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Original article

RECOMMENDATIONS TO IMPROVE THE LEVEL OF READINESS FOR INDUSTRY 4.0 IN MONGOLIA

RECOMENDACIONES PARA MEJORAR EL NIVEL DE PREPARACIÓN PARA LA INDUSTRIA 4.0 EN MONGOLIA

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Abstract

The Fourth Industrial Revolution, also called Industry 4.0, is characterized by the presence of cyber-physical systems that allow the hybridization of the physical world with the digital one. This process is deeply permeating all sectors of society, government organizations, the business sector and citizens. However, harnessing the advanced digital production technologies of the Fourth Industrial Revolution remains extremely concentrated in a few economies. In the case of Mongolia, the percentage of products manufactured by high-tech companies is very low, and the rate of adoption of this new paradigm is quite slow. For this reason, it is necessary to evaluate at the macro level the preparation conditions that the Mongolian nation has to adopt Industry 4.0. In this article, studies that include dimensions of Mongolia's readiness for Industry 4.0 are analyzed, in particular the assessment provided by the GRAMI4.0 model, complemented with some additional specific indicators. Comparisons are made with other countries in the Asian region to establish the position of the country under study with respect to its neighbors. The results of the evaluation made it possible to outline a SWOT matrix and propose general recommendations with the intention of increasing the awareness of government institutions that are

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leading the electronic transition and industrialization processes, to favorably contribute to the adoption of Industry 4.0 in a more growth in the Mongolian economy.

Keywords: Industry 4.0, GRAMI4.0, SWOT matrix, assessment, digital technologies

Resumen

La Cuarta Revolución Industrial, también llamada Industria 4.0, se caracteriza por la presencia de sistemas ciberfísicos que permiten la hibridación del mundo físico con el digital. Este proceso está calando profundamente en todos los sectores de la sociedad, las organizaciones gubernamentales, el sector empresarial y los ciudadanos. Sin embargo, el aprovechamiento de las tecnologías digitales avanzadas de producción de la Cuarta Revolución Industrial sigue estando extremadamente concentrado en unas pocas economías. En el caso de Mongolia, el porciento de productos fabricados por empresas de alta tecnología es muy bajo, y el ritmo de adopción de este nuevo paradigma es bastante lento. Por eso se hace necesario evaluar a nivel macro las condiciones de preparación que tiene la nación mongola para adoptar la Industria 4.0. En este artículo se analizan estudios que incluyen dimensiones de alistamiento de Mongolia para la Industria 4.0, en particular la evaluación proporcionada por el modelo GRAMI4.0, complementado con algunos indicadores específicos adicionales. Se hacen comparaciones con otros países de la región asiática para establecer la posición que ocupa el país objeto de estudio respecto a sus vecinos. Los resultados de la evaluación permitieron esbozar una matriz DAFO y proponer recomendaciones generales con la intención de incrementar la conciencia de las instituciones gubernamentales que están liderando los procesos de transición electrónica y de industrialización, para contribuir favorablemente en la adopción de la Industria 4.0 de forma más acelerada en la economía de Mongolia.

Palabras clave: Industria 4.0, GRAMI4.0, matriz DAFO, evaluación, tecnologías digitales

Introduction

Mongolia is a sovereign, landlocked state located in East Asia. It borders Russia to the north and China to the south. Mongolia has an area of 1,564,116 km2 and a population of 3.4 million as of 2022.[1] Mongolia is one of the countries with abundant natural and mineral resources.[2] In this sense, it ranks 41st in the world index. The mining sector is the main sector that determines the country's geoeconomic space and the future of regional development at the macroeconomic level. It represents 20% of the gross domestic product, 70% of the industrial product, and 94% of the income from exports, employing more than 56,635 people.[3] However, in recent years, the economic recovery has been delayed and inflation has risen, facing unexpected crises and mixed risks.[4]

Today, there is talk of the fourth Industrial Revolution, also associated with Industry 4.0. Industry 4.0 enables and supports new scenarios in production, where man, machines, production lines, software systems, and products communicate and cooperate in real time to facilitate decision-making. Decentralized decision-making and self-organized production.[5] Many sectors will have an intensive impact shortly. For example, the fields of artificial intelligence, drones, robotics, and 5G can be highlighted.

In 2016, Klaus Schwab6 defined the first concept of the Fourth Industrial Revolution (4IR), with a definition as follows: “The Fourth Industrial Revolution generates a world in which virtual and physical manufacturing systems flexibly cooperate globally”. [6] It is an industry based on intelligent factories integrated with new technologies, such as the Internet of Things (IoT), cloud computing and analysis, Artificial Intelligence, robotics, augmented reality, or machine learning in its production facilities and operations.

There is a set of valuable digital technological tools that enable digital transformation, such as the Internet of Things,[7] Big Data,[8] Artificial Intelligence,[9] Cloud Computing,[10] Autonomous Robots,[11] and the 5th generation networks. 5G generation,[12] additive manufacturing or 3D printing,[13] and vertical and horizontal integration,[14] among others.

