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Barriers to Industry 5.0 Adoption in Developing Economies

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ABSTRACT
Industry 5.0 is the next industrial revolution that puts human-machine interaction, hyper-personalization, sustainable manufacturing, and resilient value chains into focus. The developing economies are limited massively in terms of their ability to adopt this paradigm despite the fact that the advanced economies are gradually shifting to this paradigm. The following paper discusses structural, technological, economic, institutional, and socio-cultural aspects as obstacles to the spread of Industry 5.0 capabilities. Based on a mixed-methodology framework, which incorporates literature review, stakeholder interviews, and comparative evaluation, the authors of the study highlight the following key issues: insufficient digital infrastructure, insufficient human capital preparedness, significant risk of capital investment, weak innovation ecosystems, and regulatory misalignment. Findings indicate that most companies in developing countries are still stuck in Industry 3.0 or initial Industry 4.0 maturity levels with the region opening increasingly large technological divides. The interrelation of barriers is emphasized in the discussion showing how socio-technical constraints support one another. The paper is completed by identifying feasible constraints like lack of longitudinal adoption of adoption data and industry-specific heterogeneity, and offers viable future directions that can be implemented by policymakers, industries and researchers to hasten the responsible adoption of Industry 5.0..

Keywords: Industry 5.0; developing economies; human–machine collaboration; digital transformation; socio-technical barriers; innovation ecosystem; infrastructure readiness; adoption challenges.

INTRODUCTION:

Industry 5.0 is the latest development in the change of the global dynamism in the industrial field favoring human-centric, resilient, and sustainable manufacturing paradigm. In contrast to Industry 4.0, where the main emphasis was made on automation, cyber-physical systems, and machine to machine connections, Industry 5.0 emphasizes the human-focused approach to intelligent systems and the search to get personalized production, resource optimization, and social well-being [11]. This is not a mere change of technology but moves in a strategic change to establish industries that are environmentally conscious, ethically controlled, and quickly able to change with any forms of disruption. Though, developed countries are gradually working towards the transformation, the developing economies have a different set of structural, financial, technical, and socio-institutional obstacles to successful adoption. These gaps are dangerous to increasing the technology gap throughout the world without action.

The drive to this effort is the necessity to comprehend why less developed economies cannot pass to the Industry 3.0 and even the initial levels of Industry 4.0 even with the evident advantages of the more sophisticated systems of industry. A lot of such nations work under conditions of low quality digital infrastructure, unequal policy frameworks, lack of innovation ecosystems, and high levels of skills shortages. Introduction of Industry 5.0 in said conditions is not only a technological issue, but also an institutional, cultural and economic one [12]. Besides that, the global competitiveness is increasingly becoming dependent on the agencies in the combination of technologies such as collaborative bots, AI-powered automatization, digital twins and sustainable production designs. Without any additional revelation regarding the impediments, the policy makers and the industry could be left with wrong strategies that are non-helpful to the concrete constraints on the ground.

This paper is geared towards providing a detailed discussion to the multifaceted obstacles to affect the successful industry 5.0 deployment in the upcoming economies. This will entail researching into the preparedness of the infrastructural, limits on human capital, financial and investment constraints, regulatory mechanism lapses, social-cultural opposition and hindrance to industrial maturity. The combination of the outcomes of the literature study and cross-country comparison and thematic evaluation of the hits and misses will help underline the fact that there are not only barriers but also ways in which they interact and intensify one another. The publication ultimately contributes to a comprehension of the current state of preparedness and the reforms to be made according to which the developing economies will become successful in the next industrial paradigm [13].

Novelty and Contribution

What is new in the research is the combination of approaches that comprehend the problems of the adoption of Industry 5.0 and goes beyond the separate study of digital infrastructure or the readiness of the workforce. Although current studies are largely centered around Industry 4.0 issues or provide technology-oriented discourse, the work represents a unique way of embedding Industry 5.0 within the context of developing economies and the acknowledgment that the new aspect of human-machine cooperation, sustainability, and resilient production environments are becoming predominant. The study contributes to the discussion by disregarding Industry 5.0 as some technological breakthrough and a socio-technical revolution that demanded the alignment of digital maturity, the workforce flexibility, governance capability, and the industrial culture. This macro-framing allows the specialization in the details of the usually under-considered limiting factors that are making the developing countries unattainable progress towards the new manufacturing paradigms.

