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Measuring Technological Level and Capability of the Industries in East Azerbaijan and Providing Proper Strategies for Improvement and Promotion of Technology

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ABSTRACT

With the rapid process of industrial, economic, and technological development in today's world, the blurring of geographical boundaries (due to IT, ICT, etc.), and the increasingly intensive competitions in the area of production, supply, and services, new technologies and seeking advantage in this regard is one of the vital, strategic goals of managers and organizations. First,by applying the ESCAP Technology Atlas framework, the present research aims to assess the level (score) of the components of technology in three industries – i.e. Petroleum, Manufacturing, and Mining. Then, to determine and calculate Technology Contribution Coefficient (TCC) and its power factor (β_i), it uses AHP's pair wise comparison method with the components that affect technology and applies the model presented in ESCAP to determine and calculate technological capability in the studied industries (technology transformation, modification, sale, innovation, and commercialization). Finally, t-test will be applied to determine the significance in the scores obtained from the studied industries and analysis of variance will be used to examine the significant difference in the observed scores. At the final stage and after determining the score of technology components and the gap between the components vis-à-vis the desired level, solutions and suggestions will be provided for improvement and promotion in industries.

KEY WORDS: Technology, technological capability, technology contribution coefficient, technology measurement and evaluation techniques, pairwise comparison (hierarchy method).

INTRODUCTION

Technology is an essential tool for all economic units. Not only does it facilitates transformation operation, but also provides the infrastructure for survival and development of businesses in today's global, integrated economy. In any case, for real development of a business, senior managers must take a strategic approach to technology; they must determine the priorities, identify the factors interfering with the success of the business, improve technological capabilities, and promote the implementation of technology. Therefore, measuring the existing technological level and capabilities of a business enables access to this information for proper management of technology [9].Evaluation and policy-making in technology is one of the necessities of any developing country in order to keep pace with the fast changes in business arena [2]. Iran as a developing country has no choice but to adopt proper strategies and policies regarding technology transfer and promotion. The first step is to identify and evaluate the components of this context. Planning for the objectives requires an understanding of the resources, limitations, weaknesses, and strengths; in sum, it entails comparing the current condition with the desired condition. Technology – as one of the infrastructures for development– is not an exception [7]. What is the current technological level and capability in the industries of East Azerbaijan (petroleum, manufacturing, and mining)? How is the balance between the components of technology in these industries? How can technological level and capacity of the industries be improved? These are some of the most important challenges of the present research. Thus the researcher seeks to provide the measures of technological level and capability by taking into account the components of technology in the studied industries. The following questions are discussed:

1- What is the technological level of the industries (petroleum, manufacturing, and production) in East Azerbaijan and how can it be improved and promoted?
2- How is the condition of the four components of technology vis-à-vis the best practice in each of the industrial units?
3- How much is the current technological capability of the studied industrial units?
4- What are the desirable strategies for improvement and promotion of technological level?
5- Is there a significant difference between the mean scores of the components of technology and technological capability?

The term "technology" is essentially a combination of the two Greek words "techno" meaning art or craft and "logy" which means sciences. Based on investigations, one can venture to say there are as many definitions for technology as

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there are scholars in this area and despite superficial differences, these definitions have much in common [4].Technology is the application of sciences in industries using systematic procedures and techniques [6].

Methods for Evaluating Technological Level

Many methods have been discussed regarding the measurement of technological level in businesses or at the national level and these methods have studied technology from different aspects. Each of these methods has its own strengths and weaknesses. Some of these methods are outlined as follows [1]: (1)Economic Evaluation of Technological Position, (2) Unspooled Method (3) Strategic Analysis Method, (4) Multi-Criteria Method, (5) Technological Criteria Method, (6) Technology Fit Method, (7) Porter's Model,(8) Technology Atlas method. As was mentioned, based on the Technology Atlas, added technology and technological level are determined by four components: techno ware (object-embodied facilities), human ware (person-embodied abilities), info ware (document-embodied facts), and or aware (institution-embodied frameworks).