This paradigm and its enabling technologies have brought with it the revival of new patterns of competitiveness and advanced economies that become a great challenge for many countries in the implementation phase of this new era.[15] For example, in Mongolia, on 19 On August 2022, Unitel Group turned on the 5G network test station in the central square of Ulaanbaatar for the first time and opened it to the public. With the full introduction of this technology, not only will users be able to use high-speed Internet, but it will also bring important changes and advantages in terms of infrastructure in the health field, mining, and education.[16]

Also, in 2019, the Government of Mongolia established the "National Committee for Electronic Development" as part of its implementation in the country to make technological progress accessible, fast and safe to citizens. Work is being done on the goal of turning the country into a "Digital Nation" in 2021-2024.[17,18] However, a minimum of the total product produced in the country has high technology and innovation, therefore, in 2018, the Committee was established Electronic Policy in Parliament to prepare for the Fourth Industrial Revolution. The government is focusing on preparation for the Fourth Industrial Revolution and effective participation at the state policy level, setting specific goals and objectives in the "Three Pillar Development Policy" and working to start implementing them.[19]

Countries must understand how and where the advanced production technologies associated with Industry 4.0 (4IR) can be harnessed to address some of the world's most pressing environmental, economic, and social challenges. The regulatory and technology access gaps are greater in developing and the least advanced countries, so there are fears that some of them will be left behind. At the same time, with the recent coronavirus COVID-19 pandemic, it is more important than ever to use 4IR technologies to move out of the pandemic onto a path of sustainable and inclusive growth.[20]

The drivers or enablers of the Fourth Industrial Revolution that are present today in the national environment in Mongolia are known, as well as where the main difficulties lie. Despite the will expressed by the high direction, the bases for a national strategy that impacts the adoption of Industry 4.0 in an accelerated manner in the coming years have not been identified. Insufficient preparation of the productive systems to adopt Industry 4.0 persists, whereby it is necessary to multidimensionally evaluate the country's situation in the face of this paradigm, to obtain recommendations that can contribute to establishing a roadmap and, with it, accelerate its development towards the Fourth Industrial Revolution.

Considering this context, the article aims to offer some recommendations derived from the analysis of

several previous evaluations on dimensions that contribute to the level of preparation of Mongolia, combined with a SWOT analysis (Weaknesses, Strengths, and Opportunities), obtained from the findings. of the evaluations and indicators analyzed.

Materials and methods

In order to analyze the level of readiness of Industry 4.0 in Mongolia and make recommendations on potential improvements, a methodology is used that follows the following steps:

1) Selection of studies on Mongolia about the level of preparation in Industry 4.0.
2) Synthesis of the behavior of the dimensions and indicators analyzed using a SWOT matrix (Weaknesses-Threats-Strengths-Opportunities)
3) With the findings obtained and the SWOT matrix, obtaining recommendations for improvement.

Figure 1 shows the methodological scheme of the research.

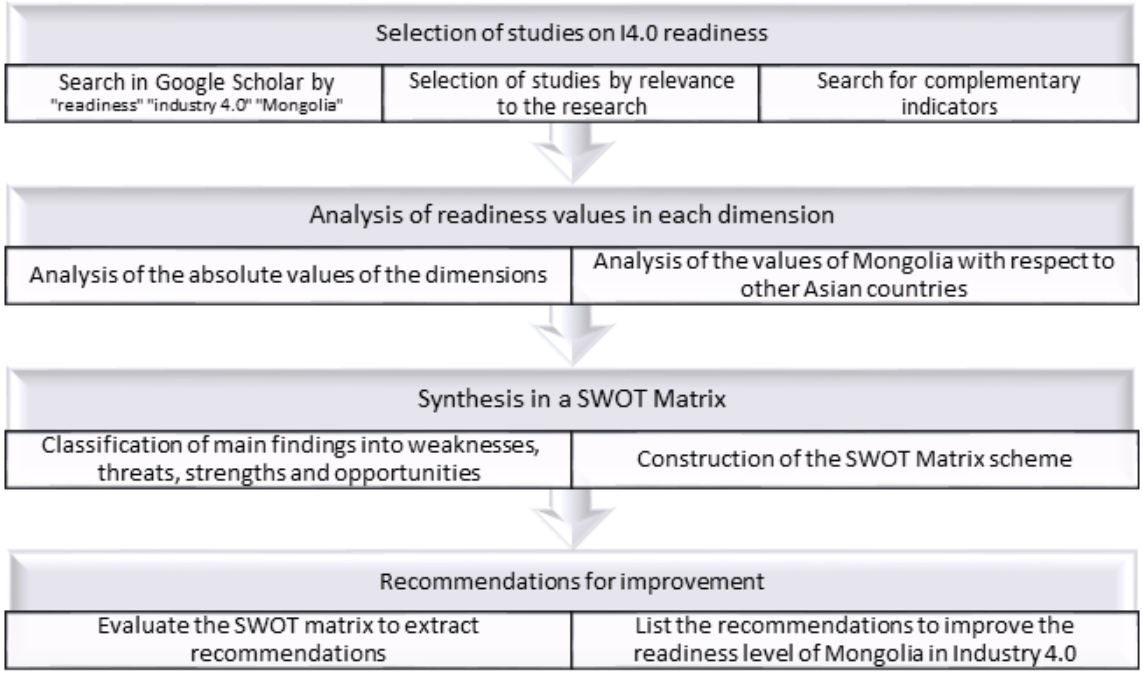

Figure 1. Methodological scheme of the research.
Source: Own elaboration.