The main input of this work is that it has identified and classified the barriers into technological, economic, institutional, and socio-cultural spheres and shown their interdependencies, instead of considering them as individual problems. The paper gives a more germane and context-dependent insight on how infrastructural deficiencies, financial insecurity, fragmented ecosystems of innovation, flawed policy guidance, and cultural slackness toward high-level automation all herset. It adds a systematic story that can be followed by policymakers and leaders in industries to diagnose the gaps in preparedness and focus on the interventions. In addition, the analysis has also identified some key lessons, which include human-centered skills training, the need to align governance models with technological progress, and the intent of sustainable production motivation, which are not typically covered by the literature on Industry 4.0.

The other commendable input is that the findings are practically relevant. The work does not merely categorize the barriers, but it goes into detail the practical implications of the barriers as it concerns the national competitiveness, the involvement of SME in the sectors, industrial modernization and long-term stability. The research may help the researcher to develop the conceptual focus to draw the region-specific Industry 5.0 preparedness models and provide policy-makers with practical recommendations concerning the establishment of the regulatory environment and policy reforms of digital infrastructure development and training of the workforce. Filling the gaps in the empirical knowledge and offering the analytical perspective of the future, the work will become an indispensable source of information to anyone, looking to close the technological divide and make the switch to Industry 5.0 more prominent in developing economies.

2.Related Works

The available literature on the topic of industrial transformation is clear that the transition of the world of Industry 4.0 to Industry 5.0 is not only a technological change but also a socio-economic and organizational change. Enabling technologies, which include collaborative robotics, AI-based decision-making systems, digital twins, enhanced sensor network systems, and sustainable manufacturing processes, are seen as the focus of much of the early research in the context of their opportunity to make the subsequent advancements in productivity, personalization, and environmental responsibility. Nonetheless, the studies carried across developing regions always point out that there is a significant gap in readiness that does not allow the significance adoption of such technologies [4]. A number of researches point out that a lot of developing economies continue to have certain relic manufacturing solutions, less automation, and less digital connection, which is why the demands of Industry 5.0, including the human-machine interface and stable production cycles, are hard to fulfill without deeper upgrading.

In 2025 Rejeb *et al.*, [5] introduced the research on the issue of digital transformation shows that the problem of infrastructural constraints is one of the biggest ones. These are unstable power supply system, poor penetration of broadband, inadequate access to high speed connectivity and unreliable cloud infrastructure. Research has also shown that the digital literacy frameworks in most of the developing nations do not have the capacity to sustain superior industrial mechanisms, and labor talents disparities are evident in spheres like operation of robots and information analysis as well as AI facilitated process controls. These restrictions result in an imbalance between the technological progress and real performances in industries.

As the studies on such an issue center on economic obstacles, the cost of implementing Industry 5.0 technologies is a major concern as it is considered too high. Majority of the companies and more so the small and medium firms are unable to invest in automation, robotics or high-tech cyber-physical system due to lack of funds [3]. Research also observes that, unavailability of credit, lack of consumer confidence, and vagueness of turnover-o-investment due dates give businesses discouragement in terms of modernizing their systems of production. In addition to this, innovation systems in the emerging economies have been identified to be feeblest, and low investment in research and development, less industry-academic cooperation and lack of technology incubators and manufacturing innovation skills.

In 2025 M. Akhavan *et al.*, [14] suggested the policy-related barriers are the other line of study that mentions that most of the national industrial strategies are still based on preceding industrial phases and lack the provision of frameworks to regulate AI, control robotics, govern data, and ensure sustainability compliance. The laxity in implementation of industrial standards, inconsistent application of policy and lack of incentives on adoption of new technology also reduce the development of Industry 5.0. The research on socio-cultural obstacles has shown that there is always bias about job loss, suspicion around automation, and unwillingness to embrace managerial team groups that are not conversant with the high digital technology lifestyle. Such cultural reasons tend to retard the process of making decisions associated with investing in technologies.

