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Radar Charts Analysis to Compare the Level of Innovation in Mexico with Most Innovative Countries in Triple Helix Schema Economic and Human Factor Dimension

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***Abstract*—**This paper seeks to compare the innovation of Mexico from an economic and human perspective, with the seven most innovative countries according to the Global Innovation Index 2013, done by the World Intellectual Property Organization (WIPO). The above analysis suggests nine dimensions: Expenditure on R & D, intellectual property, appropriate environment to conduct business, economic stability, triple helix for R & D, ICT Infrastructure, education, human resources and quality of life. Each dimension is represented by an indicator which is later used to construct a radial graph that compares the innovative capacity of the countries analyzed. As a result, it is proposed a new indicator of innovation called The Area of Innovation. Observations are made from the results, and finally as a conclusion, those items or dimensions in which Mexico suffers lag in innovation are identify.

***Keywords*—**Dimension, measure, innovation level, economy, radar chart.

I. Introduction

INNOVATION is "The successful original result applicable to any area of society, and is the result of the execution of a non-deterministic process that begins with an idea and evolves through different stages, generation of knowledge, invention, manufacturing and marketing, and is supported by a favorable organizational paradigm, in which the technology plays a key role, and the social context that values investment in knowledge creation a necessary condition"[1]. The search that different nations undertake to achieve this result is different in all of them, and their actions are influenced by its history and tradition, which define their way of thinking and how they see the future. Thus, their vision on innovation for future is enclosed by these factors, as well as the intensity that each factor gets manifested in them.

Innovation is difficult to measure with a simple variable that is chosen subjectively. To obtain a reliable measurement the analysis must be made from the perspective of the various variables that compose it. This composition makes possible to determine how innovation behaves in different regions of the world.

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II. Selected Countries for Analysis

The Global Innovation Index (GII), developed by the World Intellectual Property Organization, Cornell University and INSEAD, ranks a total of 142 countries in terms of their enabling environment to innovation and their innovation outputs [2]. This index is comprised of a total of 84 indicators that include information from the elements of the nation economy that enable innovative activities, and its results of the exercise of innovation. In its 2013 edition, the seven countries that achieved the highest overall score for this indicator were Switzerland, Sweden, UK, Netherlands, United States of America (USA), Finland and Hong Kong (China). In this classification, Mexico listed a number 63.

In the following tables are listed those countries included in this analysis with key indicators such as Population, Gross Domestic Product (GDP) and GDP per capita:

TABLE I
Population

Classification according to GII 2013	Country	Population (Millions of habitants)
1	Switzerland	8.1
2	Sweden	10
3	UK	65.8
4	Netherlands	17.4
5	USA	327.9
6	Finland	5.7
7	Hong Kong	7.5
63	MEXICO	117.8

TABLE II
GDP and GDP per Capita

Country	GDP (billions of dollars)	GDP per capita (dollars per year)
1.Switzerland	622.9	45,285.8
2.Sweden	520.3	41,749.6
3.UK	2,433.8	36,727.8
4.Netherlands	770.2	42,321.6
5.USA	15,653.4	49,802.1
6.Finland	247.2	36,458.5
7.Hong Kong	258.0	50,708.9
63.MEXICO	1,162.9	15,300.3

The selected countries belong to the high income group. Mexico belongs to the group of middle-high income countries.

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III. Description of the Indicators

For this study, have been proposed five dimensions that reflect innovation from an economic standpoint. The proposed dimensions are: Expenditure on R&D, appropriate environment to conduct business, economic stability, triple helix for R&D, and ICT Infrastructure. The study also provides four indicators related to human factor, which are: education, human capital, quality of life and intellectual property. Each of these dimensions is focused on a specific indicator.

