Sustainability in Industry 4.0

Smart-Edu4.0

Erasmus+ project

Co-funded by the
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of the European Union

Four pillars of sustainability

1. Social
2. Human
3. Economic
4. Environmental

To achieve sustainability in an organization or business, all four pillars of sustainability (human, social, economic, environmental) should be satisfied.

https://www.futurelearn.com/info/courses/sustainable-business/0/steps/78337

Four pillars of sustainability

1 Social sustainability ⟶ focuses on improving social equality!

- Invest and create services for the society
- Preserve future generations from decisions we make today
- Maintain and improve social quality

  (by encouraging cohesion, honesty, importance of people relationships)

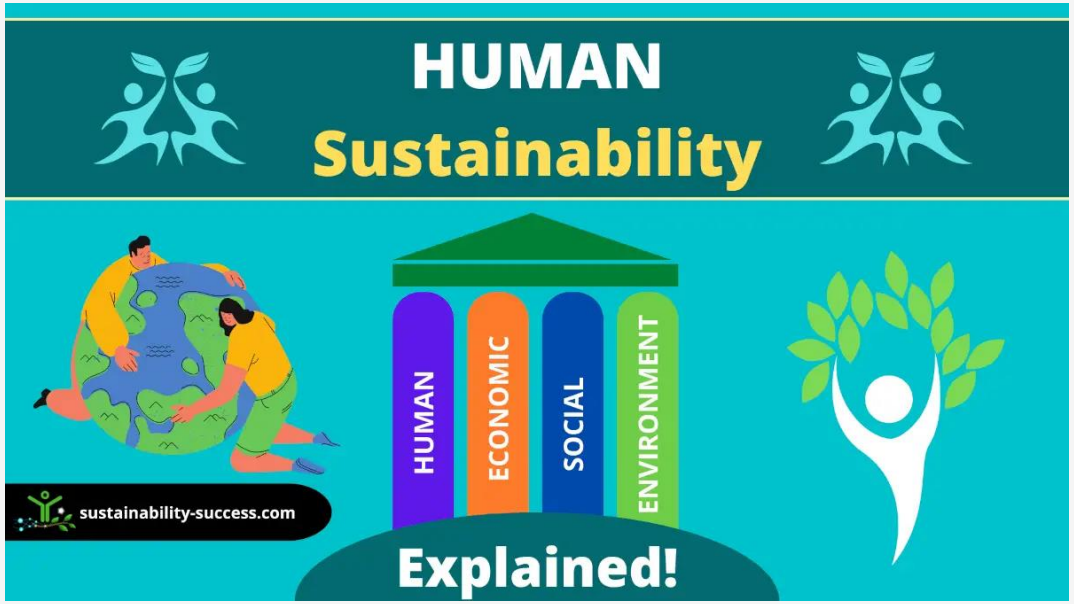
- Promote Ideas, information and laws regarding equality and rights.

https://www.futurelearn.com/info/courses/sustainable-business/0/steps/78337

Four pillars of sustainability

2 Human sustainability

- invest in health and education systems
- access to services, knowledge and nutrition
- invest on the development of human skills
- focus on the importance of individual
- achieve economic wellbeing for everyone



https://www.futurelearn.com/info/courses/sustainable-business/0/steps/78337
https://sustainability-success.com/human-sustainability/

Four pillars of sustainability

3 Economic sustainability ⟶ aim to improve the standard of living

- Efficiently use of assets to maintain company profitability over time

Economic Sustainability Examples

- Devising less wasteful systems
- Prioritizing low-impact economic development
- Switching to renewable energy sources

https://www.ebrd.com/news/2018/2018-nobel-prize-focus-on-sustainable-growth.html

https://www.futurelearn.com/info/courses/sustainable-business/0/steps/78337

Four pillars of sustainability

4 Environmental sustainability

- aim to improve human welfare through the protection of natural resources

  (land, air, water, minerals, etc.)

- Business should achieve positive economic outcomes without doing any harm to the environment

To achieve sustainability in an organization or business, all four pillars of sustainability (human, social, economic, environmental) should be satisfied.