Formula for the Contribution of Techno ware

$$T_i = \frac{1}{9}\left[LLT_i + \frac{SL(uLT_i - LLT_i)}{10}\right] \quad (1)$$

$$T = \sum W_i T_i \quad (2)$$

Formula for the Contribution of Human ware

$$H_i = \frac{1}{9}\left[LLH_i + \frac{SH_i(uLH_i - LLH_i)}{10}\right] \quad (3)$$

$$H = \sum H_i W_i \quad (4)$$

Formula for the Contribution of Info ware

$$I = \frac{1}{9}\left[LL_I + \frac{S_I(uL_I - LL_I)}{10}\right] \quad (5)$$

Formula for the Contribution of Or aware

$$O = \frac{1}{9}\left[LL_O + \frac{S_O(uL_O - LL_O)}{10}\right] \quad (6)$$

Formula for Technology Contribution Coefficient

$$TCC = I^{\beta_I} \cdot O^{\beta_O} \cdot H^{\beta_H} \cdot T^{\beta_T} \quad (7)$$

There have been many studies regarding the measurement of technological level and many methods and instruments have been introduced. Based on these methods, a broad range of research studies can be presented in the context of technology measurement at the international level. A comparative review of these methods reveals that the most important and comprehensive source is a method introduced in the book "Technology Atlas Team: A Framework for Technology-Based National Planning" which was translated and published in Iran in 1980. Besides analyzing the basic outline of development of Iran, this book carries out a case study on the technological content of the country's Iron and Steel Industry. The results of this research showed that among the four components of technology, orgaware had the lowest level (0.34) in this industry.

The results of technology measurement in Textile Industry showed that among the components of technology, human ware and techno ware obtained the highest scores (both 0.54) and that info ware had the lowest score in comparison with other components [3]. In a study of Iron and Steel Industry which examined Isfahan Steel Plant, the score of the four components of technology were calculated as follows: Technoware (T) with 0.34, Humanware (H) with 0.67, Infoware (I) with 0.56, and Orgaware with 0.34. In other words, the preference of technology components is determined as $H > I > T > O$ [5].

METHODOLOGY

The present research is applied in terms of its purpose and descriptive-survey in terms of its method.

Population

The major limitation in measuring technological level through Technology Atlas is the size and importance of industrial units and that usually in industries with fewer employees the results do not have acceptable validity and reliability. Thus, the population of the research includes all the industrial units in East Azerbaijan with at least 50 employees. According to the information provided by Industries and Mines Organization in East Azerbaijan, there are 735 industrial units active in Mineral, Non-Ferrous, Ferrous, Casting, and Machinery and Equipment Manufacturing sectors. Thus, a total number of 17 large industrial units that comprise 90% of the industries of East Azerbaijan make up the population of the research based on the preference and requirements of Humanware measurement in Technology Atlas. The required data are collected through a questionnaire filled out by the managers of the mentioned industrial units and those units with less than 50 personnel were omitted from the population. Thus, the studied population is

limited to the units in petroleum, manufacturing, and mining industries of East Azerbaijan that have more than 50 personnel.

Sample

Considering the limitations in terms of costs and time as well as the lack of personnel in small manufacturing units in the province, a total number of 17 units were considered for further study. In statistical theories it is not possible to select the sample from industries with less than 50 active personnel; thus, these units are omitted from the population and the sample will be selected from the rest of the industries which comprise 90% of the large and effectual industries in the province. Cochran's formula is applied to precisely determine the sample size:

$$n = \frac{Nz^2.p.q}{Ne^2 + z^2p.q}$$

By replacing the above numbers in Cochran's relation, 16 units were selected as sample. Effectively, all the population of the research will be studied

$$n = \frac{17(1.96)^2.(0.5).(0.95)}{17(0.01)^2 + 1.96^2(0.5).(0.95)} = 16$$

Data Collection

The required data were collected through attribution studies and field studies where questionnaires were distributed among the experts and managers and they participated in interviews. The questionnaire is designed in five sections for measuring each of the components of technology (Technoware, Humanware, Infoware, and orgaware) and technological capability of the industrial units based on the Technology Atlas framework. The validity and reliability of the questionnaire has been proved in several similar studies. Due to their nature, these questionnaires were filled out using the views of experts, supervisors, directors, and managers. Further, due to the complexity of the components of technology and the importance of each component, only the opinion of informed individuals were used so that they obtained quantities would be valid.