TABLE III
Dimensions and Indicators to Analyze

Dimension	Indicators
1. R&D Expenditure	GDP percentage
2. Intellectual Property	Patent applications by residents
3. Appropriate environment to conduct business	Ease of doing business index
4. Economic Stability	S&P Global Equity Index
5. Triple helix for innovation	Link between University and Industry
6. ICT infrastructure	Preparation for the use of ICTs Index
7. Education	Expenditure per student at tertiary level (% of GDP per capita)
8. Human Capital	Number of researchers per million of inhabitants
9. Quality of Life	Human Development index

The following describes each of the dimensions, depending on the associated indicator.

A. Expenditure on R&D: Percentage of GDP Spent on R&D

According to the Institute of Sciences of Hong Kong [3] "a way of measuring the technological development of a country, is to measure the investments made in research and development (R&D), made by the private and public sectors. These investments are generally represented as a percentage of GDP devoted to R & D, and the way this percentage is calculated is by dividing total expenditures on research development to GDP ".

B. Intellectual Property: Resident Patent Applications per Million Inhabitants

This indicator represents the patent applications submitted within one country. Data was obtained from the database of the World Bank, where data was found for 214 countries, of which 91 countries were selected, the other countries were eliminated due to the absence of patent applications. As a remark, the indicator had to be adjusted in order to avoid bias. For the adjustment, it was necessary to remove countries that had a large number of patent applications, such as Japan and the Republic of Korea.

C. Appropriate Environment to Conduct Business: Ease of Doing Business Index

According to the OECD [4], the legal and regulatory framework is a critical factor that affects countries' entrepreneurial performance, and it's necessary to establish an appropriate framework for businesses to access and grow into the market; various organizations have made approaches to measure the degree to which the regulatory framework of countries has managed to create a conducive environment to the establishment of new businesses. One of these approaches is the index of ease of doing business calculated by the World Bank [5], this index includes factors contained in 10 topics: Starting a business, dealing with construction permits, getting electricity, registering property, getting credit, protecting investors, paying taxes, trading across borders, enforcing contracts and resolving insolvency.

D. Economic Stability: S&P Global Equity Index

S&P Global Equity Indices measure the U.S. dollar price change in the stock markets. It consists of three indexes: the S&P Frontier Broad Market Index, the S&P Global Broad Market Index and the S & P / IFCI. Overall, the Global Equity Index is designed to include the most liquid issuers from emerging and developed markets, covering nearly 11,000 titles from 83 countries [6], [7]. The measurement of the variation of the exchange rate, especially against the dollar compared to the U.S., to monitor the economic stability of the country. An exchange rate stability promotes the generation of important benefits, incentives for risk taking, transnational investment, international exchange of technology, increased trade and production, and of course benefits the economic agents operating in international financial markets, such as currencies.

E. Linking R&D: University-Industry

The triple helix is the model that describes the process in which academia, government and industry work together to create or discover new knowledge, technology or products and services which are transmitted to end-users in order to satisfy a social need [8]. The countries concentrate their efforts in the union of the university or academy with industry in research and development (R&D) because they are the two helixes that are more controllable for the innovation model. The government helix is unstable because it is subject to political changes that occur periodically, affecting its study. The collaboration of the university or academy and industry is more dynamic, but stable in the way they relate, hence addressing the relationship with more effort. This indicator is derived from a study made by the World Economic Forum [9] to generate the Global Competitiveness Index. This study assesses the competitiveness landscape of 148 economies; providing information about their productivity and prosperity, with an assessment of 1-7, where the highest value is 5.8, the lowest is 2.2 and the average value of the analysis of the countries analyzed are 3.7.

F. ICT Infrastructure: Index Preparation for the Use of ICTs

The Global Innovation Report [10] shows the evolution of information technology and communication (ICT) as well as the importance of ICT diffusion, the use of new developments and their relationship to economic growth and the improvements in the living conditions of a country. The Networked Readiness Index (NRI) identifies technological readiness factors and shows the ability of countries to take full

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advantage of new information and communications technologies in their competitiveness strategies. This index has allowed public and private stakeholders to monitor the progress of a growing number of economies around the world, and to identify competitive strengths and weaknesses of nations concerning technological readiness. The NRI assesses 71 indicators for each of the 138 countries surveyed in the Global Innovation Report, which includes a technical appendix which explains the structure and what are the calculations performed for this indicator. NRI has a scale of 1 to 7, seven being the optimum value.