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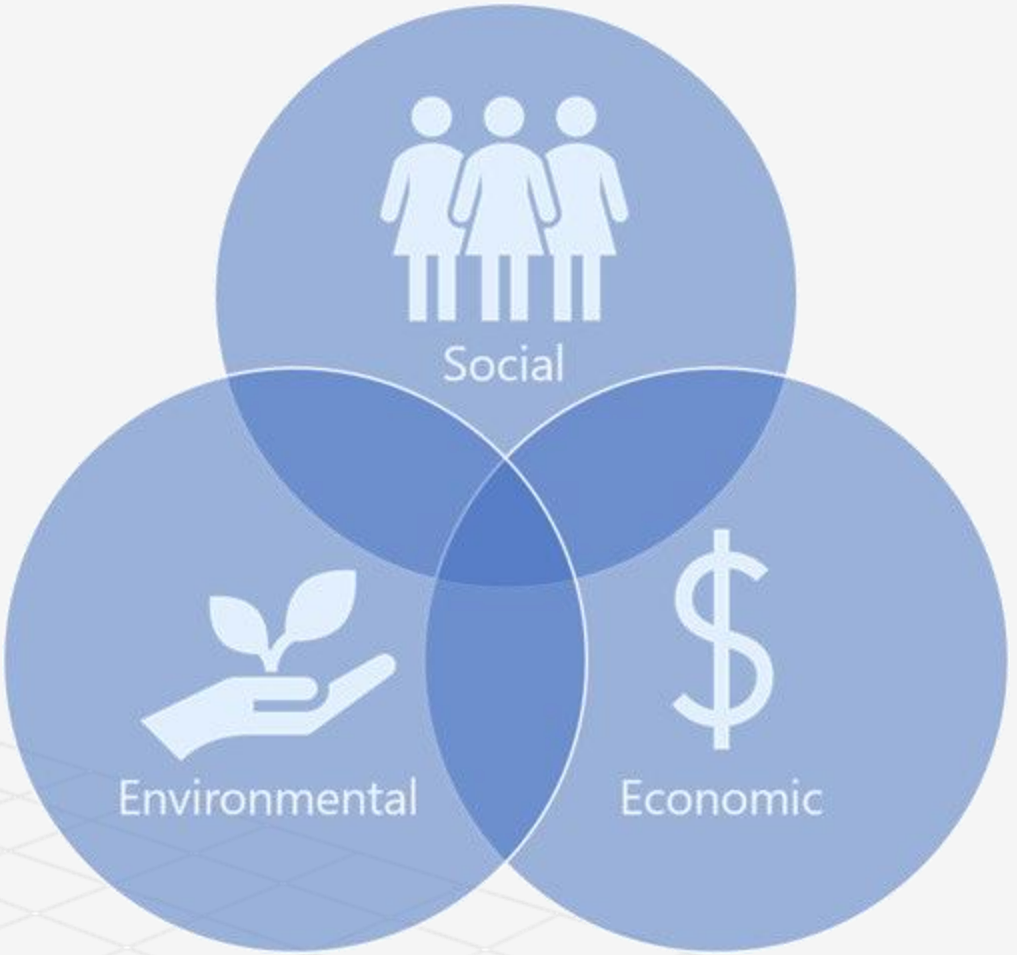
Triple Bottom Line (TBL)

In the literature, sustainability consists of the three pillars: **social, economic** and **environmental** which constitute the **Triple Bottom Line (TBL).**

The sustainability concept was first introduced by the United Nations World Commission on Environment and Development in **1987**. That year, the commission defined sustainability as an economic development model that allows to "meet the needs of the present generation without compromising the ability of future ones to meet their own needs.

Sustainability is a multi-dimensional concept encompassing environmental, social, and economic dimensions.



https://i0.wp.com/ecocation.org/wp-content/uploads/2022/01/triple-bottom-line.png?resize=768%2C725&ssl=1

Elkington, J. (1998). Partnerships from cannibals with forks: The triple bottom line of 21st-century business. *Environmental quality management*, *8*(1), 37-51.
Braccini, A. M., & Margherita, E. G. (2019). Exploring organizational sustainability of industry 4.0 under the triple bottom line: The case of a manufacturing company. *Sustainability*, *11*(1), 36.

