

The Technology Transfer in the Development of the Small and Medium Metal-mechanic Ecuadorian Enterprise

¹Walter D. Quezad*, ²Gilberto D. Hernández, ³Erenio González S., ⁴Mario J. Mantulak, ⁵Wilson Corrales

^{1,2}Department of Industrial Engineering/Universidad Central de Las Villas, Cuba

³Department of Chemical Engineering/Universidad Central de Las Villas, Cuba

⁴Department of Industrial Engineering/Universidad Nacional de Misiones, Argentina

⁵Department of Industries Engineering/Universidad Técnica de Cotopaxi, Ecuador

Email- ^{1*}wquezadatorres@gmail.com, ²ghdez@gmail.com, ³erenio@uclv.edu.cu, ⁴mmantulak@gmail.com, ⁵wilson.corrales@utc.edu.ec

Abstract—

The position of Ecuador, according to indicators of innovation and competitiveness on a global scale, expose problems that in general affects the Ecuadorian industry, specifically the metal-mechanical one, that is considered an important source of employment and revitalization of the country's economy since 2010. The government has prioritized the metal-mechanical industrial sector as one of the strategic sectors for the transformation of the productive matrix of the country. The small and medium enterprises (SMEs), included in this sector, have problems associated with their technological resources, that have been turned into challenges to be faced in order to reverse the situation. This paper shows the results of a situational diagnosis aimed at identifying the problems related to the management of the processes of technology transfer in the sector that includes the analysis of the administrative, technical, technological, and economic factors involved in these processes in a selected group of SMEs, as well as their social, economic and environmental impact. The main results achieved in the design of an alternative and complementary methodological procedure are presented. The procedure is supported by a set of engineering and management tools to execute an important process of technology management, the technology transfer with strategic scope, aimed at increasing competitiveness with social responsibility.

Keywords— SMEs; technology transfer and technology management; industrial development and metal-mechanical industry

I. INTRODUCTION

The metal-mechanical industry is a productive sector that contributes to the development of a country in terms of wealth and employment generation. It is one of the main economic activities of industrial nature, not only for its technological content and added value of its products, services and processes, (including the recycling and reuse of metallic waste) but also as a fundamental link in the productive chain of a country [1].

On the other hand, small and medium-sized enterprises (SMEs) are included in a category of enterprises that comprises a broad and diverse group of organizations with different degrees of maturity [2], which are practically present in all the productive and service sectors, maintaining a growing importance in the economic and social development of any country. Specifically in Latin America, they are considered as part of the business fabric with a significant participation in the economy, as it is a great source of employment generation and therefore they have a high social impact.

In the Ecuadorian context, the metal-mechanical industry is not exempt of the benefits it generates in Latin American countries, because that industry is prioritized by the Ecuadorian government as one of the most important strategic sectors in the country productive matrix since 2010. According to statistical data published in [3], it was estimated that by 2014, it would reach a share of 11.30% in the manufacturing business sector, the second most important after the agro-industry, although it only contributed to 1.5% of the national Gross Domestic Product (GDP) or 25% of the total national non-oil GDP [4], considered non-oil GDP that revenues

from the economic activities, excluding those generated from the extraction of crude oil and its by-products, which rates are relatively high in respect to other national revenues in Ecuador.

With regard to exports, authors that [3] highlighted that by that time 75 % of the Ecuadorian metal-mechanical production was destined to different countries: Venezuela, with 23.63 %; Colombia, with 18.75 %; Peru, with 12.46 %; China, with 11.16 %; United States of America (USA), with 7.72 % and Chile, with 4.17 %. The most favored markets (Venezuela, Colombia and Peru with approximately 55% of the total production) are currently backed by bilateral trade agreements.

According to the last Economic and Activity Census, carried out in 2010 by the National Institute of Statistics and Censuses (INEC) of Ecuador, there were approximately 8 020 metal-mechanical enterprises in the country by that time. It is also supported by statistics and data published by the Latin American Faculty of Social Sciences in Ecuador as well as the Ministry of Industries and Productivity [5]. Those enterprises were concentrated mainly in the provinces of Guayaquil, Pichincha, Tungurahua, Azuay and Loja [6]; although they have spread to other provinces as Cotopaxi y Chimborazo in the last years [7].

According to the data from the aforementioned census and the only official statistics currently published in respect to metal-mechanical sector, the meta-mechanical enterprises are distributed in the country as follows: micros (98.02%), small (1.60%), medium (0.14%) and large industries (0.24%) according to the current classification of industries, regarding size, number of employees and revenues produced by the metal-mechanical industry [8].

On the other hand, authors like [9], agreed that in the last decades and from the perspective of local and regional development, the real and potential role of the SMEs is highlighted as innovative establishments. However, despite their indisputable importance, conceptual innate capacity and conditions of adaptation to a competitive and innovative environment, many of them (mainly those from developing countries that work for the domestic markets, (as in the case of Latin-American SMEs) present problems that limit their permanence and development in markets; specially those of competitive products and services.

This situation may be caused by several factors, namely erroneous structural-organizational policies, failed internal conducts and decisions, due to their exogenous nature or problems of strategic planning and technological innovation [10], that generally respond more to non-formalized strategies than to a well-structured planning of the process. The competitive pressure imposed by the large companies that dominate the markets and the negative influences derived from the phenomenon of informality [11], [12], so widespread in this geographic region, among other factors to be considered.

