concept of applying the concepts of factory 4.0, as shown in Figure 10.
- They also pointed out that the effect of factory 4.0 on the sustainability TBL concept line is interactive in nature, as shown in Figure 11. Such interaction indicates that implementing factory 4.0 features can lead to simultaneous enhancements in TBL aspects. The next part provides an in-depth analysis of the influence of factory 4.0 on each of these sustainability aspects.



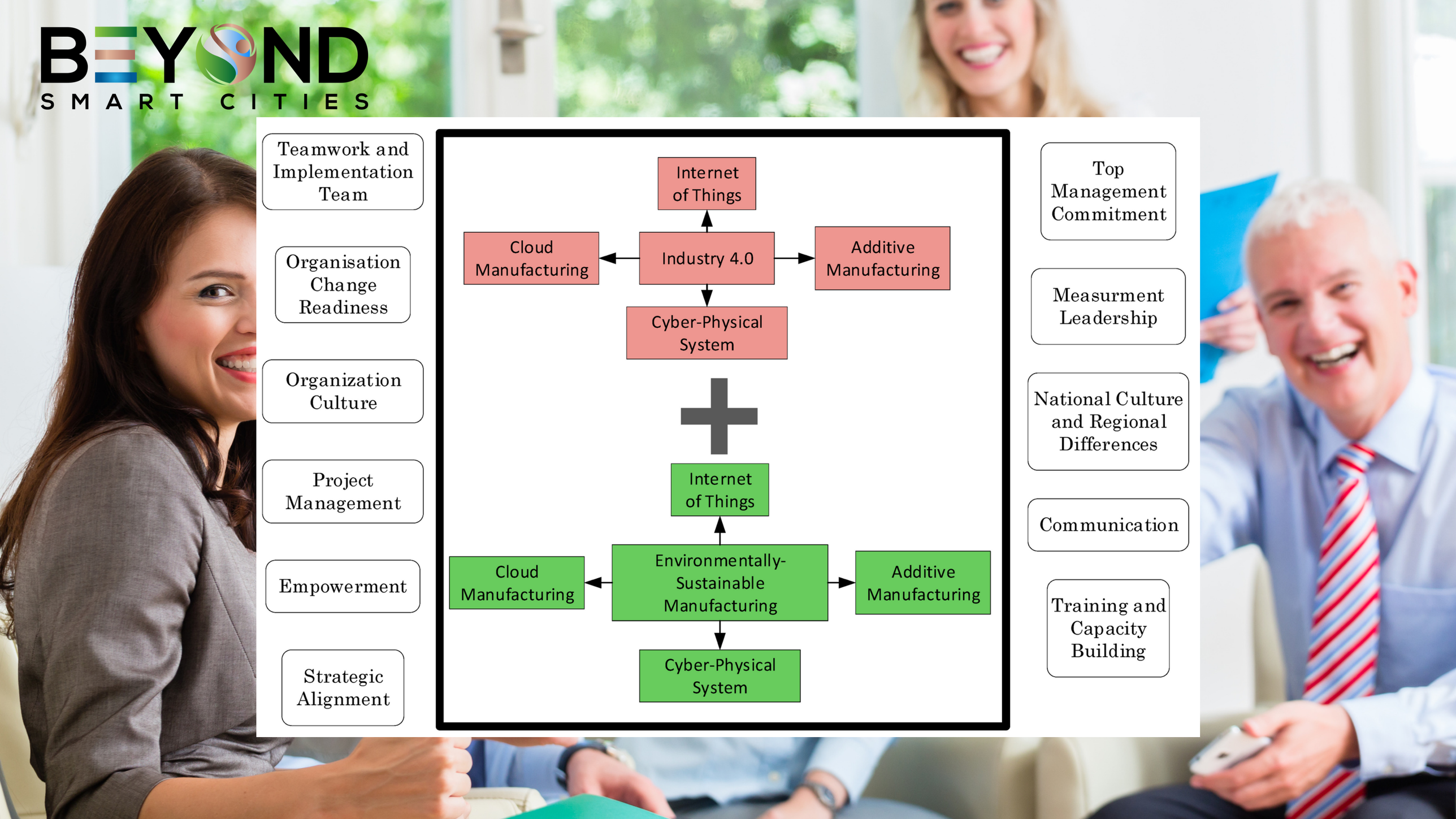


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THE CRITICAL SUCCESS FACTORS FOR ACHIEVING FACTORY 4.0 AND ENVIRONMENTAL SUSTAINABILITY HARMONY