G.Education: Expenditure per Student at Tertiary Level (% of GDP per Capita)

According to OECD in its 2012 report studio called Science, Technology and Industry, formal education remains the primary vehicle for improving the supply of skills needed for innovation, science, technology, engineering and mathematics; innovation requires other skills such as entrepreneurship, creativity and leadership. This indicator shows the average amount of resources that is designated for the education of a student, "Referencing the student and educational level unit, it is expected that as the latter is more advanced, the unit cost increases at that level. This is because investment in human resources, educational materials and infrastructure to provide some degree of education, is directly related to the educational level, the higher the level, the greater the investment required and the lower the number of people who serve. When expressed as a percentage of GDP per capita, this indicator provides a relative value useful for international comparisons."[11].

H.Quality of Life: Human Development Index

The Human Development Index (HDI) created by the United Nations Development Programme (UNDP), is an indicator that measures development multidimensional average achievements in a country in three basic dimensions of development: Health, Education and Living Standard. The performance of each of these dimensions is expressed in values from 0 to 1, then the HDI as a simple average value of the three previous rates. Health: measured based on life expectancy at birth collected in the HDI is calculated using a minimum of 20 years and a maximum value of 83.57 years, which is the maximum value observed for the indicators of the countries in the period 1980 to 2012. Education: Provided education is measured by the average years of schooling and expected year of schooling. Standard living: Measured by purchasing power parity (PPP) in U.S. dollars (U.S. $).

I. Human Capital in R&D: Number of Researchers per Million Inhabitants

The highly trained human resources dedicated to research is essential for the creation and dissemination of new knowledge, and are the link between technological development and economic growth, social development and quality of life. The fact that a country has an adequate number of personnel involved in R & D is a critical factor in their ability to innovate [1].

To understand how to get the values of each of the dimensions from the indicators go to the next section.

IV. Methodology

A. Standardization and Radar Chart

For data analysis, and more importantly, to the development of radar chart, it is necessary that the data describing the selected indicators are on equal terms for study, data normalization. Its application becomes essential from the beginning because the data obtained from different sources and are in different terms. Comparing the variables should be standardized so that a single measurement is used in the radial axes in order to observe the efficiency or, where appropriate, the effectiveness of the decisions.

To perform the normalization of the data has it has been determined that the indicators are expressed in terms of a scale of 1 to 10. Being (1) the lowest number corresponding to a poor outcome and therefore, the highest number (10) to a result that serves as an ideal approach. The nine indicators explain the situation of innovation from an economic perspective, so that, when evaluated with a standard score can be compared on the same scale with other countries.

B. Description of Calculation of Areas

The calculation of radial graphs areas allows overall performance to be compared among all countries with the analyzed indicators. The nine indicators used were selected to reflect the innovation of a country from an economic and human factor perspective, so that the analysis allows us to observe the impact of the economic aspects of a country in its innovation.

The radial area of the graph is obtained by summing the area of triangles formed between two adjacent indicators, being nine indicators one obtains nine triangles. For practical example Mexico's case is taken.

Fig. 1 represents triangle ABC, where the angle A is 40° (360° from nine sides of the radar chart), its side $(AC)^{-}$ is 8 (metric qualification "Quality of Life") and his side $(BC)^{-}$ is 9 (metric qualification "environment appropriate to conduct business"). To get the area covered by the following formula:

$$area = \frac{\overline{AB} * \overline{AC} * \sin A}{2} = \frac{4 * 7 * \sin(60°)}{2} = 12.12 \qquad (1)$$