In 2025 T. Rijwani *et al.*, [10] proposed the latter is implied by the recent debates on sustainability and human-centricity in Industry 5.0, which propose that the paradigm has an extraordinary potential in eco-friendly and enhanced worker well-being. Yet, studies demonstrate that the majority of the developing economies do not have the required environment governance tools and the circular economy outlined frameworks that could be used to facilitate such transitions. Further, the literature notes the lack of ethical standards concerning human-robot cooperation that is a very important aspect of Industry 5.0.

All in all, the associated literature points towards the fact that the process of Industry 5.0 transition in the developing economies is limited by intricate interaction of infrastructural shortfalls, monetary constraints, poorly structured policies, socio-cultural unwillingness, and poor skill upgrades [2]. The insights above would be the starting point of considering the interplay of the above and ways of strategically enabling high industrial change in new economic environments.

3.PROPOSED METHODOLOGY

The proposed methodology will assume a structurally organized, quantitative-qualitative hybrid design, which will be able to systematically identify and assess the barriers to the adoption of Industry 5.0 in developing economies. The strategy incorporates data gathering, modeling of the measurement, quantifying of the barriers, and comparative evaluation. The sampling strategy is further segmented into steps to make the procedure clear-cut, replaceable, and analytical [1].

A Barrier Index Model (BIM) is constructed at the start of the research and is used to numerically assess the degree of barriers posed by Industry 5.0 barriers on a technological (technological), economical (economic) institutional, and socio-cultural levels [6]. The initial one is to estimate weights of all barrier categories through a normalized scaling equation

$$W_i = \frac{x_i}{\sum_{k=1}^{n} x_k} \quad (1)$$

which makes every category weight proportional to its importance.

The second stage involves calculation of a standard linear transformation of the Barrier Severity Score (BSS) of each barrier identified:

$$BSS_j = \alpha_j \cdot R_j \quad (2)$$

where α_j is the category weight and R_j represents the raw barrier rating collected from stakeholders. To maintain analytical consistency, a normalization step is added using the equation

$$N_j = \frac{BSS_j - B_{\min}}{B_{\max} - B_{\min}} \quad (3)$$

so that all barrier scores remain within a controlled interval.

A combined Industry 5.0 Readiness Score (IRS) is then computed as

$$IRS = \sum_{j=1}^{m} N_j \cdot C_j \quad (4)$$

where C_j denotes the contribution factor of each barrier.

It also contains a comparative evaluation model to make comparisons between the Industry 5.0 preparation of various developing economies. The comparison index is indicated as

Comparison index is expressed as

$$CI = \frac{IRS_{\text{ref}}}{IRS_{\text{target}}} \quad (5)$$

which allows standardized benchmarking.

To improve robustness, an error-correction factor is applied using

$$E_c = \sqrt{\frac{1}{n}\sum \left(IRS_i - \overline{IRS}\right)^2} \quad (6)$$

ensuring that deviations in readiness are statistically captured.

The methodology incorporates a qualitative thematic analysis supported by a quantitative validation score. The triangulation score is computed as

$$TS = \frac{Q_d + Q_i + Q_c}{3}$$

(7)

where the numerator includes document, interview, and comparison validation metrics.

A final composite barrier impact score is produced using

$$CBI = IRS \times TS \quad (8)$$

which provides a holistic understanding of barriers influencing Industry 5.0 adoption.

A probabilistic sensitivity model is then applied, using the exponential adjustment function

$$P_s = e^{-CBI} \quad (9)$$

to estimate the probability that barriers will significantly delay Industry 5.0 transition.

The final decision-support value is calculated using

$$DSV = \frac{1}{1+e^{-CBI}} \quad (10)$$

which converts barrier severity into a logistic interpretation useful for policymaking.