The SMEs of the Ecuadorian metal-mechanical industry are not exempt of these and other kinds of problems, and the scientific production for dealing with them is still scarce. However, some media and authors as showed in [13], [14], [15] point out that in the period 2011-2012, there was a considerable growth in the participation of SMEs in this industrial sector in the Ecuadorian GDP. Yet, since 2015, there was a slowdown in the industry due to the contraction in the sectors of the metal-mechanical production chain, mainly the construction and petroleum, among them [16], a situation that should have maintained until 2016 according to published projections [17].

In the face of this reality, the Ecuadorian metal-mechanical SMEs must impose new challenges in order to improve and intensify its productive performance in terms of efficiency, productivity and competitiveness in the national and international markets. According to [18], state that to achieve this goal, it is essential to promote internal processes of research, development and innovation (R+D+i), as well as investment in the renewal of their technologies, including the development and application of management mechanisms that facilitate these processes and permanent training of their human capital (that generally possess the capacities and skills in their respective professions). They also refer to the application of appropriate strategies either for searching new markets or substituting imports selectively in the domestic market.

With the aforementioned background, the present work was focused on the Ecuadorian metal-mechanic SME, with the objective of designing an alternative instrument, complementary to the national strategy for changing the productive matrix of Ecuador [19]. The instrument will take into consideration the requirements to strategically manage the technology and its associated processes (for example, the technologies transfer processes), that in the opinion of [20], allow the use of a set of knowledge, procedures and expertise aimed at improving the use of technological resources. The ones that are available in this important business segment, as a contribution to the improvement of its competitive performance with social responsibility.

II. METHODS

For the development of the research, a bibliographic review was carried out to explore and characterize the state of global knowledge and Ecuadorian practice on the subject matter of study. The main historical and recent indicators on innovation and competitiveness worldwide were highlighted, according to the world ranking published by the World Intellectual Property Organization (WIPO) and the World Economic Forum, respectively. The indicators in Ecuador were reviewed using the data published by the Secretariat of Higher Education, Science, Technology and Innovation (Senescyt) in its study of Science, Technology and Innovation Activities (ACTI) on investments in Research, Development and innovation (R+D+i) in Ecuador.

A critical analysis on the management models of the most widely used technology at the international level and in the Latin American region was carried out, with particular emphasis on those that support the processes of technology transfer in the business sector. Among these models, the macro model for technology transfer in Ecuador stood out [21], framed in the public investment project, as part of the national strategy for the change of the country productive matrix. This project has been promoted by the Vice-presidency of Ecuador in charge for the articulation of active work with other State portfolios since 2010.

This macro model proposal for technology transfer constitutes an important and pertinent methodological reference for the structuring of this complex process, as an alternative to the requirements of the project for the change of the country productive matrix in order to improve its performance indicators, especially those related to the technology transfer in the different sectors and economic activities. Those indicators should also be considered priorities at each stage of their general development strategy and incorporate, not only national state and private enterprises, but also foreign enterprises interested in investing in the country, as well as universities of the categories A and B [22]. They should generate the so-called centers of technology transfer (CTT) that play a decisive role in the conception of the proposed model, providing the necessary criterion of territoriality. However, as indicated in the proposal itself, it needs to be complemented with specific sectorial and business contributions, which facilitate its practical application, especially in metal-mechanic SMEs. They must also respond to these objectives to face the challenges, promoting opportunities through the technological change in a globalized economy, as proposed by the Inter-American Development Bank [23].

Also, as part of the research, a situational diagnostic instrument was designed and applied in situ to a sample of 200 metal-mechanical SMEs located in three cities in the center of the country, corresponding to the provinces of Cotopaxi (47), Tungurahua (74) and Chimborazo (79). They were considered a representation of the type of enterprises under study, that revealed not only their general characteristics (productions and markets), but also various problems that affect them or may affect important strategic decisions about their technological resources and, consequently, about its productive performance and survival in the sector.

Finally, an alternative methodological instrument, that it represented an alternative solution and not the only to manage these processes and complementary to the proposal macro national model for technology transfer; was synthesized from the information obtained from the knowledge about the topic, object of the theoretical study and the practice of Ecuadorian SMEs to manage the processes of technology transfer in this type of enterprises. It has been validated in metal-mechanical SMEs that operate according to the client's demand, for the construction of equipment for food processing and road transport, manufacturing of office metallic furniture, metallic structures and others, applying the case study research method..

III. RESULTS

It is known that the binomial technology - innovation is what values the knowledge generated in the processes of scientific research transforming it into socially useful products and services. On the other hand, the United Nations Organization for Industrial Development [24] also notes that both technology and innovation give way to industrialization, which is, in turn, one of the foundations for the development of a country.

Therefore, at the enterprise level, both technology and innovation are built on the ground for the enterprise to reach a competitive position. Under these postulates, Ecuador's position, on a global scale regarding indicators of innovation and competitiveness, reveals the problems that generally affect its industry, specifically the metal-mechanical one, considered one of the most important links in the productive chain, generator of the country's wealth, employment and development.