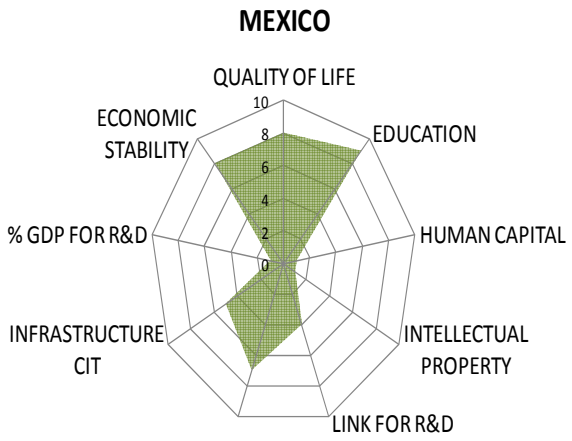


Fig. 1 Area calculation example Mexico

It is noteworthy that the radial chart area depends on the order in which the indicators are place, so in this analysis the indicators were arranged clockwise from lowest to highest factor with economic impact. All graphs have the same order for proper comparison.

V. Results

Tables IV and V present the value obtained for each of the countries analyzed in relation with the stated dimensions.

TABLE IV
COUNTRIES ANALYZED IN RELATION TO INTELLECTUAL PROPERTY

Countries most innovative + Mexico	Intellectual property	Linking to R&D	Enabling environment for business	
1.Switzerland	SHE	3	10	8
2.Sweden	SWE	3	9	9
3.UK	GBR	4	9	9
4.Netherlands	NLD	2	8	8
5.USA	USA	10	10	9
6.Finland	FIN	5	9	9
7.Hong Kong	HKG	1	7	10
63.MEXICO	MEX	1	4	7

TABLE V
COUNTRIES ANALYZED IN RELATION TO TIC'S INFRASTRUCTURE

Countries most innovative + Mexico		Infrastructure ICTs	% GDP in R+D	Economic stability
1.Switzerland	SHE	7	7	9
2.Sweden	SWE	8	8	7
3.UK	GBR	7	4	10
4.Netherlands	NLD	7	4	10
5.USA	USA	7	6	9
6.Finland	FIN	7	9	9
7.Hong Kong	HKG	7	1	8
63.MEXICO	MEX	5	1	8

Fig. 2 shows the radial graph for all countries analyzed using the indicators described in the previous section.

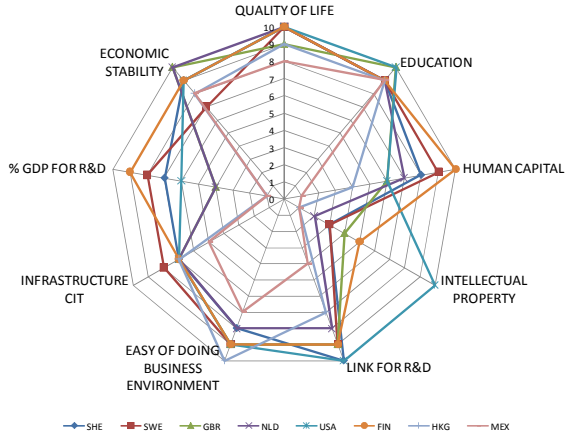


Fig. 2 Area calculation for every country

To facilitate understanding the information, the analysis is presented in radar charts showing the values of the dimensions for each country.