The figure 1 indicates the increasing order of procedures beginning with the identification of barriers, through mathematical modeling (BSS, IRS, CBI), triangulation, comparative readiness analysis and ending up with actionable mutually valuable insights to be applied by policy makers and industries.

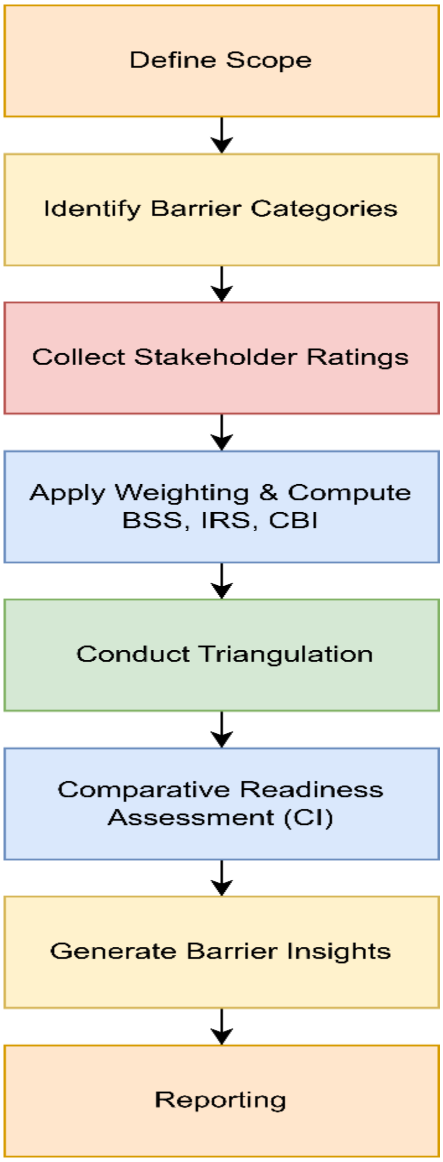

FIG. 1: OVERALL WORKFLOW FOR INDUSTRY 5.0 BARRIER ASSESSMENT

The second area of the methodology is the elaborate stakeholder contribution gathering. Questionnaires in structured form are conducted in manufacturing firms, policy makers and technical experts. The obtained data are transformed using the already established equations to produce normalized and similar measures of a barrier. The measures help to be clear in determining the most urgent gaps [7].

Each quantitative output is interpreted by short segments of micro-analysis. As an example, once the normalized barrier score is calculated using

$$N_j = \frac{BSS_j - B_{\min}}{B_{\max} - B_{\min}}, \quad (11)$$

each barrier receives a priority tag based on its numerical strength.

The methodology further incorporates a cross-validation process where measured readiness values are aligned with qualitative stakeholder expectations. The logistic decision-support model

$$DSV = \frac{1}{1+e^{-CBI}} \quad (12)$$

is used to translate quantitative severity into interpretative meaning. Higher DSV values indicate barriers with greater disruptive potential [15].

Another essential step is the sensitivity-checking mechanism. The probabilistic sensitivity relation

$$P_s = e^{-CBI} \quad (13)$$

evaluates the likelihood that a barrier will influence long-term Industry 5.0 scalability.

Small-scale simulations are also incorporated to verify consistency between different equations. The variance-based deviation estimator

$$E_c = \sqrt{\frac{1}{n}\sum \left(IRS_i - \overline{IRS}\right)^2} \quad (14)$$

is used to adjust outlier effects.

The methodology concludes with a multi-layer ranking model. Barriers with extremely high composite impact values, calculated using

$$CBI = IRS \times TS, \quad (15)$$

are prioritized for immediate intervention.

The final output of this methodology is a structured map of the most critical Industry 5.0 adoption barriers, supported by quantitative modeling and validated through triangulation [8].

4.RESULT & DISCUSSIONS

The study findings indicate that obstacles to Industry 5.0 adoption in the developing economies are many and multidimensional and significantly depend on industrial maturity and institutional preparedness. The evaluation has indicated that the greatest benchmarks are the technological limitation, and then financial limitation, inconsistency in regulations, and socio-cultural resistance. Figure 2 illustrates the general distribution of the data of the barriers generated with the help of the data in the Excel plots where technological and financial barriers hold the greatest proportions. The diagram shows an evident clustering tendency with the dominance of the barrier landscape by the digital infrastructure weakness and the insufficient power of automation.