TBL-Environmental Dimension

Environmental dimension

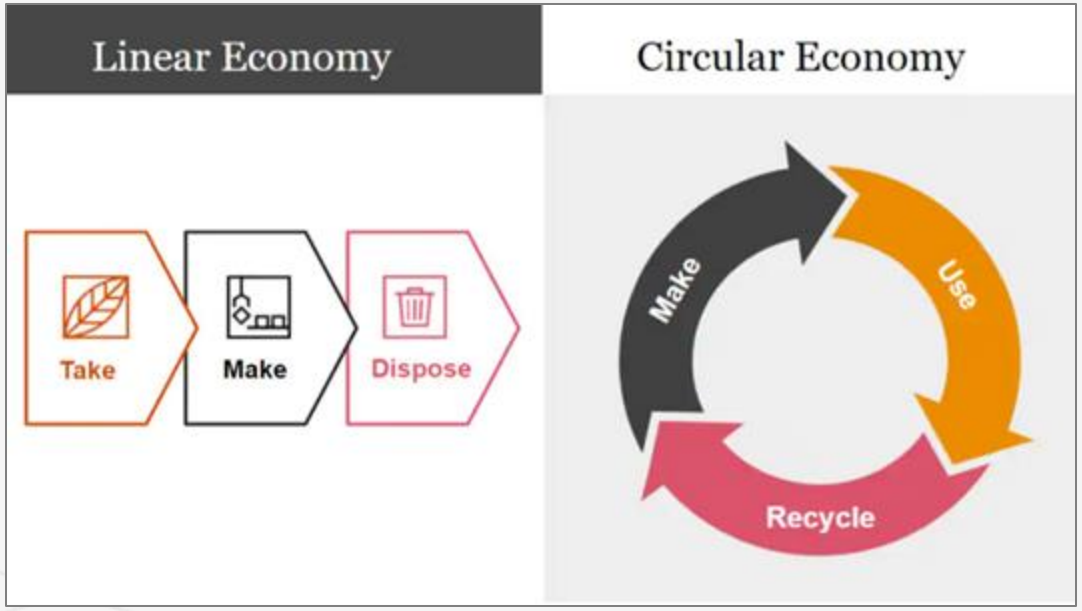
- compatibility between the trend of use and renewal of resources in nature.

- consume only the natural resources that can be reproduced from nature

- produce emissions that can be absorbed naturally by the existing ecosystem

through

i. recycling
ii. regeneration of resources,
iii. redesign of processes and products to minimize resource usage,
iv. replacement of non-renewable with renewable resources,
v. adoption of models of the circular economy



https://www.pwc.com/gr/en/advisory/risk-assurance/sustainability-climate-change/circular-economy-model.html

Elkington, J. (1998). Partnerships from cannibals with forks: The triple bottom line of 21st-century business. *Environmental quality management*, *8*(1), 37-51.
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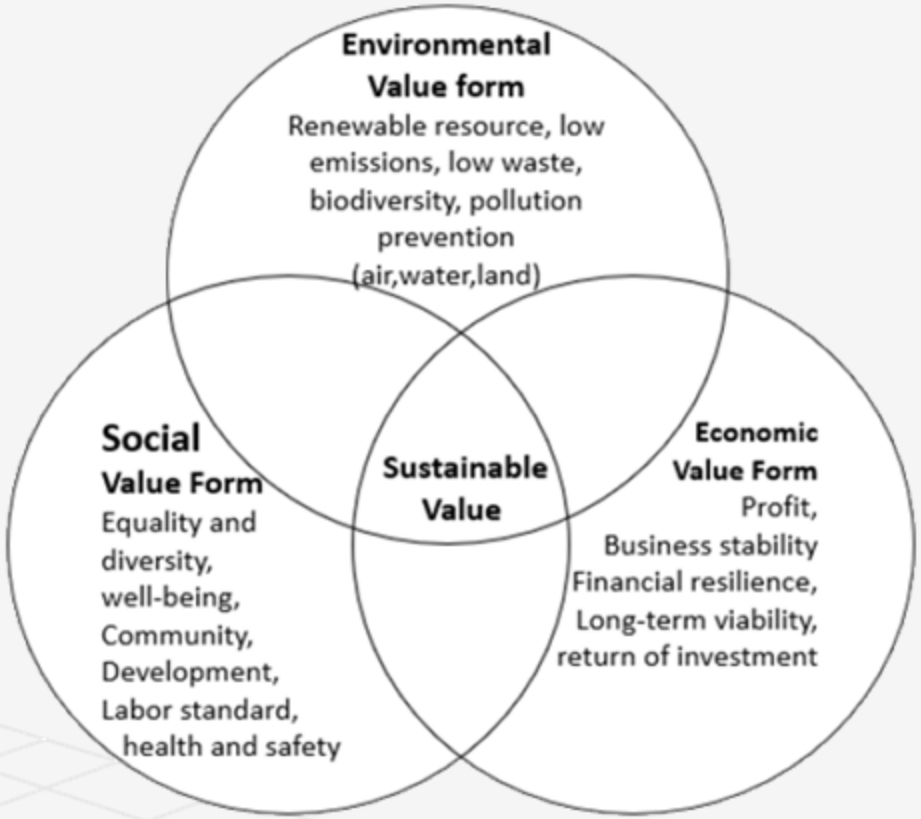
TBL- Social and Economic Dimension

Social Sustainability includes:

- Job satisfaction
- Quality of life
- Social integration in communities
- Equity and justice in the distribution of goods and services
- Equal opportunities in education

Economic Sustainability:

- create value
- balance costs and revenues
- is related to the financial performance of an organisation



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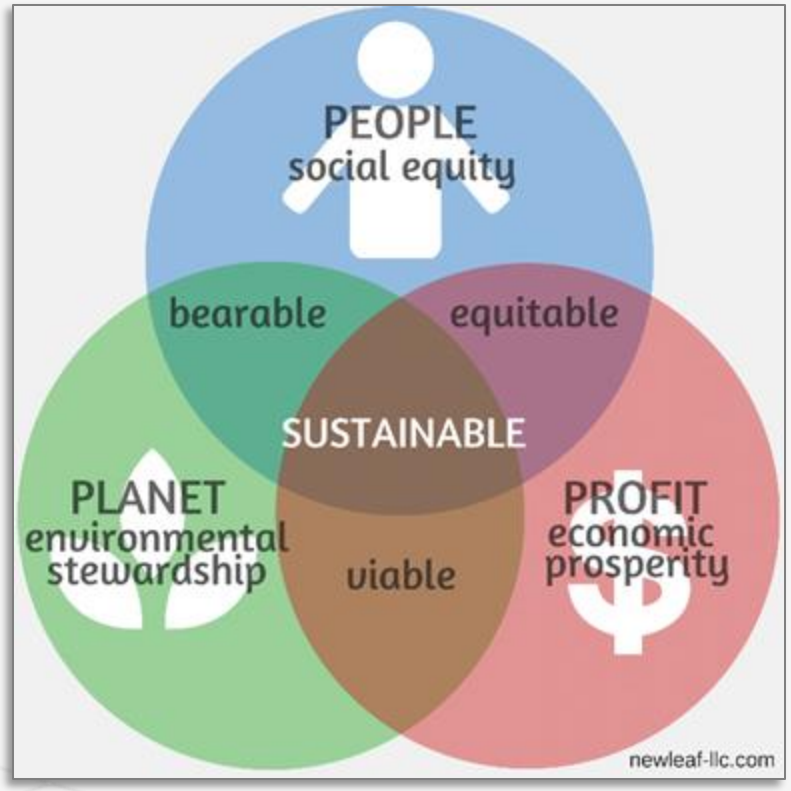
Triple Bottom Line (TBL)

The tree TBL dimensions (environmental, economic and social) interact, overlap and sometimes conflict. e.g. cleaner production processes may require extra investments.

Organizations need to accomplish all of them! Each dimension represents a necessary, but not sufficient condition for achieving sustainability.

Organizations are working towards establishing synergies between the environmental and the economic dimensions of sustainability, BUT they are still struggling to address the TBL!



https://www.researchgate.net/figure/The-Image-of-the-Triple-Bottom-Line-by-New-Leaf-Sustainability-Consulting_fig3_336373474

Braccini, A. M., & Margherita, E. G. (2019). Exploring organizational sustainability of industry 4.0 under the triple bottom line: The case of a manufacturing company. *Sustainability*, *11*(1), 36.

Sustainable Development Goals (SDGs)

- 17 interlinked global goals
- designed by United Nations
- They are a “blueprint to achieve a better and more sustainable future”

1. No poverty
2. Zero hunger
3. Good health and well-being
4. Quality education
5. Gender equality
6. Clean water and sanitation
7. Affordable and clean energy
8. Decent work and economic growth
9. Industry innovation and infrastructure

https://blog.dormakaba.com/how-industry-4-0-is-ushering-in-a-sustainable-era/
https://www.un.org/sustainabledevelopment/sustainable-development-goals/

Sustainable Development Goals (SDGs) (...continued)

10. Reducing inequality
11. Sustainable cities and communities
12. Responsible consumption and production
13. Climate action
14. Life below water
15. Life on land
16. Peace, justice and strong institutions
17. Partnerships for the Goals

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Technologies used in I4.0

- Internet of Things (IoT):

The connection of machines equipped with sensors to the Internet. Internet-connected machines can generate, process and communicate data in real time to humans or other machines.

Example: A sustainable smart building with connected IoT sensors will turn-off lights and air-condition when people exit a room.

- Robotics:

Devices that can autonomously perform gestures or movements. They are designed and programmed to perform any desired manipulation tasks. Robots can be autonomous in their operation, or collaborative with humans.

Example: In the assembly line, different kinds of robots take on the hard work into the process and workers act as supervisors.

