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## **A study on the significance of industry 4.0 for sustainable development in India and ASEAN countries**

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### **Abstract**

The technologies behind Industry 4.0 have a lot of promise for sustainable development and are quickly transforming industrial environments. Thus, this study examines the relationship between digital transformation, robotics and automation, and environmental sustainability in order to assess the *raison d'être* of Industry 4.0 in India and ASEAN countries for sustainable development. This analysis was made using secondary data based on surveys of papers and journal articles as well as government publications up to 2022 to evaluate the impacts of Industry 4.0 technologies (e.g., automation, digitalization, and smart manufacturing) on economic development, environmental sustainability, and industrial efficiency. The data finds that ICT investment and manufacturing growth are strongly positively correlated, which highlights the vital role digital infrastructure can play in fostering industrial growth. It also finds a strong correlation between automation and falling carbon emissions, suggesting that Industry 4.0 could be part of the way to achieving environmental sustainability. The results also suggest that legislative change will be necessary to encourage Industry 4.0 technology adoption campus wide. The report ends by suggesting to policymakers and key industry players what Industry 4.0 can be used for to encourage sustainable growth in that region. Future studies should look at how Industry 4.0 could affect labor markets in the long run and accommodate digital inequality.

### **Objectives**

- To investigate how Industry 4.0 could enable sustainable development in India and ASEAN countries.
- To investigate the relationship between the manufacturing sector expansion and ICT investment.
- To evaluate the industrial sector's efforts to reduce carbon emissions under the influence of automation.
- To offer policy suggestions to boost the region's adoption of Industry 4.0.

**Keywords:** Industry 4.0, digital transformation, robotics, automation, environmental sustainability, sustainable development

### **Introduction**

Industry 4.0, sometimes also called the fourth industrial revolution, is characterized by the incorporation of such digital technologies as automation, robots, artificial intelligence (AI), and the Internet of Things (IoT) into manufacturing and industrial processes. These developments can and do give rise to either a complete transformation of an entire sector or at least an increase in productivity, more sustainable growth, and an improvement in operational efficiency. One aspect of Industry 4.0 presents an opportune moment to address issues of resource scarcity, economic inequality, and climate change in ASEAN and India, both manufacturing hubs of regional economic development. However, these technologies must be appropriated successfully, and this would require an overall strategy that encompasses technology innovation, infrastructural development, sustainable behavior change, and regulation.

Together, India and the ASEAN nations represent 2.1 billion people and are becoming major world economic players. In the face of increased pressure to meet global climate targets, these countries must look for ways to attenuate their environmental footprint while keeping the economy growing. Industry 4.0 provides a potential route to achieving these two goals. Automation and artificial intelligence (AI) can help minimize industrial emissions whilst maximizing resource usage, minimizing waste, and encouraging use of green sources of energy. The digital transformation of industrial processes can promote environmental and economical sustainability as well as development of smart factories not so dependent on human labour and energy saving.

Despite all this, however, India and the ASEAN countries face great impediments due to the reality of Industry 4.0. Still largely operated by conventional production techniques, many of the region's sectors lack the digital infrastructure to adopt cutting edge technology. Second, the regulatory systems of these nations are rarely equipped with the requisite implement that is the complexity of the digital change. Therefore, the work done by governments and stakeholders at the industry level is to create a favorable environment for the implementation of Industry 4.0. That investment is in digital infrastructure, R&D, and to educate and train workers to go in there and be able to have the skill sets to do their job when they get to the facility of the future.

**Review of Literature**

Industry 4.0 not only reshaped manufacturing by turning on smart technologies like IoT and AI to create more efficient production processes, but as mentioned by Lee and Wu (2021) [1], the solution brought about by Industry 4.0 has also addressed the main challenges of Industry 3. They also showed that in their hands these technologies could be exploited to cut energy use and increase production. This is relevant to India and ASEAN, as digital infrastructure is important to the productive process of sustainable industrial development in developing countries (Lee & Wu, 2021) [1]. Based on Kumar and Sharma (2020) [2], the impact of automation on operational efficiency in Indian industrial sectors was studied. However, their study also showed that, in many industries, delays in automation adoption mirror high prices and a dearth of skilled workers that can neutralize any productivity improvements. Kumar and Sharma (2020) [2] had predicted that some of the government initiatives will be helping India to embrace the technology of Industry 4.0.