Thus, in the last annual edition of the innovation ranking (2017), Ecuador was ranked 92 out of 127 nations included in the study [25]. Despite the fact that this position represents an improvement, it does not evidence a considerable variation in the permanent growth with respect to the last six years, being one of the lowest in the region.

In this ranking, seven fundamental influencing factors are considered about the innovation processes, called "pillars", as shown in Fig. 1.

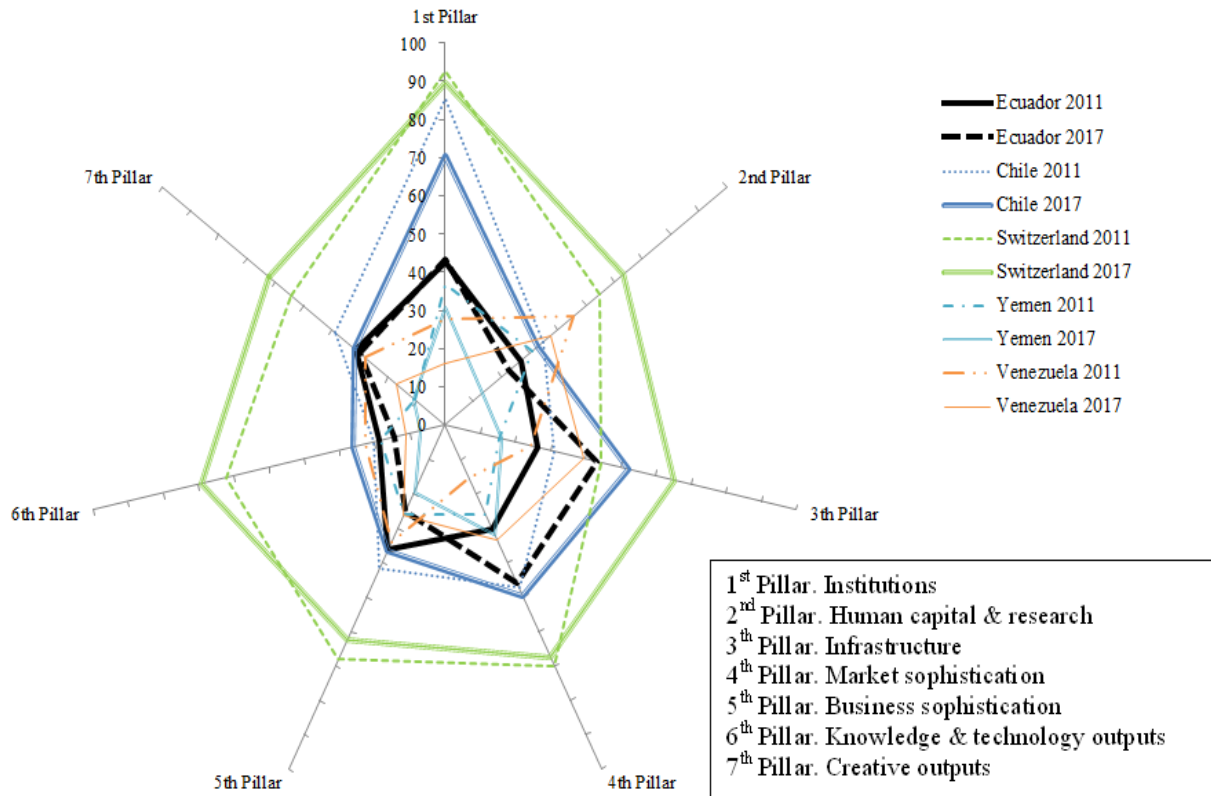


Fig. 1 Comparative position of Ecuador with respect to the pillars according to the world ranking of innovation between the periods 2011-2017

Source : elaborated by the authors based on [25].

The results obtained by Ecuador in the years 2011 and 2017 are shown in this figure, in comparison with the best or worse referents on a global scale (Switzerland and Yemen, respectively) and in Latin-American region (Chile and Venezuela, respectively).

It can also be seen from Fig. 1, that in the year 2017 in Ecuador, the pillars related with Knowledge and technology (14,3 %), Human capital and research (22,8 %) and Business sophistication (25,1 %), have deteriorated in respect to the year 2011 and just exceeded (negatively) by those figures obtained by Venezuela in the region, in the same period (except in the 2nd y 3rd pillar), and those obtained by Yemen on a global scale, in all the pillars.

With respect to the competitive index, Ecuador has performed in a similar way, although in 2016 occupied the second place in Latin America, in road quality and infrastructure, which contributed integrally to the socio-economic development of the country and the region [26].

Nevertheless, and according to the last ranking published by [27], in respect to that index, based this time in 12 pillars, Ecuador occupied the place 97 out of the 137 evaluated countries. This behavior compared with the previous six years does not evidence significant improvement, although there was an improvement in respect to 2011, when it occupied the place 101 as the lowest competitive behavior and in 2014 when no participation was registered.

In Fig. N° 2, the comparative results are shown (with the same reference countries taken for the innovation index) in respect to the evaluation of the 12 main influencing factors on this index (pillars).