RESULTS

First, the required data were collected from the industrial units and were analyzed using EXCEL, SPSS, Export Choice, and MATLAB based on the methodology of Technology Atlas and the analytic hierarchy process (AHP) and the four components of technology and contribution of each component was calculated.

Evaluation of Technological Level in the Industries of East Azerbaijan

Table 1 – Mean scores of the components of technology and technology contribution factor (TCC) in all the industries

Group	Industrial Units	Technoware	Humanware	Infoware	Orgaware	TCC
Petroleum Industries	Refining (Tabriz Refinery)	78%	73.4%	83.6%	58.2%	53%
	Petrochemicals(Tabriz Petrochemical)	85.6%	69%	72%	64.2%	51%
	Mean of the Group	81.8%	71.2%	77.8%	61.2%	52%
Manufacturing Industries	Diesel Engine Manufacturing (IDEM)	98%	81.3%	94.4%	97%	89.5%
	Machinery Manufacturing (MST)	65.2%	41.3%	94.4%	97%	89.5%
	Electromotor (Motogen CO.)	60%	72.5%	62.5%	69%	51.3%
	Charkheshgar Co.	70%	79.6%	62.5%	69%	51.3%
	Ball-Bearing Manufacturing	62%	71.4%	79.7%	63%	47%
	Pomp Manufacturing	74.4%	67%	65.1%	42%	30%
	Compressor Manufacturing	62%	61%	63.9%	55.1%	61%
	Piston Manufacturing	82%	68%	57.7%	69.8%	74%
	Tractor Manufacturing (Tabriz Tractor Manufacturing Co.)	71%	62%	60%	58%	63.5%
	Forging (Tabriz Tractor Manufacturing Co.)	76%	64%	59.3%	83.3%	67.8%
	Motor Manufacturing (Tabriz Tractor Manufacturing Co.)	59.4%	81.6%	75.4%	82%	69%
	Casting (Tabriz Tractor Manufacturing Co.)	63.6%	78%	63%	59%	68.5%
	Industrial Machinery	57%	68%	61.6%	57.4%	61.4%
	Mean of the Group	72.6%	69%	67.5%	67.2%	60.5%
Mining Industries	Cement (Sufian Co.)	78%	61.5%	75.5%	60.44%	69.1%
	Mean of All the Industries	69.7%	68.7%	69.5%	62.9%	60%

According to table 1, it is revealed that there a relatively desirable balance between Technoware, Humanware, and Infoware and that there is only a 6.5% gap between orgaware and the other components (62.9%).

Statistical Testing of the Means of the Four Technology Components and TCC

Proper tests are used to verify the significance of the calculated means of the four components of technology and the values obtained for technology contribution coefficient (TCC) and to examine the differences observed in the means.

Table 2 – The results of t-test for the means of each technology component and technology contribution coefficient

Variable	Mean	DOF	Calculated T	Significance Level
Technoware (T)	700%	16	23.34	0.000%
Humanware (H)	683%	16	28.62	0.000%
Infoware (I)	694%	16	27.89	0.000%
Orgaware (O)	655%	16	28.62	0.000%
Technology Contribution Coefficient (TCC)	603%	16	17.66	0.000%

As can be seen in the above table, all the means calculated for the variables are significant at $\alpha = 0.05$ level.

Further, to examine whether the differences in the means obtained for technology components are significant, analysis of variance will be used in case of homogeneity of variances; otherwise, Kruskall-Wallis test will be applied. Thus, first the homogeneity of variances between groups is tested and the results are presented in table 3.

Table 3 – The results of homogeneity of variances between groups

Variable	DOF 1	DOF 2	Lev	Significance Level
Technoware (T)	1	14	1.257	0.315
Humanware (H)	2	14	1.527	0.251
Infoware (I)	2	14	1.108	0.357
Orgaware (O)	2	14	2.797	0.095
Technology Contribution Coefficient (TCC)	2	14	1.994	0.173

As shown in the table, the results confirm the homogeneity of variances between different groups; thus, analysis of variance can be applied. Table 4 presents the results of analysis of variance (F-test).