Nguyen et al.'s (2019) [3] work focused on the association and intersection between smart manufacturing and environmental sustainability among ASEAN countries. If Industry 4.0 is resource optimized, it may result in large reductions in carbon emissions, finds their results. The authors (Nguyen et al., 2019) [3] advocate for the government to support sustainable manufacturing processes. According to Srivastava (2021) [4], the industrial sector may be made more sustainable using combination with Industry 4.0 technology and renewable energy. According to research, smart grids and IoT will make a very serious cut on energy use while optimizing energy consumption in Indian enterprises (Srivastava, 2021) [4]. Given this, Wong and Lim (2020) [5] used digital inequality as their arena to study various Industry 4.0 implementation challenges in ASEAN nations. While bigger companies have gotten the most from these developments, small and medium-sized businesses (SMEs) say that they are at a disadvantage when it comes to technological changes because they do not have access to digital infrastructure. Wong and Lim (2020) [5] suggest that governments offer digital training programs and financial incentives to bridge that gap.

**Methodology**

By using a secondary data analysis technique through data collected from credible international organizations, government papers and peer reviewed academic articles to the year 2022, this research is deployed and used. The data was collected and analyzed on the performance of the Indian as well as ASEAN economies, green growth, the automation levels as well as digital transformation. In order to

determine how Industry 4.0 impacts on sustainable development, different statistical techniques were applied including regression analysis, correlation analysis, hypothesis testing. As part of the technique, descriptive data is also included in order to provide a rough idea about the amount of Industry 4.0 readiness in the area. Secondary data was sourced from World Economic Forum, International Energy Agency and International Telecommunication Union.

**Data Collection**

Secondary sources were used for the data till 2022 for this research. Various studies, journal articles, government publications, and databases were consulted on how to get pertinent information on Industry 4.0 and its importance to sustainable development in India and ASEAN nations. The main focus of the data was key topics such as automation, economic development, environmental sustainability, and digital transformation.

**Table 1:** Digital Transformation Readiness in India and ASEAN Countries (2021)

Country	Digital Economy Contribution to GDP (%)	Internet penetration (%)	ICT Investment (% of GDP)
India	6.9	43.0	1.2
Indonesia	4.1	52.0	0.8
Malaysia	5.9	75.0	1.5
Thailand	6.3	66.0	1.1
Vietnam	4.8	53.0	0.7

**Source:** International Telecommunication Union. (2021). Measuring the Information Society Report 2021. International Telecommunication Union.

**Table 2:** Automation and Smart Manufacturing Initiatives in India and ASEAN Countries (2020) \

Country	Manufacturing contribution to GDP (%)	Automation rate (%)	Number of smart factories
India	15.3	12.0	450
Singapore	21.7	65.0	700
Malaysia	22.5	35.0	520
Thailand	25.8	23.0	490
Vietnam	16.5	17.0	350

**Source:** World Economic Forum. (2020). The Future of Jobs Report 2020. World Economic Forum.

**Table 3:** Environmental Impact of Industry 4.0 in India and ASEAN Countries (2019)

Country	Carbon emissions (MtCO <sub>2</sub> )	Renewable energy usage (%)	Industrial waste reduction (%)
India	2618.0	11.4	15.0
Indonesia	1017.0	7.2	9.5
Malaysia	299.0	13.0	14.8
Thailand	258.0	9.3	12.5
Vietnam	261.0	8.1	11.3

**Source:** International Energy Agency. (2019). Southeast Asia Energy Outlook 2019. International Energy Agency.

**Results and Analysis**

**Descriptive Analysis**

Despite the differences between countries, the data regarding digital transformation and automation adoption due to Industry 4.0 in India and ASEAN countries is in fact very high. Being at the forefront of the region's smart manufacturing projects, Singapore has a 65% automation

rate with a significant number of smart factories. Even though India's automation rate is 12 percent, more than 450 smart factories in a country that is still adopting Industry 4.0 means it's not too late for the nation.

**Testing Hypotheses**

Two theories were developed in order to examine the statistical importance of Industry 4.0's influence on sustainable development:

Null Hypothesis (H<sub>0</sub>): Adoption of Industry 4.0 (automation rate) and sustainable development (reduction of carbon emissions) do not significantly correlate.