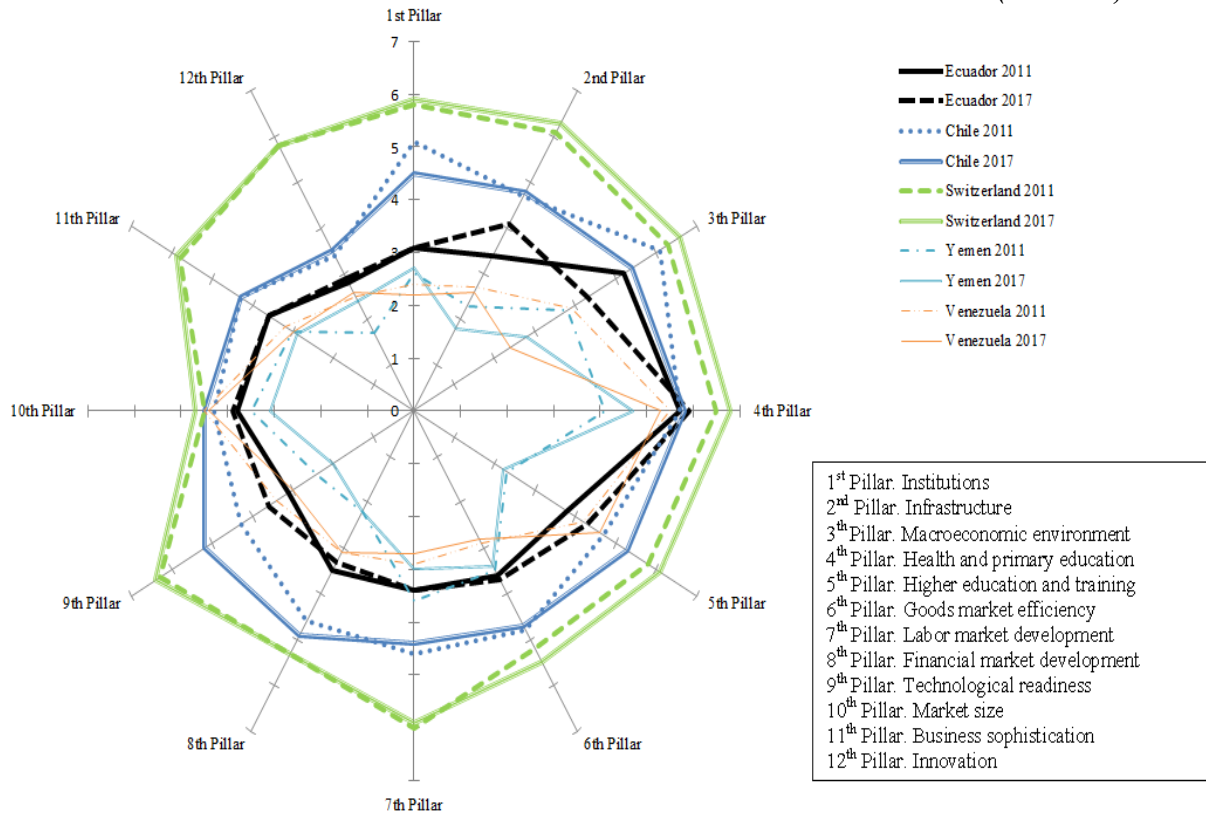


Fig. 2 Comparative position of Ecuador with respect to the pillars according to the world ranking of competitiveness in the period 2011-2017

Source: elaborated by the authors based on [27].

It can also be seen from Fig. 2, that in the year 2017 in Ecuador, the pillars related with Institutions (3,1 %), Goods market efficiency (3,7 %), Labor market development (3,4 %), Financial market development (3,3 %), Technological readiness (3,6 %) and Innovation (2,9 %) among others, have the same or deteriorated in respect to the year 2011 and just exceeded (negatively) by those figures obtained by Venezuela in the region, in the same period (except in the 10th pillar), and those obtained by Yemen on a global scale, in all the pillars.

These results are, in a great extent, a result of the fact that in 2008, Ecuador invested just 0,35 % of the GDP in projects of R+D+i for different concepts, according to statistics published more recently by [28].

In 2011, this figure increased significantly to 1.58% (approximately 1 244 MM USD) according to data published by the [29]; also for that same year it was reported that just over 36% of all Ecuadorian companies dedicated themselves to the introduction of new innovations, although 67% of them were financed with their own resources [30].

By the year 2014, the National Government allocated 2% of GDP (approximately 1 923 MM of USD) for these activities [31], but despite the efforts and even with the investment generated, for example, in 2016 by the Senescyt in R+D+i projects and the strengthening of knowledge and human talent, of approximately 160 MM USD, representing 60% of the total amount invested by this State portfolio [32]; it has not been possible to counteract the negative behavior of Ecuador with respect to these two important indicators of development. The reasons for this behavior are the magnitude of the accumulated historical problems and the availability of resources of all kinds that those activities entail.

The ACTI survey applied to 7,055 companies belonging to the group of SMEs and large companies from different sectors and 158 institutions at the national level, including government agencies and universities, in the periods 2009-2011 and 2012-2014 by the Senescyt, together with the INEC of Ecuador, revealed that in the years 2012-2014, investment in innovation focused mainly on the service industry, to the detriment of the participation of the manufacturing industry (where metal-mechanic is obviously included) in R+D+i projects, despite its strategic importance in the national productive matrix [33]; as shown in Fig. 3.