- Industry 4.0's influence on the three sustainability directions is the first step to assessing its sustainability.
- Starting with economics, a factory will increase process and product performance, quality, and flexibility, but it will demand a large capital investment compared to the traditional one.
- Industry 4.0's diversified manufacturing capabilities will lower operating and running expenses.
- With rising demand for this innovative technology, capital investment costs should decrease.
- Factory 4.0 promotes sustainability in the economy.
- Environmental research is next.
- Factory 4.0 reduces resource use and waste, improving the process's environmental effect.
- Factory 4.0 technology may increase environmental risk.
- These resources may be rare and need significant extraction and processing, negating factory 4.0's environmental benefit.
- However, factory 4.0 will simultaneously link energy sources, producers, and market demand.
- Better energy management will reduce energy overproduction and shortages.
- This may offset the environmental impact of new technology.
- Process efficiency enhances economics and uses less resources.
- Factory 4.0's renewable energy boosts clean energy use.
- Figure 12 shows eleven key success factors (CSF) for industrial 4.0 and environmental sustainability.

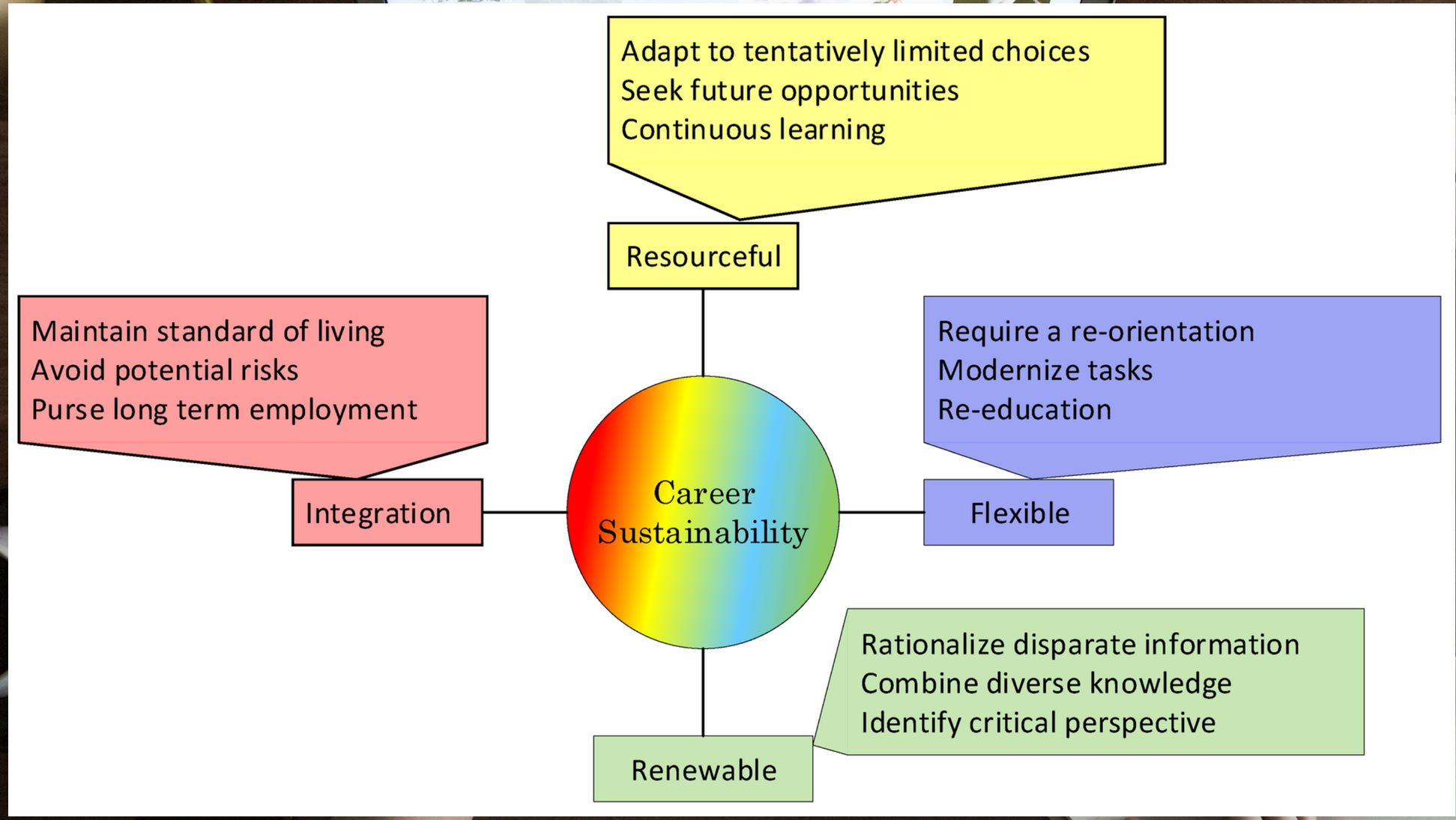
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FOUR DIMENSIONS OF CAREER SUSTAINABILITY IN INDUSTRIAL INNOVATION