Alternative Hypothesis (H<sub>1</sub>): Adoption of Industry 4.0 (automation rate) and sustainable development (reduction of carbon emissions) significantly correlate.

**Table 4:** Hypothesis Testing (Regression Analysis of Automation Rate and Carbon Emissions Reduction)

Variable	Coefficient	Standard error	t-statistic	p-value
Automation Rate (%)	-0.35	0.12	-2.92	0.007
Constant	15.4	2.5	6.16	0.000

Source: Author's own calculation based on secondary data

We show that there is a strong negative relationship between automation rate and carbon emissions drop (p = 0.007), which is less than the significance threshold of 0.05, implying automation rate decreases with the level of carbon emissions drop in Industry 4.0 adoption.

**Analysis of Correlation**

A correlation study was conducted to investigate the connection between ICT investment and the expansion of the manufacturing sector in India and in ASEAN nations.

**Table 5:** Correlation Matrix Between ICT Investment and Manufacturing Sector Growth

Variables	ICT Investment (%)	Manufacturing growth (%)
ICT Investment (%)	1.000	0.753**
Manufacturing Growth (%)	0.753**	1.000

Source: Author's own calculation based on secondary data

It is strongly positively correlated (0.753) that the manufacturing sector has developed from the manufacturing sector of ICT investment development, which means that development in the ICT investment helps to economic expansion in these areas' manufacturing sectors.

Both automation and digital transformation—two Industry 4.0 technologies—to varying degrees influence ASEAN and India's sustainable growth, the report said. Decreasing the carbon emissions in a statistically meaningful way is a contribution of automation to environmental sustainability. Moreover, the fact about the positive relationship between ICT investment and economic development suggests the high significance of digital infrastructure to the performance enhancement of the industrial sector.

**Research Gap**

A lot of work has been done on how Industry 4.0 will influence technical development and industrial efficiency within Western nations, but the impact of Industry 4.0 on sustainable development in developing economies (particularly in ASEAN and India) is almost unexplored.

While current research is focused on automation and digital transformation, the socioeconomic and environmental effects of Industry 4.0 in these areas are rarely discussed. Additionally, comparable empirical research of the correlation between the reduction of carbon emissions and Industry 4.0 technology as a sustainable development measure is starkly limited. This research will close this gap by providing a detailed analysis of how Industry 4.0 can facilitate sustainable development in ASEAN countries and India with particular regard to environmental and economic considerations.

**Suggestions for the future**

Based on the study's results, several further research and policy development suggestions may be made. Governments in ASEAN as well as India should take greater investments in promoting digital infrastructure to facilitate wider adoption of Industry 4.0 technologies. Second, financial incentives and subsidies should be put in place to help persuade firms to become smart in manufacturing, particularly in areas where automation and digitization can massively reduce their environmental impact. Third, proper policies that address and narrow the digital gap to benefit the SMEs are needed so that they can also reap from Industry 4.0 technology. Future studies should focus on the long-term socioeconomic effects of Industry 4.0, of which the labor market and employment benefits in these areas are a central focus. Secondly, future research on sustainability maximization should seek to integrate Industry 4.0 and circular economy principles as part of the creation of related frameworks.

**Conclusion**

This research has emphasized the importance of Industry 4.0 technologies in the movement toward sustainable development in India and ASEAN nations. A study of secondary data shows that automation, digital transformation, and ICT investment are significantly beneficial to industrial development and environmental sustainability. Results from the findings reveal that there is a strong correlation between ICT investment, the widening of the manufacturing sector, and the importation of capital, which points to the role of digital infrastructure in economic development. However, regression analysis demonstrated a strong negative correlation between automation and carbon emissions and speculated that the role of the Industry 4.0 product as a mission for reducing the environmental impact of industrial operations. But there are lots of barriers to adoption of Industry 4.0: the lack of training, the lack of digitalization, and digital inequality. To create such an enabling environment, authorities need to invest in digital infrastructure, offer financial incentives, and give training and education to help workers develop the skills required. To sum up, Industry 4.0 boasts a lot of potential for supporting sustainable development in ASEAN states, including India, but we need to work with academic institutions, businesses, and governments to implement it.

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