Results

In the search with academic Google using the keywords in English: “readiness” & “industry 4.0” & “Mongolia”, although 229 results came out, only one study reported in 2021 addressed the evaluation of readiness in Industry 4.0 holistically and at the country level; that is, not in specific sectors/scenarios. The study obtained corresponds to the assessment carried out by Tripathi, S. and Gupta, M[21], which evaluates seven dimensions with 63 indicators. twenty-one.

In the GRAMI4.0 model, each of the pillars of preparation for I4.0 is adopted by combining the macro transformation factors that represent essential areas in the socioeconomic industrial development of a nation. These pillars are grouped into seven dimensions, which are: (1) Favorable environment, (2) Human resources, (3) Infrastructure, (4) Ecological sustainability, (5) Innovation capacity, (6) Cybersecurity, and (7) Consumers.[21]

It is included a summary of the assessment of Mongolian readiness for Industry 4.0 using the GRAMI 4.0 methodology, in **Figure 2**.

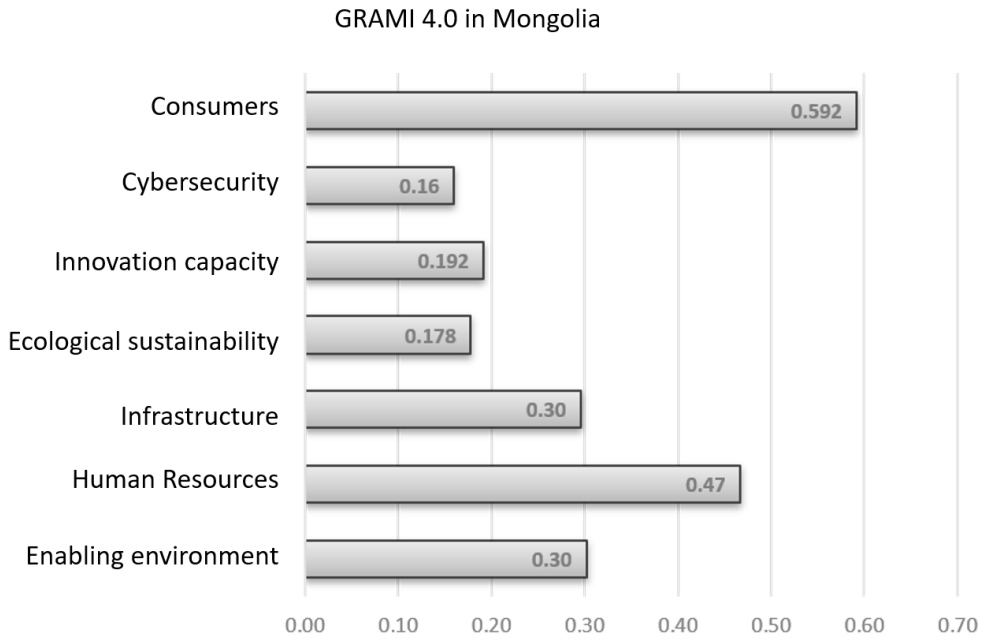

Figure 2. GRAMI 4.0 dimensions in Mongolia.
Source: Own elaboration from GRAMI4.0[21]

The GRAMI4.0 enlistment index is obtained from the weighted combination of these dimensions, and in the case of Mongolia it reaches a value of 0.312 in the study by Tripathi, S. and Gupta, M[21]. This value reveals that Mongolia has a low Industry 4.0 readiness score. Globally, the median score for the I4.0 Readiness Assessment is 0.406. A wide range of performance is observed in the regions between Denmark (0.65, 1st place) and Chad (0.11, 26th place). 12 of the 20 leading countries are European, 4 Asian and 2 countries from Oceania and North America (NA). At the other end of the spectrum, 14 of the bottom 20 nations are African.

The regional analysis shows that Asia is the most diverse region with a readiness score of I4.0 spread between Japan (0.641, 5th place) and Yemen (0.131, 125th place). 39 Asian countries were assessed, among which 13 are above 50 and 18 have an I4.0 readiness score above average. EA (East Asia) is the most prepared region with 4 of the top 10 Asian countries having above average I4.0 preparation. EA has an average score of 0.52.

Table 1 summarizes the values for countries in East Asia, where Mongolia is located.