- Finally, examine social sustainability.
- Machines replacing humans is an old notion.
- This is because blue-collar employment have been automated.
- Factory 4.0 relies on self-deciding machines.
- However, this will create new occupations planning, implementing, and maintaining this network of devices.
- Society will improve education and training for people.
- Factory 4.0 will also improve worker safety.
- The dynamic character of career sustainability in industrial innovation was described in a four-dimensional theoretical framework.
- Figure 13 depicts career sustainability model pillars.
- Resourceful means employees should adapt to changing employment limits due to industrial innovation and learn to expand their possibilities over time.
- Renewability means employees may learn new skills and keep learning.
- Workers' handling of varied knowledge from many sectors is integrative.
- Workers should understand and use this knowledge to stay employed.
- In Figure 13, resourceful means people may pursue long-term, risk-free, secure occupations.
- They'll live well.
- If employees have additional cash and resources, they can do this.

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Adapt to tentatively limited choices
Seek future opportunities
Continuous learning
Resourceful
Maintain standard of living
Avoid potential risks
Purse long term employment
Integration
Career Sustainability
Require a re-orientation
Modernize tasks
Re-education
Flexible
Rationalize disparate information
Combine diverse knowledge
Identify critical perspective
Renewable

THE OPPORTUNITIES AND CHALLENGES ASSOCIATED WITH INDUSTRY 4.0.

- Industry 5.0 emerges from industry 4.0's social and career sustainability issues.
- Human, cyber, and physical (machine) system interactions distinguish Factory 5.0 from Factory 4.0.
- Since the second industrial revolution, human and physical systems have become one.
- However, technological advances have made cyber systems an integral element of this composite system, generating human cyber-physical systems (HCPSs).
- The cybersystem enables the machine to control and decide (factory 3.0) or even more intelligently (factory 4.0).
- Gacia and colleagues created a cyber-physical discrete manufacturing network.
- They demonstrated OSCM and NOAM software for cyber-physical manufacturing.
- These tools increase manufacturer-designer collaboration, resulting in more lucrative and sustainable manufacturing strategies.
- A case study of discrete manufacturers in Illinois and Wisconsin used the suggested model and solution method.
- The technique identified production model plans with varying greenhouse gas emissions and their profit or loss, illustrating the trade-off between goals.
- However, HCPSs have significant promise for improving manufacturing efficiency and quality, and industry 4.0 may reduce the human workforce, diminishing job prospects and increasing unemployment.
- This may hinder Factory 4.0 adoption.
- However, HCPS factory 5.0 may solve this issue.
- In this innovative idea, robots observe and learn from people like apprentices.
- When labor unions and politicians oppose industry 4.0 due to career sustainability issues, this new paradigm of robots complementing people is the only option.
- Figure 14 depicts Industry 4.0 problems and potential.