- Additive manufacturing

Known as 3D printing. A wide range of different materials (e.g., plastics, metals, composite materials) can be used

Braccini, A. M., & Margherita, E. G. (2019). Exploring organizational sustainability of industry 4.0 under the triple bottom line: The case of a manufacturing company. *Sustainability*, *11*(1), 36.

Technologies used in I4.0

- Cloud computing

Enable to IT infrastructure companies to offer services through the internet

- Big Data and Analytics:

The overwhelming and unstructured amount of data generated by I40 technologies within the organization. They are stored on servers through cloud computing and are analysed with business intelligence, machine learning and analytics software.

Example:

Data from smart vehicles are transferred to a cloud server, analysed and suggest routes and modes of transportation with the minimum environmental impact.

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Industry 4.0 – Advantages and Disadvantages

Advantages

- more effective ways of producing goods
- improve warehouse management (through sensors)
- reduce warehouse inaccuracy
- shorten time to market
- improve product manufacturing life cycles
- efficient use of resource
- balance energy consumption based on the needs
- ameliorate working environment (passing hard-muscular work to machines)
- safer workplace
- increase employees morale

Disadvantages

- pollution increase because of the exploitation of electricity and natural resources
- workforce reduction because many activities pass from humans to machines

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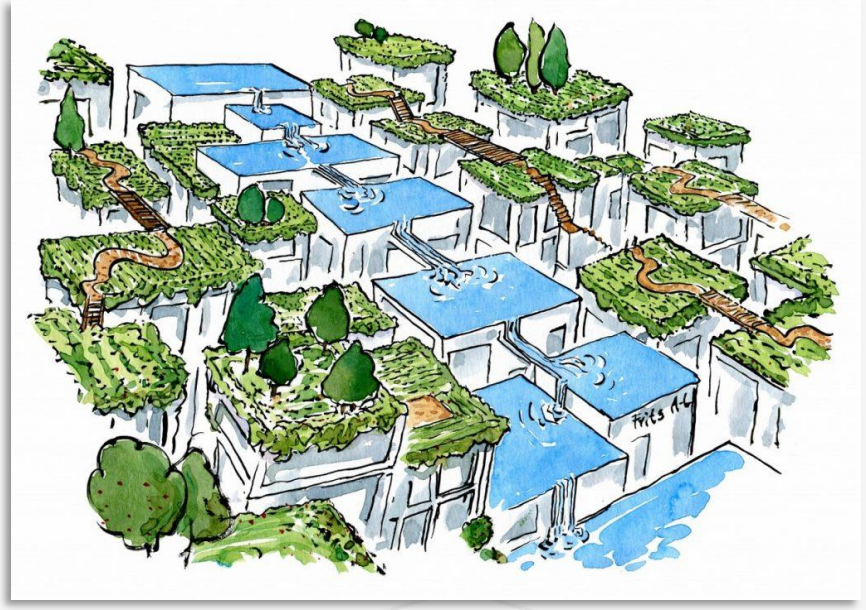
Industry 4.0 and sustainable *architecture*

- Home that automatically schedule all needed repairs (with bacteria)
- Construction elements that grow with time
- 3D printed sustainable homes (for homeless people and not only)
  - design and construction precision → material waste close to zero
  - usage of eco-friendly materials
  - every part can be replaced, repaired and reused in the future
- Construct houses according to region climate conditions
  - more energy efficient
  - withstand a possible climatic scenario
  - monitor various ecosystem parameters from online databases and rearrange cooling or heating



https://www.sustainability-times.com/clean-cities/industry-4-0-could-revolutionize-sustainable-architecture/
https://8477405x.blogs.upv.es/units/u7/

Industry 4.0 and sustainable *architecture* – *Maintenance and Repairing*

Maintenance and Repairing – example of Zaanstad (Dutch city)

partnership between *housing authority* and *data scientists*

↓

Machine learning algorithm

based on 135 million data records regarding buildings history, infrastructure, weather patterns, satellite data

↓

Predict which buildings need immediate repair: 11.000 houses prioritized for repair!

↓

Time and resources are saved

https://www.sustainability-times.com/clean-cities/industry-4-0-could-revolutionize-sustainable-architecture

Industry 4.0 – highlight and challenges

Highlights

Machines outcompete humans in terms of

- resource,
- energy efficiency,
- precision and
- quality of work

Challenges

Technologies require great amounts of resources

Ensure not to cause greater resource consumption and rise of emissions

https://www.sustainability-times.com/clean-cities/industry-4-0-could-revolutionize-sustainable-architecture/
https://www.virtuslab.com/blog/what-is-industry-4-0-challenges-and-benefits/

Industry 4.0 and reduction of production environmental impact

Constructions are increasing due to urbanisation.