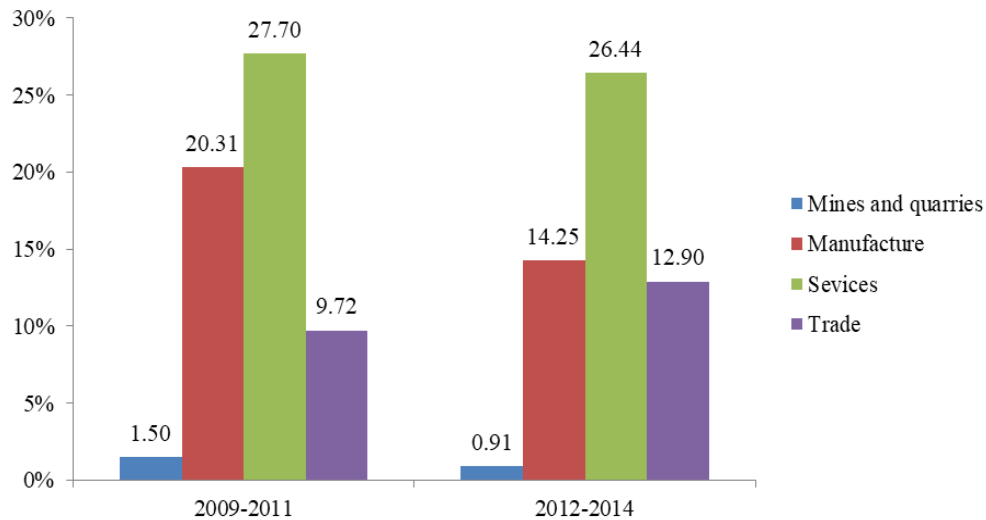


Fig.3 Inversión en innovación por sectores productivos en Ecuador en los periodos 2009-2011 y 2012-2014.
Source: elaborated by the authors from data provided by [33].

On the other hand, as it is shown in Fig. 4, corresponding to the period 2012-2014, represented in Fig. 3, just over 70% of the total of the enterprises considered in that study, allocated those funds to the acquisition of machinery and equipment, hard and software, as well as consultancy activities and external technical assistance (without convincing evidence of the objective of these strategic decisions and their real impact on these important indicators that these rankings show), much higher than the 22.58% of these that dedicated it to financing R+D+i activities, both internal and external.

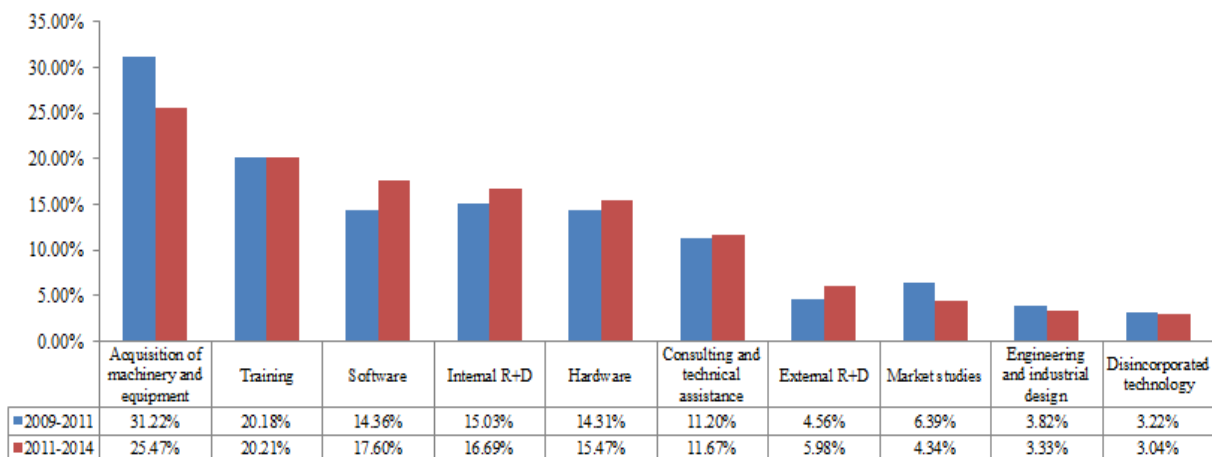


Fig. 4 Investment/expenses for the introduction of innovations in the products and processes of the enterprises belonging to the productive sectors in Ecuador in the periods 2012-2014.
Source: elaborated by the authors from the data provided by [33].

This shows that the problem lies not only on the amount of funds allocated to innovation and technology, but also on the fact of what they are allocated for and how, in addition to the fact that there are still other structural problems that must be solved.

A. Situational Diagnosis of Technology and its Management in a Sample of SMEs in the Ecuadorian Metal-mechanical Industry

The results of the situational diagnosis revealed that 63% of the enterprises, included in the sample, are engaged in the manufacture of various metallic products: general locksmith work, followed by those dedicated to manufacturing of bodywork and transportation (e.g. auto parts, such as: chassis, exhaust pipes, car fenders and other vehicular structures) (16 %), that are destined mainly to the domestic market with low quality standards that greatly limit their export (Fig. 5a).