Table 4 – The results of analysis of variance (F-test) of differences between the means of technology components

Variable		Sum of Squares	DOF	Mean Squares	Calculated F	Sig.
Technoware (T)	Between Groups	0.049	2	0.023	1.643	0.229
	Within Groups	0.198	14	0.014		
	Total	0.245	16			
Humanware (H)	Between Groups	0.011	2	0.005	0.521	0.605
	Within Groups	0.144	14	0.01		
	Total	0.155	16			
Infoware (I)	Between Groups	0.021	2	0.011	1.007	0.39
	Within Groups	0.148	14	0.011		
	Total	0.167	16			
Orgaware (O)	Between Groups	0.015	2	0.008	0.386	0.687
	Within Groups	0.279	14	0.02		
	Total	0.294	16			
TCC	Between Groups	0.026	2	0.013	0.62	0.552
	Within Groups	0.291	14	0.021		
	Total	0.317	16			

The results of the above table indicate that the difference between technology components in different industrial groups is not significant. In other words, considering the calculated F at 95% confidence level, none of the differences observed between technology components are significant at $\alpha = 0.05$ level.

Testing the Means of Technological Capability in the Industries of East Azerbaijan

Table 5 – The results of t-test for the mean of technological capability measures

Measure	Calculated Mean	DOF	Calculated T	Sig.
Supply Capability	6.330	16	30.87	0.000
Transformation Capability	6.27	16	22.51	0.000
Sale Capability	6.92	16	28.90	0.000
Modification Capability	5.76	16	20.07	0.000
Design Capability	5.12	16	21.28	0.000
Commercialization and Innovation Capability	4.54	16	17.31	0.000
Total	5.72	16	25.14	0.000

As can be observed in the table above, all the calculated means for capability criteria of different groups are significant at $\alpha = 0.05$ level.

In case of homogeneity of variances, analysis of variance will be used to find whether or not the differences between the indices of the three groups are significant.

Table 6 – The results of testing homogeneity of variances of technological capability criteria

Variable	DOF 1	DOF 2	Lev	Significance Level
Supply Capability	1	14	0.912	0.424
Transformation Capability	2	14	1.801	0.201
Sale Capability	2	14	1.274	0.31
Modification Capability	2	14	2.18	0.15
Design Capability	2	14	1.66	0.225
Commercialization and Innovation Capability	2	14	1.66	0.225
Total	2	14	1.66	0.224

As shown in table 6, all the criteria of technological capability in different groups have homogeneous variances at $\alpha = 0.05$ level.Thus, analysis of variance (F-test) can be applied in the next stage and the following table presents the results.

Table 7 – The results of analysis of variance (F-test) of differences between technological capability indices

Variable		Sum of Squares	DOF	Mean Squares	F	Sig.
Supply Capability	Between Groups	2.266	2	1.133	1.727	0.214
	Within Groups	9.186	14	0.656		
	Total	11.451	16			
Transformation Capability	Between Groups	2.027	2	1.014	0.742	0.494
	Within Groups	19.117	14	1.366		
	Total	21.145	16			
Sale Capability	Between Groups	0.891	2	0.446	0.424	0.662
	Within Groups	14.709	14	1.051		
	Total	15.60	16			
Modification Capability	Between Groups	2.479	2	1.239	0.871	0.44
	Within Groups	19.929	14	1.424		
	Total	22.408	16			
Design Capability	Between Groups	3.637	2	1.819	2.097	0.16
	Within Groups	12.145	14	0.867		
	Total	15.78	16			
Commercialization and Innovation Capability	Between Groups	2.105	2	5.646	10.67	0.002
	Within Groups	8.768	14	0.529		
	Total	10.873	16			

The results of the above table (table 7) show that the differences observed in the means of technological capability criteria are not significant except for Commercialization and Innovation Capability ($\alpha = 0.05$) and almost all the different industrial units have similar problems and shortcomings. The difference observed in the mean of Commercialization and Innovation Capability across groups and industries is significant ($F = 10.67, p = 0.002$).