Construction materials are responsible for air pollution due to CO2 emissions:

1 ton of cement produces 1 ton of CO2

Heavy metals like chromium, nickel, cobalt, lead and mercury are found in cement dust

Cement dust affects plants by

- reducing growth,
- decrease in chlorophyll,
- low starch content and
- lowering fruit setting

Aquatic ecosystem gets also affected if *concrete wastewater* (with alkaline pH) is discharged in waterbodies.

After water, concrete is the second most consumed substance!!

To avoid environmental issues, construction materials should have biological origin e.g. replace cement with biocement and concrete with bioconcrete

Waghmode, M. S., Gunjal, A. B., Bhujbal, N. N., Patil, N. N., & Nawani, N. N. (2019). Eco-Friendly Construction. In *Reusable and Sustainable Building Materials in Modern Architecture* (pp. 80-92). IGI Global

Industry 4.0 and Sustainable Development

Sustainable Development (SD) definition:

"The development that meets the needs of the present without compromising the ability of future generations to meet their own needs"

Several definitions for *Sustainability* and *Sustainable Development.*

The most current and relevant of SD is **the Triple Bottom Line (TBL)** which entails three pillars:

Economic sustainability: aims to improve productivity and ensure profit

Social sustainability: contributes to the creation of better job prospects

Environmental sustainability: targets on smart energy consumption

Circular Economy, CE aims for ➡ the *sustainable use of natural resources* and

'take, make, use, dispose/waste

the *shift from the linear model* of *to the circular model*

'reduce, reuse, recycle, recover, remanufacture, redesign'

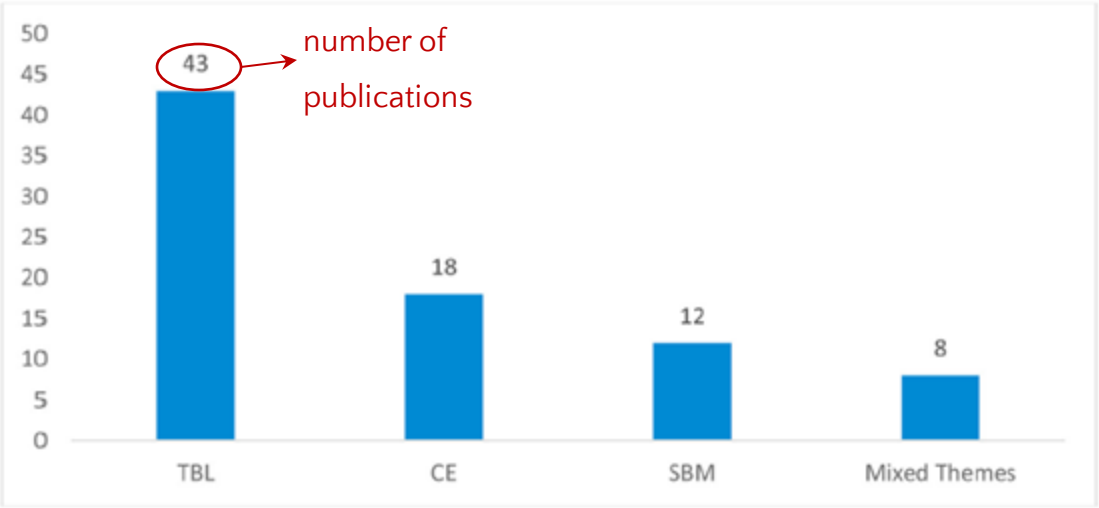
Khan, I. S., Ahmad, M. O., & Majava, J. (2021). Industry 4.0 and sustainable development: A systematic mapping of triple bottom line, Circular Economy and Sustainable Business Models perspectives. *Journal of Cleaner Production*, 126655.

Industry 4.0 and Sustainable Development

In the literature, the most studied area regarding Sustainability and Industry 4.0 is the **Triple Bottom Line (TBL)** and among the three pillars, they mainly focus on the environmental issues.

However, there are also some novel researches regarding Circular Economy (CE) principles of 3Rs (reduce, reuse and recycle) and 6Rs (reduce, reuse, recycle, recover, remanufacture and redesign) as I4.0 approaches.