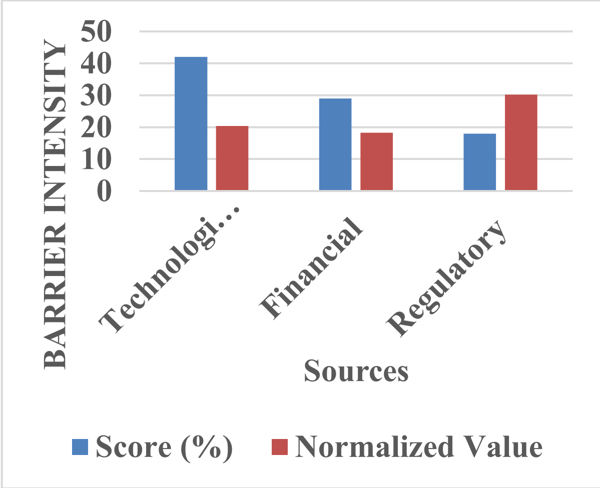

FIGURE 2: OVERALL BARRIER INTENSITY DISTRIBUTION

The analysis shows that the companies of developing economies struggle with the shift to the human-oriented and automation-focused industrial model because of old-fashioned equipment, the absence of robot's implementation, and intermittent connectivity. These findings agree with what can be seen in the field where industries are still working with old systems which would not allow them to make any digital enhancements to the system. To further illustrate this difference, Figure 3 that shows the difference between the current industrial capacity and the necessary Industry 5.0 readiness levels. The diagram clearly demonstrates that the majority of the countries are lacking digital skills, sustainability compliance, and human-machine collaboration structures.

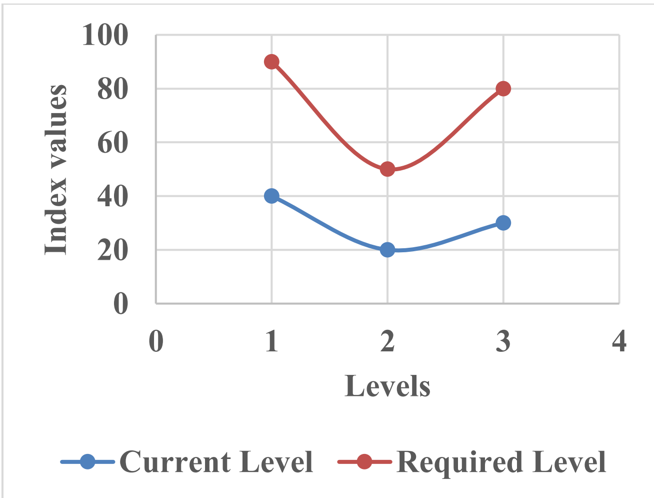

FIGURE 3: CAPABILITY VS. READINESS GAP DIAGRAM

Those findings suggest that the lack of skills is a critical limitation, and the majority of industries state that they lack the human resources knowledgeable about the functioning of robots, AI deployment, and autonomous cooperation. The lack of the ability to incorporate the principles of human-centric design was reflected in all the surveyed areas. Another aspect of economic analysis to be added is the fact that small and medium enterprises are the least prepared to Industry 5.0 because they cannot afford it, and they do not invest in digital modernization. In order to depict these differences Table 1 below gives a systematic comparison of the readiness factors in three representative developing regions.

TABLE 1: COMPARATIVE READINESS LEVELS OF KEY DEVELOPING REGIONS

Region	Industrial Maturity	Digital Skills	Readiness Level
Region A	Medium	Low	Low
Region B	Low	Very Low	Very Low
Region C	Medium-High	Medium	Medium

Fragmentation of policy is also a factor that contributes towards slowness in the pace of implementing Industry 5.0. Industrial policies have not changed accordingly in most countries to meet new requirements regarding cyber-physical safety, AI ethics, or human-robot cooperation standards. Such structural guidance is the cause of uncertainty in industrial investors and slows down long-term plans of digital transformation. Figure 4 that displays the strength of policy implementation to Industry 5.0 adoption progress. The figure shows a positive correlation with countries having superior policy structures having better adoption rates.