Table 1. GRAMI4.0 dimensions in East Asian countries

Region	Range	Country	Favorable National Environment	Human Resources	Infrastructure	Ecological Sustainability	Innovation Capacity	Cybersecurity	Consumers	Punctuation GRAMI 4.0
EA	5	Japan	0.542	0.803	0.762	0.363	0.552	0.326	0.866	**0.642**
	12	China	0.639	0.445	0.709	0.543	0.56	0.611	0.742	**0.607**
	24	Malaysia	0.5	0.692	0.639	0.216	0.524	0.326	0.866	**0.538**
	28	Corea del Sur	0.453	0.641	0.746	0.031	0.494	0.313	0.963	**0.52**
	96	Mongolia	0.302	0.467	0.296	0.178	0.192	0.16	0.592	**0.312**

Source: self-made from GRAMI4.0[21]

Figure 3 shows the comparative behavior of these East Asian countries for each of the dimensions of the GRAMI 4.0 assessment.

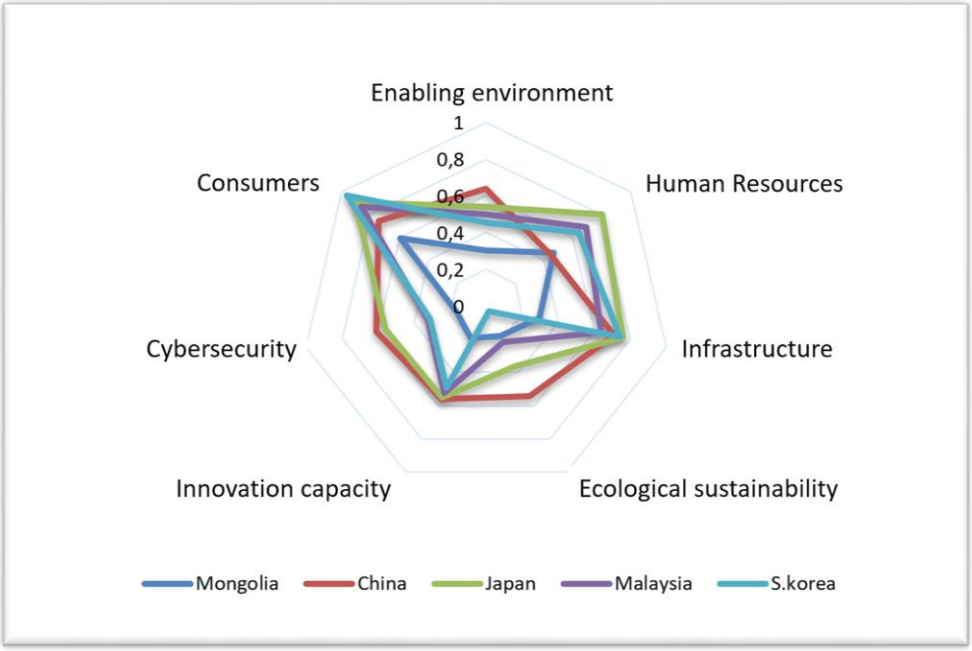

Figure 3. Readiness analysis of East Asia subregion in dimensions.
Source: Own elaboration from GRAMI4.0[21]

Figure 3 shows a great disparity within the East Asia region, led by China (0.607, 12th place) and with the lowest index (0.312) is Mongolia in 96th place, which suggests the need to strengthen leadership and develop proactive policies towards I4.0.

Analysis of complementary indicators

Other studies complement the analysis of the GRAMI4.0 model, such as the assessment of the attractiveness of the telecommunications and information industry in Mongolia[22] based on 15 factors, one of which, identified as Growth Potential in Information and Communication Technologies (TIC), has a key impact on the I4.0 enlistment level in this country.

According to this study, in the past decade, Mongolia's ICT revenue has grown year by year, as shown in Figure 4. The use of telecommunication products and services such as mobile phones and landlines is expected to continue to grow, Internet, cable TV and postal services.

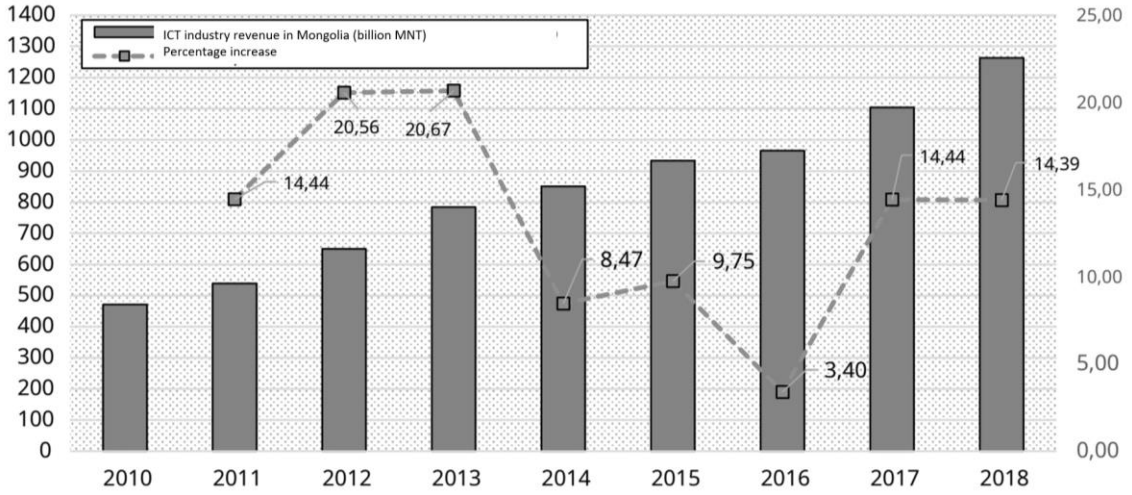

Figure 4. Annual revenue of the ICT industry in Mongolia (MNT million)
Source: adapted from Jambal & Jambal[22]