Despite the significance of the subject, few papers have focused on the necessary implementation of **Sustainable Business Models (SBMs)** in operational environments



Key themes under sustainability and I4.0

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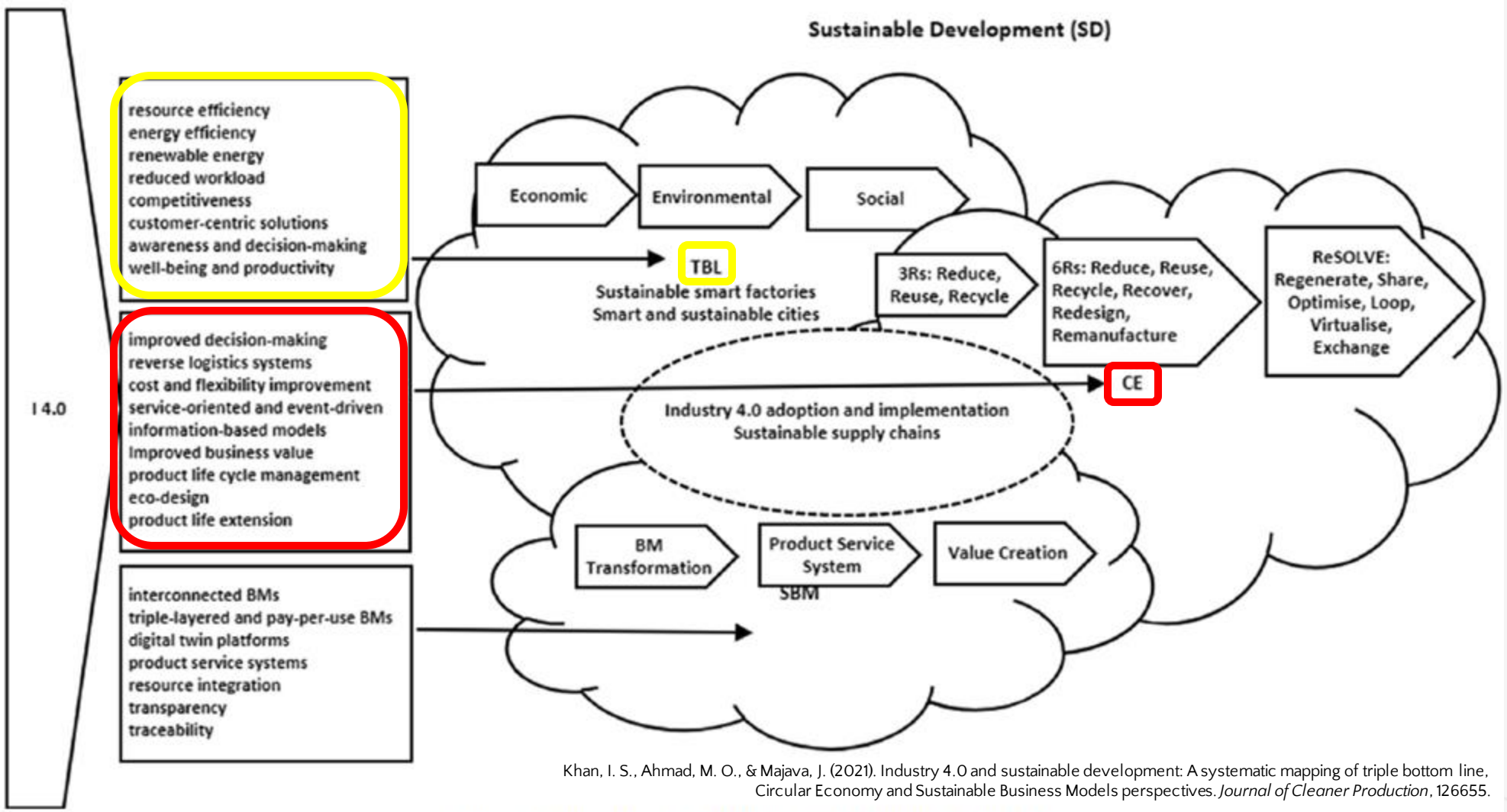
Industry 4.0 and Sustainable Development



Khan, I. S., Ahmad, M. O., & Majava, J. (2021). Industry 4.0 and sustainable development: A systematic mapping of triple bottom line, Circular Economy and Sustainable Business Models perspectives. *Journal of Cleaner Production*, 126655.

Fig. Key research areas and topics studied under I4.0 and SD

Industry 4.0 and sustainability

Industry 4.0 affects to:

- raw materials,
- energy,
- products,
- waste,
- assets,
- information

Industry 4.0 affects environmental sustainability positively or negatively?