Industry 4.0

Challenges

Higher competitiveness

New employee abilities

New regulations and requirements

Ignoring some sustainability aspects

Opportunities

New business models

Increase efficiency

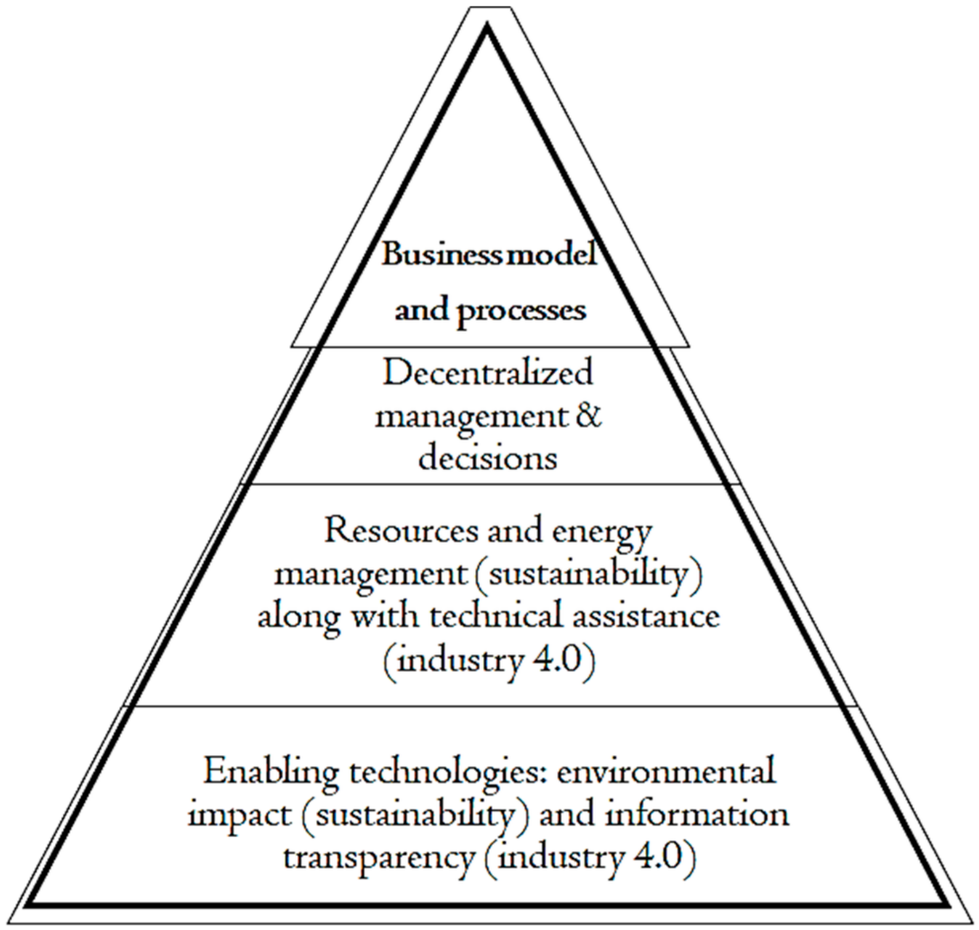
Increase speed and flexibility

The elements of the smart and sustainable business model.

With careful and calculated implementation, factory 4.0 and sustainability perspectives can sustain and expand economic growth, customer relationships, goods and facility values, employee safety and well-being, and environmental stewardship [1]. Thus, there is pressure to incorporate both views to create a smart, sustainable company strategy that meets both internal and external demands. Figure 15 depicts the smart, sustainable, integrated company model. This approach may increase profit, fulfill government requirements, meet consumer expectations, and improve employee life quality by using these elements:

- decentralized management;
- advanced technologies for better environmental impact; and
- promising energy management through information transparency and technical assistance through the industry 4.0 approach.

Finally, the integrated smart and sustainable business model should be based on policies that increase competence to satisfy urgent facility needs. This will enhance future environmental quality and industrial business projections. This approach's problems will be discussed next.





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