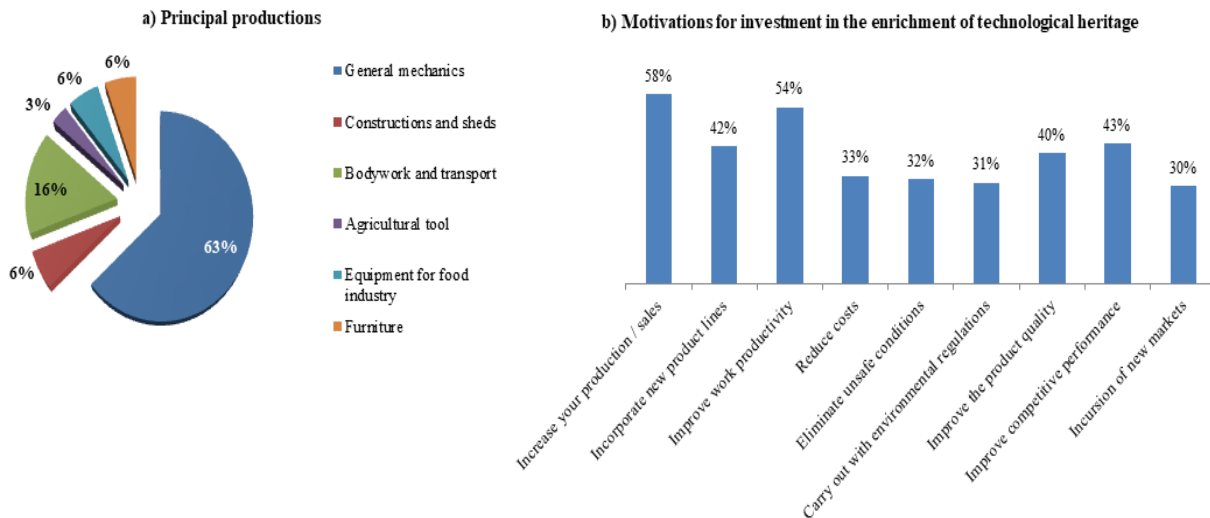


Fig. 5 Main products and investment motivations for the enrichment of the technological heritage in the studied sample of Ecuadorian SMEs of metal-mechanical industry

However, as a result of this study, in Fig. 5b shows that the main motivations for investment with a view to enriching their technological heritage, declared by the SMEs considered in the sample, set a trend generally favorable to the increase in production and sales (58 %), the improvement of labor productivity (54 %) competitive performance (43 %), the incorporation of new product lines (42 %) and the improvement of their products quality (40 %), as the most significant ones. Other motivations were oriented to solving internal problems associated with cost reduction (33%), eliminating unsafe working conditions (32%) and complying with current environmental regulations (31%), although, it is a matter of concern that only 30 % declared to be motivated to start new markets.

It was also found that the technology available to these SMEs is mostly conventional and 100% use basic manual tools. However, their average age does not presents such unfavorable situation, since most of the SMEs studied (61%) is 10 years old or less (Fig. 6).

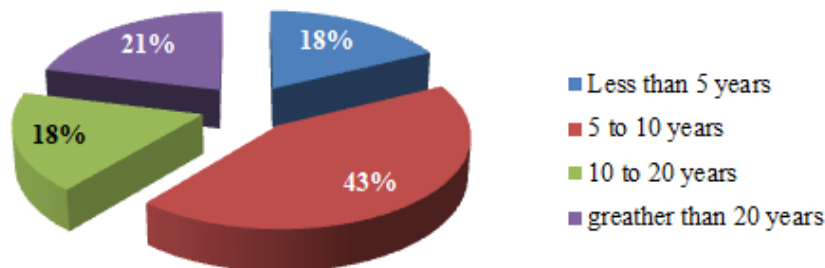


Fig. 6 Average age of the technology available in the studied sample of Ecuadorian SMEs in the metal-mechanical industry

Although it contrasts with the fact that only 12% of them (for the manufacture of metallic products, all of medium size) have implemented innovation processes with concrete results associated with incentives for this concept. However, 42% do not consider it as a priority; due to lack of resources and purchasing power of the consumer market and 46% of the SMEs only innovate occasionally. The operating infrastructure presents favorable conditions in 80% of the cases, although it is deficient in terms of defined spaces for the storage of raw materials and finished products (40%) and non-existent for the case of production waste.

Another significant aspect of the study is related with the limited experience of the SMEs in the establishment of cooperation mechanisms and strategic alliances, both among them and with other interested social actors like the government and universities, for a better use, development and exploitation of available technological resources. To this end, the law of public-private partnerships promoted by the national government, whose main objective is to boost the economy through the attraction of foreign and national investment to the execution of public projects [34], is one of the proposals that seeks to promote technological

development in the Ecuadorian industry. However, to propose new strategies that promote research contributing to the diversification of knowledge, to strengthen and generate new technologies and encourage the development and innovation in enterprises [35], remains one of the challenges that the Government and the University must face to improve the competitive performance of Ecuadorian SMEs.