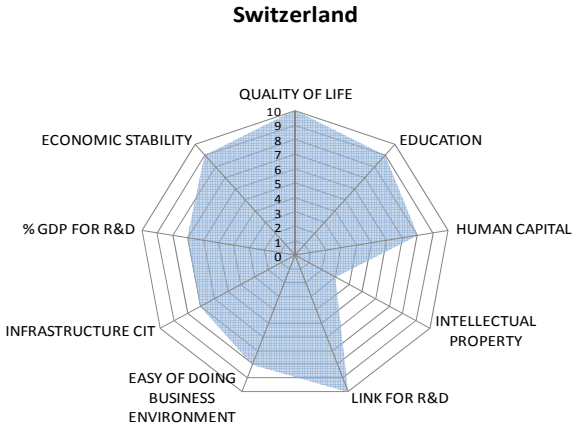


Fig. 3 Area radar chart for Switzerland

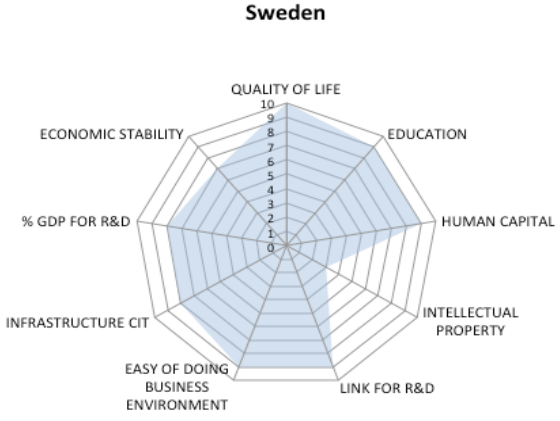


Fig. 4 Area radar chart for Sweden

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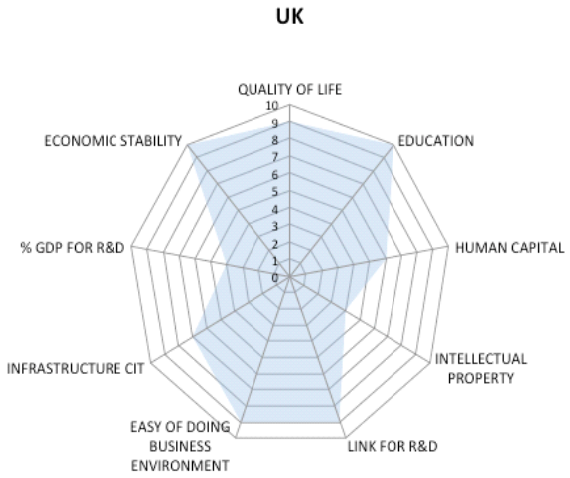