DISCUSSION AND CONCLUSION

The Results Related to Humanware (H)

The results showed that Humanware obtained a total score of 68.7% which is the highest score among the components of technology in the industries of the province. This component has been analyzed from two perspectives.
A- In studying the most and least effective indices that affect the total score of the contribution of Humanware in technology, it was revealed that tendency for success, cooperation, and learning were the most effective and tendency to accept risk was the least effective index.
B- The results of the research also revealed that among different groups and classes of human resources, engineers, experts, R&D personnel, and supervisors had the highest contribution and manufacturing supervisors, manufacturing workers, and support workers was the least contribution in the final score of Humanware in all the industries of the province.

The Results Related to Orgaware (O)

The findings of the research revealed that among the sub-criteria of orgaware, the level of contribution and involvement of strategic management and commitment to organization's stakeholders had the highest and leadership for creating motivation, internal independence leadership, and innovation-fostering space leadership had the least contribution in the final score of Humanware.

Results Related to Technology Contribution Coefficient (TCC)

Regarding the methodology of the research and the way technology contribution coefficient (TCC) was calculated in different studied industries, TCC is the contribution of technology in creating a value-added unit in an industry and

its value varies between zero and one. In fact, the power value of the four components of technology in TCC is a tool for orienting and prioritizing development efforts in all the industries where a component with the highest power value will contribute to the potential increase in technology and its development and components with lower values must be reconsidered in technology development plans and reinforced through resource allocation.

According to the last row of table 1, it is revealed that the mean TCC in all the industries is 60% which indicates the moderate-to-high importance and effectiveness of technology in these industries. As was mentioned, this coefficient is somehow a combination of the values obtained for the four components of technology and signifies the overall gap between the current technological level of industries and the desired condition. In other words, in comparison with the best practice in technology, the technological level (TCC) of the studied industries is at moderate to high level (60%).

Findings Regarding Technological Capability

The findings of the research showed that the mean technological capability in the province is at a moderate level (5.8). Thus, a closer examination of the sub-criteria of technological capability reveals that the major weakness of the studied industries is their capability in technology innovation and commercialization, design, and modification.

Sub-Criteria for Technological Innovation and Commercialization

The results from the research in terms of technology innovation and commercialization suggest the weakness of East Azerbaijan in the following fundamental aspects: the low capability of the industries in bringing about fundamental improvements in received (transferred) technologies and its basic shortcoming in localizing them; low capability and weakness of the industries in building the prototype of the new product and commercializing it; low capability of the industries in performing and implementing specialized R&D activities and projects and developing such activities for the purpose of innovation in products and processes; extremely low capability of industries of the province in acquiring income through transferring patents from R&D activities; weakness and low capability of the industries in creating and designing new technology.

Sub-Criteria of Technology Design Capability

The major problems in this regard are as follows: low (moderate) capability of the industries in designing products or goods; weakness and shortcoming of these industries in redesigning products proportionate to the tangible needs of customers; inability to design new products for future markets; shortcoming in employing creativity and innovation in designing products; the important, fundamental weakness of these industries in creating a link between product design and different aspects of production processes.

Sub-Criteria of Technology Modification

Considering the results and scores obtained in this regard, the basic problems of the industries of the province are as follows: weakness in creating and improving the current technologies and processes in order to achieve desired quality; low capability in designing and implementing human resources development plans; shortcoming of industries in duplication of the equipment of procedures and processes; major weakness of the industries in effective implementation of management techniques.

Results at the Level of Industrial Groups

The results of evaluating the technological capability of different industries showed that three sub-criteria of technological capability – i.e. sale (6.9), supply (6.3), and transformation (6.25) – obtained the highest scores and had the greatest contribution in the total technological capability of the industries. The level of these indices was evaluated to be moderate to high and these criteria enjoy a relative balance. The other three sub-criteria of technological capability – i.e. commercialization and innovation (4.7), design (5.2), and modification (5.8) –had the least contribution and effectiveness in total technological capability function. These three criteria, though lacking may be, have a relative balance.

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