This deficiency has had a negative impact on the insufficient training of human resources, in a limited development of research and innovation in technologies and products, with direct consequences on the quality of the final product and, therefore, on business competitiveness.

Summing up, the most outstanding aspects related to the objectives of the research, there is a need to carry out a pertinent research oriented to improve the productivity and quality of the productions of Ecuadorian SMEs, including those belonging to the metal-mechanic industry. It is done by strengthening (or creating, where appropriate) their management processes associated with the technological resource (for example, the technologies transfer), so that they contribute to improving in a sustainable way, its competitive performance with social responsibility in the domestic and international markets.

B. Possibilities for the Development of Small and Medium-Sized Ecuadorian Metal-mechanic Enterprises from the Management of Technology Transfer

As a contribution to the development of the Ecuadorian SME of the metal-mechanic industry from the point of view of the management of technology transfer, an alternative and complementary methodological instrument was designed with a strategic focus to support its much-needed processes of technology transfer that consider the social responsibility with its environment and, therefore, more socially and environmentally sustainable. This methodological instrument is composed of a conceptual model [15], suitable for the process of technology transfer that supports a general strategic procedure, as shown in Fig. 7.

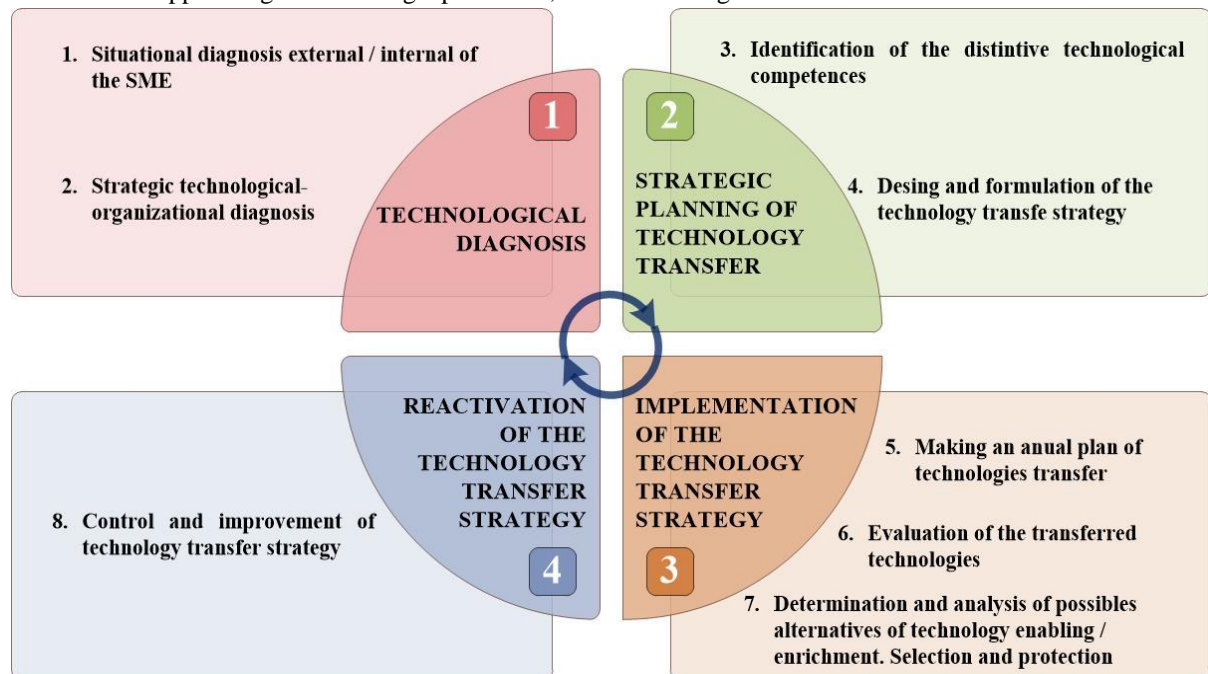


Fig. 7 General procedure for the management of technology transfer in the Ecuadorian metal-mechanic SMEs

It is composed of four (4) cyclical phases, which result in a functional adaptation of the classic phases of strategic management. The phases are structured in eight (8) stages that are based on a creative adaptation of the traditional functions of Morin [36], both active and passive or of support. They are also based on other proposals, for example, on the National Technology and Innovation Award of Mexico, referred by [37] that fit the context studied, as shown in Table 1.

The application of this procedure presupposes, however, that the SME in question meets or is willing to meet a set of minimum conditions (premises) within a certain period of time, that are also valid for this specific process to achieve the desired results and make them sustainable in time [15].