On the other hand, the IMD World Digital Competitiveness Ranking (produced by the Institute for Management Development) presents comparisons between countries in three subcategories: knowledge, technology and preparation for the future, for 63 economies.[20] A subset of countries is selected from Asia Pacific of this index, for analysis. The rankings show huge disparities between countries in the region, with Mongolia ranking as the bottom second globally (62nd) in both 2021 and 2019.

The numerical value of the IMD represents the position in the ranking and describes the importance of national factors in explaining the digital transformation of companies and the adoption of digital practices by citizens. Digital nations are the result of a combination of digital talent, digital regulation, data governance, digital attitudes, and availability of capital. Therefore, it is considered a good "proxy indicator" to tax the level of preparation in Industry 4.0.

Another indicator to assess levels of readiness in Industry 4.0 is the Global Business-to-Consumer (B2C) E-Commerce Index, which measures a country's readiness to support online commerce, where factors such as ICT development and the Internet penetration play an important role. Particularly in the East Asia region, it behaves as shown in **Figure 5**, according to the UNCTAD B2C E-Commerce Index..[20]

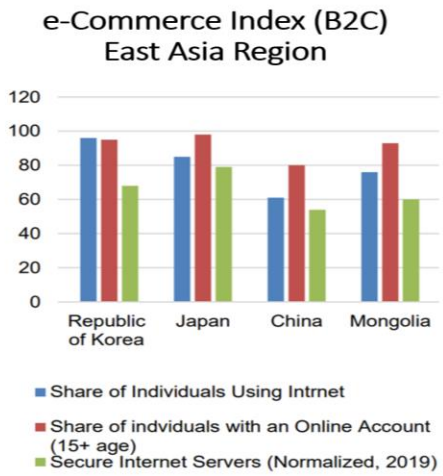

Figure 5. B2C E-Commerce Index in The East Asia Region
Source: Own elaboration from[20]

Although not at the level of the Republic of Korea and Japan, the leading countries in the group, this indicator, and particularly the proportion of people over 15 years of age with an online account, represents a strength for Mongolia to face Industry 4.0 technologies, since consumer perspective.

On the other hand, a complementary study[23] reveals the need to promote new careers and expand educational capacities in engineering, mathematics, data science and other careers that contribute to the absorption capacity of the skills associated with Industry 4.0. In the 2020-2021 academic year, 31,161 students graduated from diploma, bachelor's, master's, and doctoral programs from institutions of higher education. While in the 2021-2022 academic year, 32,925 students graduated, an increase of 1,764 or 5.7% over the previous year,23. 627 students completed diploma education, 26,240 bachelor's degrees, 5,954 master's degrees, and 104 doctorates. **Figure 6** shows this percentage distribution.

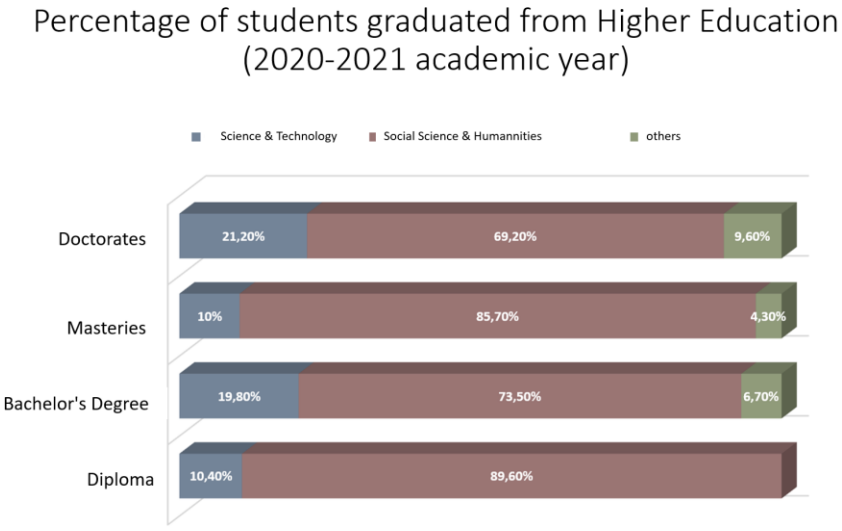

Figure 6. Statistical information for the 2020-2021 academic year of the higher education sector
Source: Own elaboration from statistical information [24]

To put this goal in perspective, only 5,189 people graduated from science and technology diploma, bachelor's, master's, and doctoral programs in 2022, compared to 19,284 graduations from Mongolia's social sciences and humanities university programs.[23]

As can be seen in Table 2, according to the classification of students by professional field of study: of the total number of students, 15.4% represent pedagogical careers; 5.3%, arts and humanities; 5% social sciences, information and journalism; 29.5% business, administration and law; 1.9%, natural sciences, mathematics and statistics; 3.36% in information and communication technology; 9.1% in engineering, production and design; 1.5% for agriculture, forestry, fisheries and veterinary medicine; 14% for health and social security; 4.0% in services; 2.2% are other races.