Fig. 5 Area radar chart for the UK



Fig. 6 Area Radar chart for the Netherlands

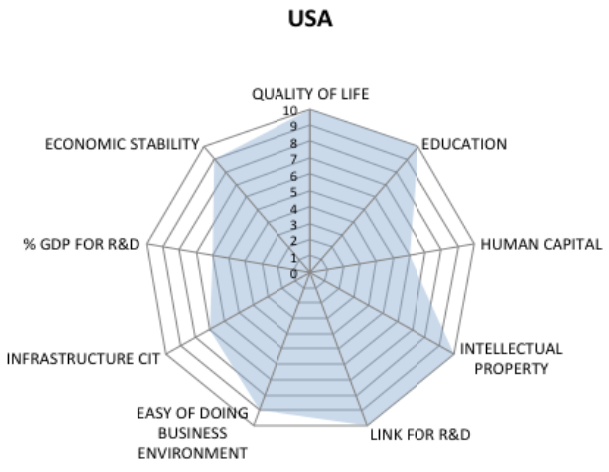


Fig. 7 Area radar chart for the USA



Fig. 8 Area radar chart for Finland

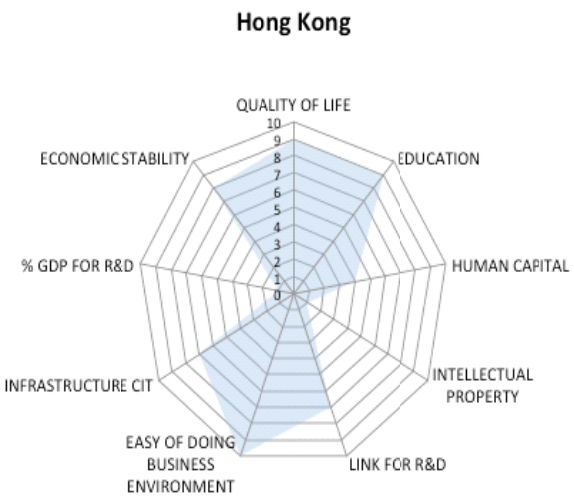


Fig. 9 Area radar chart for Hong Kong

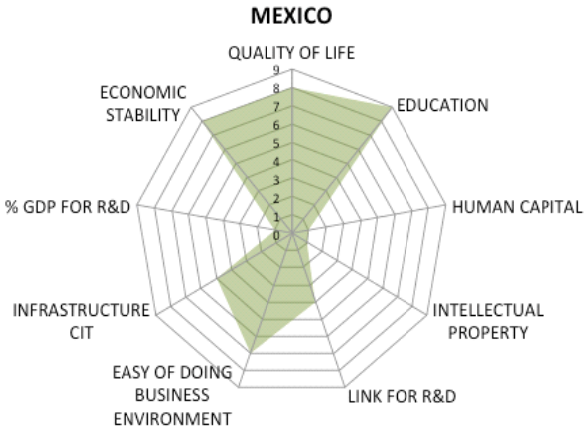


Fig. 10 Radar Chart for Mexico

Table IV shows one-way to calculate the area of the radar chart of each country. It is added in the bottom a line which mentions the optimum value of the areas, being the maximum value the areas which number will equal to 10. This table also

includes the ranking position of each country taking as reference the value of that area.

TABLE VI
COUNTRIES ANALYZED FOR AREA

	Country		Area	Position in order to the areas
1.	Switzerland	SHE	132.0688741	4
2.	Sweden	SWE	138.9970773	3
3.	UK	GBR	124.7076581	5
4.	Netherlands	NLD	96.99484522	6
5.	EUA	USA	190.0925761	1
6.	Finland	FIN	163.6788013	2
7.	Hong Kong	HKG	73.61215932	7
63.	MÉXICO	MEX	38.10511777	8
Optimal Value			259.8076211	

VI. DISCUSSION OF RESULTS

According to the analysis made over the first innovative countries made by the Global Innovation Index 2013, México has a long way to run in order to improve his economic level to be allocated in the first places.

On the other hand, United States is located in the first place; this is caused by stronger indicators as, intellectual property and the networked to R&D. Besides, Mexico is located in the last place with the same indicators as Intellectual Property to mentioned one. Likewise, this indicator is low for the rest of the analyzed countries, because of the information is only of resident patent applications, which excludes the results of patent applications by foreigners within the country.

According to the analysis, the entity with the greatest similarity to Mexico is Hong Kong. Although, despite investing the same performance in Intellectual Property and have the same level of ICT infrastructure, Hong Kong has a better overall performance in innovation, this is explained by that they have a better environment for business and stronger link to R&D.

The indicators that show more dispersion are the percentage of GDP on R & D and intellectual property. This indicates that the analyzed countries have different criteria for designing its strategy for innovation. Instead, we can see that where most countries are investing efforts in creating an environment conducive to business and ICT infrastructure.

It also shows that although countries have a high level of linkage for R&D, if is not reflected in their intellectual property, except in the case of Mexico and the United States. However, data linking R&D is more proportional to the percentage of GDP invested in R&D. Finally, we mention that the analyzed countries, have a high level of ICT infrastructure, but Mexico has a lag on this indicator.

VII. CONCLUSIONS

According to analysis, Mexico has some points on which work towards innovation levels of the major countries by Global Innovation Index 2013. It can be seen that the lowest indicators in Mexico are a reflection of the economic policies the country, as its share of GDP invested in R&D is the lowest.

To conclude, it can be inferred that the relationship between universities, government and private initiative, as well as ICT infrastructure and conducive business environment have a greater impact to assess the innovative development of the country. It is possible to observe a trend in countries with higher entailment in triple helix schemes to submit more registered intellectual property and overall more balanced radar chart which is reflected in an area of greater innovation.

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