Table I Functions of the Management of Technology Transfer for SMEs in the Ecuadorian Metal-mechanic Sector

Functions	Description
Plannig	It is oriented, in the first place, to the identification and inventory (diagnosis) of the technological heritage and its management in the SME, including the so-called support technologies or complementary ones, as well as the knowledge, the innovative potential and the available capacities to carry out the process of technology transfer, both in terms of infrastructure and human capital. This is done with a view of ensuring the necessary strategic planning process of this important component of the technological resource. Although this function is activated for the different periods of strategic planning, it also has a dynamics of annual planning that can even be disaggregated into shorter periods in certain cases.
Monitoring	This function has the characteristic of being systematic and permanent throughout the process of SME management, as well as its current execution requires the intensive use of information and communication technologies (ICT) and therefore of a good connectivity to national and international networks. It focuses on the identification, location, monitoring and evolution of available technologies, both for productive processes and management, including support or complementary, either in the domestic or international technology market, or in the hands of competitors. The national regulatory processes linked to the transfer of technologies of all kinds that may be of interest to SMEs and the different industrial property figures (e.g. patents, registrations, know-how, etc.) must also be monitored and monitored.), as well as other elements of a political-legal, socio-cultural, economic, environmental and organizational nature of the micro and macro environment that may have an impact on SMEs.
Evaluating	Its content is mainly focused on comprehensive evaluation of technologies of all types, candidates to be part of the technological heritage of the SME, in terms of its three dimensions (technical-economic, environmental and social). Then, select the one or the ones that will be acquired directly in the domestic or international technological market or developed in the SME itself, as well as those that will be subject to habilitation and/or enrichment processes for being incorporated into its technological heritage and/or offered on the technological market or sold directly on customers request. Due to the multifactorial and complex nature of this process, it is necessary to have the necessary information and the appropriate tools to make decisions of this type with a strategic approach that is favored if the SME has a general strategic framework where the development of their processes of production and management is inserted.
Enabling / Enriching	Enabling: understood as a process that addresses the assimilation/ adaptation of the technology (ies) transferred by acquisition in the domestic or international technology market, or directly from a supplier not concurrent to it, using other ways not necessarily commercial, to be used in the production and management processes of the SME or transfer it to another company through sale or assignment and even offered to the technological market, without necessarily adding value through an innovation process on the original acquired technology. Enriching: is the process by which value is added to a technology of any type already enabled for use in the SME through an innovation process, either for own use or to be transferred to the technological market or to another enterprise for any commercial or noncommercial way. To be able to assume this function, the SME must have internal capacities (human capital and infrastructure) (own external (relations of cooperation with other companies and public private institutions), as well as management mechanisms that activate it.
Protecting	It allows to protect the own technological heritage enabled and/or enriched by patents, utility models, brands, licenses, authorship registers or other forms of industrial property that casuistically apply, as well as safeguarding the explicit knowledge accumulated by

	the human and relational capital of the company through know-how, intellectual property rights (copyright), and its permanent updating in a casuistic way, based on the commercial interests of the SME in its development strategy. This important function can be assimilated by the structure and management mechanisms of the SME or subcontracted as legal advice in this field to specialized public or private external institutions. So, it needs a well-defined and coherent strategy with the policy and strategy of development of the SME as a whole.
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Source: elaborated by the authors adapted from [36] and the *Mexican National Technology and Innovation Award*, cited by [37].

The general content of the four (4) phases that make up the general procedure shown in Fig. 7 is the one that is exposed next.

Phase 1. Technological diagnosis; structured in two stages, a first focused on a situational diagnosis of the SME object of analysis that is executed, both internally and externally of the organization and a second one, aimed at revealing the weak points of the production and management processes that are carried out in the SME under study.

Phase 2. Strategic planning of technology transfer; in a first stage oriented to the identification of the distinctive technological competences and their "gaps" with respect to the competition and other specific referents and in the second, to the design and formulation of the technology transfer strategy for a horizon of previously defined planning.

Phase 3. Implementation of the technology transfer strategy; with three stages destined to the preparation of the corresponding annual plans included in the strategy, the evaluation of the transferred technologies and the determination and analysis of possible alternatives of enabling and or enrichment of them.

Phase 4. Reactivation of the technology transfer strategy; focused primarily on strategic control and the reactivation of the technology transfer strategy for a new period of strategic planning through continuous improvement processes based on the objectives set by the organization.

In the corresponding cases, these stages include specific support procedures and a group of engineering and management tools, incorporated into the procedure in the form of a "toolbox".

IV. CONCLUSIONS

The position of Ecuador on a global scale regarding indicators of innovation and competitiveness reveals, to a certain extent, the problems that generally affect its industry (particularly SMEs), where the metal-mechanic is not an exception, considered since 2010 as a strategic sector to be prioritized within the productive matrix of the country and an important link in its productive chain.

The Ecuadorian metal-mechanic SME is considered a catalyst for the national economy, despite maintaining a relatively low presence in the manufacturing industry and a reduced contribution to the national Gross Domestic Product (GDP), due to its limited export capacity caused by the low competitiveness of its products and services in the domestic and international market.

Among the shortcomings of Ecuadorian metal-mechanic SMEs to achieve a better position of their products and services, both in the domestic market and particularly in the export market, are the insufficient levels of productivity and the quality standards of their productions that ensure technological resources available and where the processes of technology transfer and its management have a decisive impact.

The Ecuadorian metal-mechanic SMEs lack a methodological instrument that allows them to plan, organize and execute, the processes associated with the technological resource and especially those associated with the transfer of technology from the strategic levels with efficiency, effectiveness and sustainability on a robust and relevant conceptual basis (social responsibility). The results obtained in the original research are summarized in the present article and are considered an important contribution.

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