Table 2. Proportion of students in higher education institutions (last 5 years)

Name of the professional direction (program)	**Proportion of the profession in the total number of students (%)**				
	2016	2017	2018	2019	2020
Education	14.0	13.2	14.8	13.3	15.4
Art and humanity	7.5	8.2	8.7	9.2	8.2
Social sciences, information and journalism	5.2	5.8	4.5	4.6	5
Business, administration, law	26.7	26.0	27.5	26.5	29.5
Institute of natural sciences, mathematics, statistics, biology	3.6	3.9	2.7	2.3	3
Technology of the information and communication	2.7	2.3	3.2	3.7	3.4
Engineering, production and design	17.3	16.5	14.5	16	13.4
Agriculture, forestry, fishing, veterinary medicine	2.6	2.2	2.2	1.6	1.5
Health and social security	11.8	13.3	14.2	15.5	14
Services	4.0	3.6	4.0	4	4.4
Others	4.6	4.7	3.6	3.2	2.2
Total	100.0	100.0	100.0	100.0	100.0

Source: Own elaboration based on national statistics of Mongolia [24]

In contrast to the information in **Table 2**, there is a great demand for graduates in careers such as Information and Communication Technologies, as well as others associated with the development of Industry 4.0, which is shown in **Figure 7**.

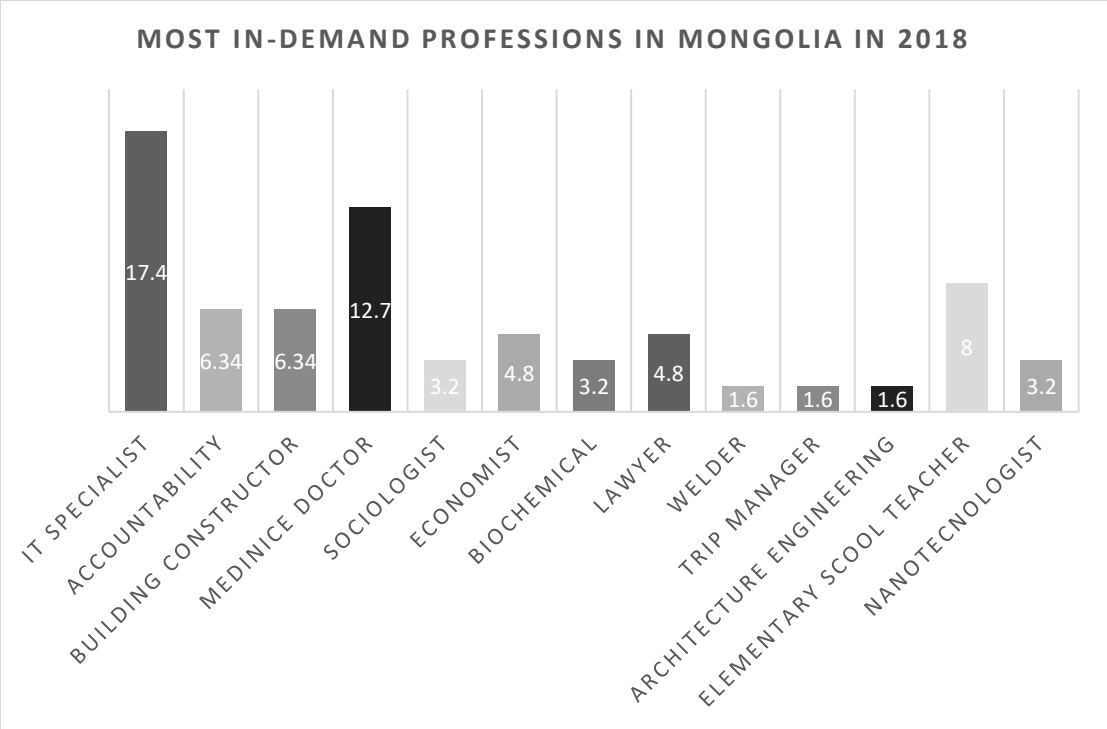

Figure 7. Most in-demand professions in Mongolia in 2018
Source: Own elaboration from statistical information [24]

Generalized SWOT Matrix of Industry 4.0 in Mongolia

From the analyzes on Mongolia's level of readiness for Industry 4.0 carried out in this article, some findings can be obtained that serve to promote a roadmap in this regard in the future. With the information analyzed, the authors have summarized the main weaknesses, threats, strengths and opportunities.