Bonilla, S. H., Silva, H. R., Terra da Silva, M., Franco Gonçalves, R., & Sacomano, J. B. (2018). Industry 4.0 and sustainability implications: A scenario-based analysis of the impacts and challenges. *Sustainability*, *10*(10), 3740.
https://www.businessamlive.com/industry-4-0-affecting-sustainability-across-sectors/

Industry 4.0 and sustainability – Negative Impacts

Environmental sustainability restricts production within limits:

- The rate of exploitation of natural resources should not exceed the rate of regeneration
- The rate of waste generation should not exceed the absorbable capacity of the biosphere
- The reduction of non-renewable resources should require comparable substitutes

Consumers are not adopting principles of sustainable consumption → They are consuming far beyond their real needs!!

Bonilla, S. H., Silva, H. R., Terra da Silva, M., Franco Gonçalves, R., & Sacomano, J. B. (2018). Industry 4.0 and sustainability implications: A scenario-based analysis of the impacts and challenges. *Sustainability*, *10*(10), 3740.

Industry 4.0 and sustainability – Negative Impacts

Benefits of proactive environmental activities:

- the satisfaction of the stakeholders who currently have many environmental concerns,
- the elimination of pollution and environmental liabilities,
- the improvement of financial performance due to opportunities in new foreign markets,
- chances for an environmentally-friendly company to a supplier in a green supply chain
- obtain environmental certification, with the attached improvement in reputation.

Bonilla, S. H., Silva, H. R., Terra da Silva, M., Franco Gonçalves, R., & Sacomano, J. B. (2018). Industry 4.0 and sustainability implications: A scenario-based analysis of the impacts and challenges. *Sustainability*, *10*(10), 3740.

What was the initial need of Industry 4.0?

Exploit available innovative digital technology and satisfy customer demand for customized and high-quality products.

Specifically Industry 4.0 was initially focused on boosting productivity, revenue growth and competitiveness!!

Industry 4.0 has to deal with the following inherent issues in order to be successful:

- the standardization of systems, platforms, and protocols,
- changes in work organisation
- digital security,
- availability of skilled workers, research and investment

Nowadays has to deal with the environmental pressure (energy demand and low-carbon energy systems)

Bonilla, S. H., Silva, H. R., Terra da Silva, M., Franco Gonçalves, R., & Sacomano, J. B. (2018). Industry 4.0 and sustainability implications: A scenario-based analysis of the impacts and challenges. *Sustainability*, *10*(10), 3740.

Optimistic and Pessimistic Scenarios

Table 5. Overview of two conceivable long-term scenarios from an optimistic and a pessimistic projection. The type of response to challenges will direct the trend.

Characteristic of the Projection	Key Factors	Response	Impact Trend
Optimistic	Device demand	Increased recycling	Positive
	Raw material demand (Li, etc.)	Research for substitutes	Positive
		Increased recycling	Positive
	Consumer concerns	Aware	Positive
	Unskilled workforce	Focus on training and formation	Positive
	Company infrastructure	Homogeneity in terms of automation and digitization	Positive
	Novel business models	Promote value co-creation Promote pro-environmental markets	Positive
	Geography	Spatially homogeneous adoption of the technology	Positive
		Exchange of technology between developed and developing countries	Positive
Pessimistic	Device demand	Increased raw materials flow in fabrication (Li and rare earth)	Negative
	Consumer concerns	Unaware	Negative
	Company infrastructure	Heterogeneity in terms of automation and digitization	
	Geography	Spatially concentrated adoption of the technology	Negative
		Technology concentrated in developed countries	Negative
	Equipment obsolescence	Increased flows of products to be disposed, recycled	Negative
		Increased fuel for transportation (towards disposal or recycling)	Negative

Bonilla, S. H., Silva, H. R., Terra da Silva, M., Franco Gonçalves, R., & Sacomano, J. B. (2018). Industry 4.0 and sustainability implications: A scenario-based analysis of the impacts and challenges. *Sustainability*, *10*(10), 3740.

Necessary transition towards effective production systems

The International Resource Panel (IRP) has estimated that extraction and processing of natural resources (from minerals to energy carriers and food) is responsible for around half of global greenhouse gas emissions and for >90% of impacts associated with water stress and biodiversity loss.

Projections indicate that raw material demand will be more than double by 2060 ⟶ 79 to 167 gigatonnes (Gt)

Pressure on the environment should grow at a slower rate compared to the activity causing it

Berg, H., Bendix, P., Jansen, M., Le Blévennec, K., Bottermann, P., Magnus-Melgar, M., & Wahlström, M. (2021). Unlocking the potential of Industry 4.0 to reduce the environmental impact of production. *European Environment Agency, European Topic Centre on Waste and Materials in a Green Economy. https://www. eionet. europa. eu/etcs/etc-wmge/products/unlocking-thepotential-of-industry-4-0-to-reduce-the-environmental-impact-of-production*.

Any questions?

Thank you ☺

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