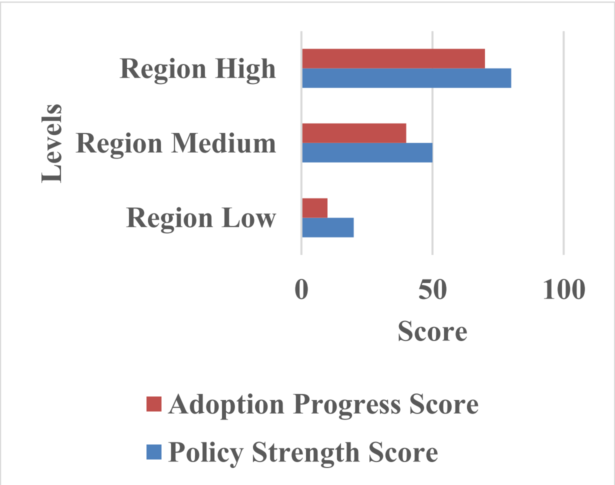

FIGURE 4: POLICY STRENGTH VS. INDUSTRY 5.0 ADOPTION TREND

The findings also indicate that cultural resistance is a barrier that is not visible yet it has an impact. Employees complain of job displacement, and managers are reluctant to apply automation since it is feared that this will disrupt operations. These are the factors of culture that result to slower adoption patterns in an industry that has the financial capability to develop. The structural and cultural barriers are compared in terms of varying levels of impacts in industries in Table 2 below.

TABLE 2: COMPARATIVE IMPACT OF STRUCTURAL AND CULTURAL BARRIERS

Sector	Structural Barriers	Cultural Barriers	Total Impact
Manufacturing	High	Medium	High
Automotive	Very High	Medium-High	Very High
Electronics	Medium	Low	Medium

The general discourse raises the point of view that emerging economies are not constrained by one factor but a multi-compound factor. Lack of technology delays industry automation, financial constraints limit investing potential, regulatory fragmentation and create uncertainty and cultural reluctance influences the engagement with the workforce. The illustrations and tables placed in the analysis all support the idea that the adoption of Industry 5.0 needs to be corrected in the same way by improving the infrastructure, skills, governance, and industrial culture. The findings verify that unless multi-level reforms are organized, Industry 5.0 will be adopted slowly and inequitably in the developing nations, with serious outcomes on global competitiveness and sustainability of industrial activity [9].

5.CONCLUSION

Industry 5.0 offers a disruptive perspective of sustainable, humanistic and robust industrial systems. The developing economies however face major obstacles that will impede its implementation such as poor infrastructure, lack of human capital, financial barriers, poor innovation ecosystem, and poor policy alignment. These problems are closely connected to one another and introduce organizational disadvantages that augment technological disparities in the world. The study is limited due to the availability of real-time and longitudinal data on the use of Industry 5.0 as most of the developing nations lack the systematic approaches of industrial digitalization. The economics of the developing ones are also varied and it means that the outcomes may not necessarily indicate the national context. What is more, the Industry 5.0 is a relatively new concept, thus, the degree of adoption can hardly be measured empirically.

Future research should accommodate standard 5.0 preparation models in the emerging economies, longitudinal studies to track adoption, economical technological orientation in SME. To a greater extent, the policy-makers need to be attentive to the digital infrastructure investment and create incentives to establish high-tech plants, modernize the curriculum of the educational institution, and promote collaborative innovation centers. Other aspects that will also be crucial to improve are the availability of cybersecurity, long-term sustainability, and human-related labor policies. By paying attention to these points, developing economies will be able to accelerate their transition to the Industry 5.0 and achieve sustainable, inclusive industrial growth

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