Weaknesses

1. Low innovation capacities, expressed in:

    - Low proportion of researchers per million inhabitants.
    - Low percentage of the Gross Domestic Product devoted to Research and Development (R&D).
    - Low university-industry relationship.

2. Insufficient use of advanced technologies in the industry.
3. Very low population density.
4. Low levels of Cybersecurity services.
5. Difficulties in obtaining financing for entrepreneurs.

Strengths

1. A favorable political environment with a commitment from the country's top management to technological development, expressed in:

    - the Digital Nation 2020 Policy (2020-2024).
    - the Vision-2050 long-term policy document, approved by Parliament on May 25, 2020.
    - To ensure the governance of these policies, the Ministry of Electronic Development was established in 2022 to intensify the electronic transition.

2. Population with high capacities to assimilate and adopt new technologies, expressed in a high literacy rate (99%).

3. Favorable digital competitiveness in some aspects, mainly those related to consumers and the penetration of mobile telephony, expressed in the sustained growth of:

    - Income in the industrial sector of Telecommunications and Information Technology.
    - Individual Internet use (including online accounts).
    - Electronic commerce and digital services from businesses to consumers (B2C).

4. High reserves of mineral resources, necessary for the development of Industry 4.0.

Although the external scenario of Mongolia was not studied primarily in this thesis, the threats and opportunities that manifest themselves as mega trends in relation to the object of study can be outlined.

Threats

1. The global crises produced by pandemics, such as Covid-19, and by regional wars have a negative impact on global logistics and on the possibilities of less developed countries to reduce the technological and industrial gap.

Opportunities

2. Global needs for mineral resources as a basic raw material for advanced technologies in the Fourth Industrial Revolution.
3. Funds from Mongolia's multilateral cooperation and trade partners in the Asia-Pacific region and in Europe

Figure 8 summarizes the main weaknesses, threats, strengths and opportunities in the corresponding SWOT matrix.

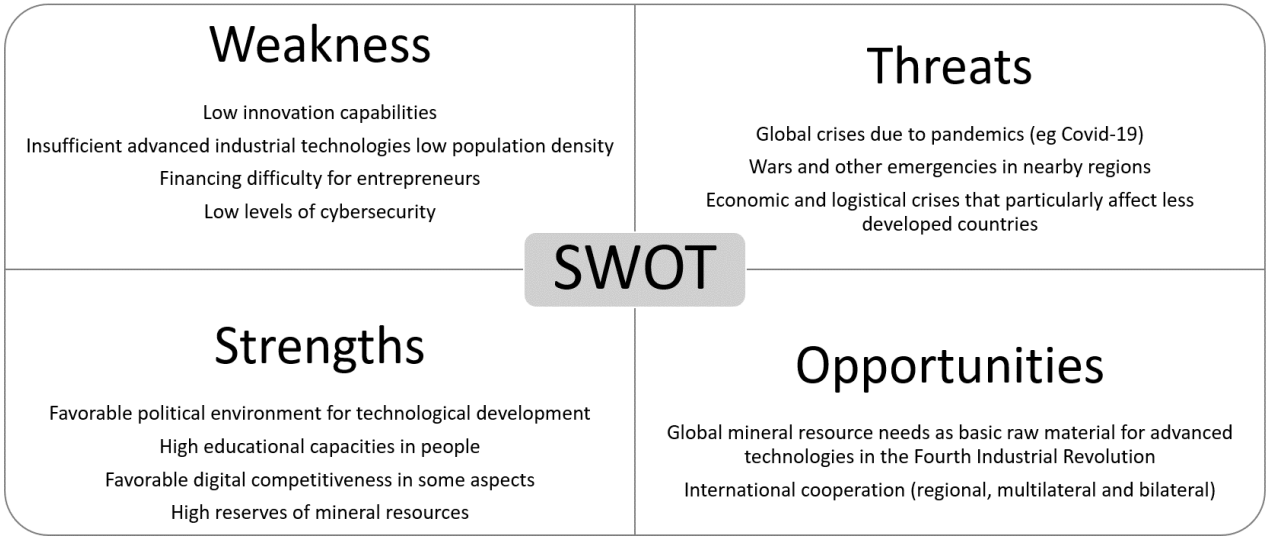

Figure 8. SWOT Matrix of Mongolia to face Industry 4.0
Source: Own elaboration

Discussion

The analysis of the GRAMI4.0 model in Mongolia showed that the lowest values in preparation for Industry 4.0 focus on the dimensions of Cybersecurity, Ecological Sustainability and Innovation Capacity, while the best one located at a value close to 60% is the relative to consumers followed by general preparation of people. However, in general it presents a very low enlistment rate.

Although lower than its Asian neighbors, the Global Business-to-Consumer (B2C) E-Commerce Index in Mongolia reveals an acceptable level, which validates the relatively high value obtained in the Consumers dimension in the GRAMI4.0 model. Regarding the National Competitiveness Index, Mongolia lags far behind other Asian countries.

Complementary research on the training of Higher Education in Mongolia, showed that currently computer specialists are the most demanded in the labor market, however, there is a deficit in the training of this profession and other technology careers.

More engineers need to be trained, be more creative, be able to see problems and train people who can solve problems. The areas with the most jobs and the potential to create the most value are undoubtedly the IT, programming and electronics industries. With a look of 20 or 30 years, the younger generation must be educated in quantum computing and biotechnology from now on.

Based on the analysis of the SWOT matrix and the findings obtained from the study, some recommendations are proposed for the future establishment of an Industry 4.0 roadmap. These recommendations are not intended to be exhaustive, but they are supported by the analyzes carried out in this article. They were prepared with the findings obtained in the GRAMI 4.021 evaluation for

Mongolia and the complementary indicators analyzed. The analyzes on the SWOT matrix are privileged, which allow strengthening the strengths in combination with the opportunities, or mitigating the weaknesses based on the strengths.

1. Take advantage of the opportunity offered by South-South, triangular cooperation projects and multilateral agencies, such as the United Nations Agency for Industrial Development (UNIDO), to enhance Mongolia's innovation capacities, based on using its high potential and human resource competencies.

2. Taking advantage of the DIGITAL NATION legal framework and the long-term vision of 2050, as well as the already advanced digital skills of consumers, mass customization of industrial production should be evaluated and promoted in more dynamic sectors, through products and platforms as services.

3. Given the low population density of Mongolia, it is suggested to take advantage of the opportunities offered by the integrationist blocs of the Asia-Pacific region to attract highly qualified foreign professionals and foreign investors, based on the creation of tax incentives, facilities for work visas of foreign entrepreneurs or experts and the creation of Special Development Zones, high technology and Technology Parks.

4. Take advantage of the needs that other countries have for mineral resources required for the development of Industry 4.0, to establish mutually beneficial agreements that allow Mongolia to insert itself into global value chains and develop the industry with new technologies of the Fourth Industrial Revolution.

5. Take advantage of the country's high educational level and promote the establishment and implementation of a policy focused on the training of specialists in the areas of natural sciences, mathematics, information and communication technologies, engineering, production, in addition to other communication skills and of design, to expedite the absorption of advanced digital technologies in production and collaborative skills to be better prepared to face the challenges of adopting Industry 4.0.

6. Considering Mongolia's low level of preparation on the issue of ecological sustainability, evidenced in the GRAMI4.0 study, while mining, which brings with it high environmental pollution, is one of its main strengths, it is strongly recommended to adopt the ISO 14,000 in all Industry 4.0 initiatives related to the extraction of mineral resources.

7. Similarly, to correct the weakness in the subject of Cybersecurity evidenced in the low value obtained in GRAMI4.0, which may become more acute as information and communication technologies develop, it is recommended that the country adopt the ISO 27000 family of standards, which provides requirements for the establishment, implementation, maintenance and continuous improvement of an ISMS based on the well-known Deming Cycle or PDCA (from the acronym of the words in English Plan-Do-Check-Act) that consists of the 4 phases of Plan, Do, Check and Act.

Conclusions

The Fourth Industrial Revolution and its new technologies constitute the basis for the success of industrial development in the modern era, allowing the creation of new goods, the emergence of new industries, as well as insertion in global value chains. They bring greater production efficiency, increased profits, and more personalized customer satisfaction. However, according to recent reports from the United Nations Agency for Industrial Development, its adoption is concentrated in countries with highly developed economies.

To understand the essence of this situation and transform it, it is necessary for countries, particularly the least developed ones, to evaluate their levels of preparation or enlistment with respect to Industry 4.0, in order to adjust their action programs based on enhancing their own strengths, resolving prioritize their weaknesses and rapidly transform their production systems, based on the use of new advanced digital production technologies.

Mongolia exhibits a discrete level in the development of Industry 4.0, according to the results of the evaluation of the GRAMI4.0 dimensions. However, important strengths can be seen, such as the vision of the country in relation to the electronic transition that is being promoted, which is supported by a legal framework in the short, medium and long range. Likewise, an increasing competitiveness in information and communication technologies facing the consumer is being appreciated, which, together with the high educational level of the population, can be used for the development of the paradigm of the Fourth Industrial Revolution, centered on people.

A group of recommendations extracted from the analysis of the SWOT matrix, built from the evaluation, reveals that there are opportunities to take advantage of these strengths and the opportunities that Mongolia has due to its geographical situation and its high reserves of mineral resources, required for development. industry, to mitigate the weaknesses still present, with a view to accelerating its earlier inclusion among the economies that adopt Industry 4.0.

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Conflict of interests

The authors declare that they have no conflicts of interest

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- Bolormaa Ganbat: Conceptualization, Data Curation, Formal Analysis, Research, Methodology, Validation, Visualization, Original Writing-Draft, Writing: review and editing.
- Tatiana Delgado Fernández: Conceptualization, Formal Analysis, Research, Methodology, Supervision, Validation, Visualization, Writing-Original Draft, Writing: review and editing.