INTELLECTUAL CAPITAL MANAGEMENT IN MEXICAN R&D CENTERS[*] [†]

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Abstract:

The accumulation of knowledge develops expertise, which is the ability to apply knowledge to different situations producing highly successful results. The relevant aspects of this expertise are recorded and shared in an organization in order to improve its performance in all its critical processes, through specific management techniques. Knowledge management has been defined as the collective use of internally and externally available knowledge, experience and competencies to attend the requirements of the organization at any time and place.

Knowledge management has tactical and operational perspectives related to the planning, introduction, operation and supervision of all the activities and programs related to the knowledge needed for shaping and managing intellectual capital.

The intellectual capital of a determined organization is the sum of its ideas, inventions, technologies, general knowledge, computer programs, designs, data treatment techniques, processes, creativity and publications. Intellectual capital can be understood simply as knowledge that can be turned into benefits.

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The analysis of the possibilities of extracting the value of intellectual capital from Mexican research and development centers is the main motivation of this piece of research, which is based on the hypothesis that the majority of the centers have placed excessive emphasis on knowledge generation activities, leaving their valuation on the side, an attitude that has prevented them from obtaining benefits and from creating greater value for Mexican society.

Keywords : R&D centres, Mexico, intellectual capital, R&D management

INTELLECTUAL CAPITAL MANAGEMENT IN MEXICAN R&D CENTERS

I. Intellectual Capital: Concept and Nature

According to Edvinsson and Malone (1998), "intellectual capital is the possession of knowledge, applied experience, organizational technology, client relations and professional skills that give the firm a competitive advantage in the market".

Hubert Saint-Onge prefers the term *knowledge capital* to intellectual capital; he defines it as the sum of *human capital* (the ability of individuals to give solutions to the clients), *client capital* (the depth, breadth, linkage and profitability of the franchise) and *structural capital* (the organizational capacities of the firm to satisfy market demands). Saint-Onge observed that, for an enterprise to be commercially viable in the long term, its human and structural capital must inevitably be centered on its clients, giving rise to the concept of client capital. Thus, his intellectual capital model shows that the confluence among human, structural and client capital is the zone where sustainable benefits are created (Westberg and Sullivan, 2001). Figure 1 shows the basic components of intellectual capital and its interrelationships.

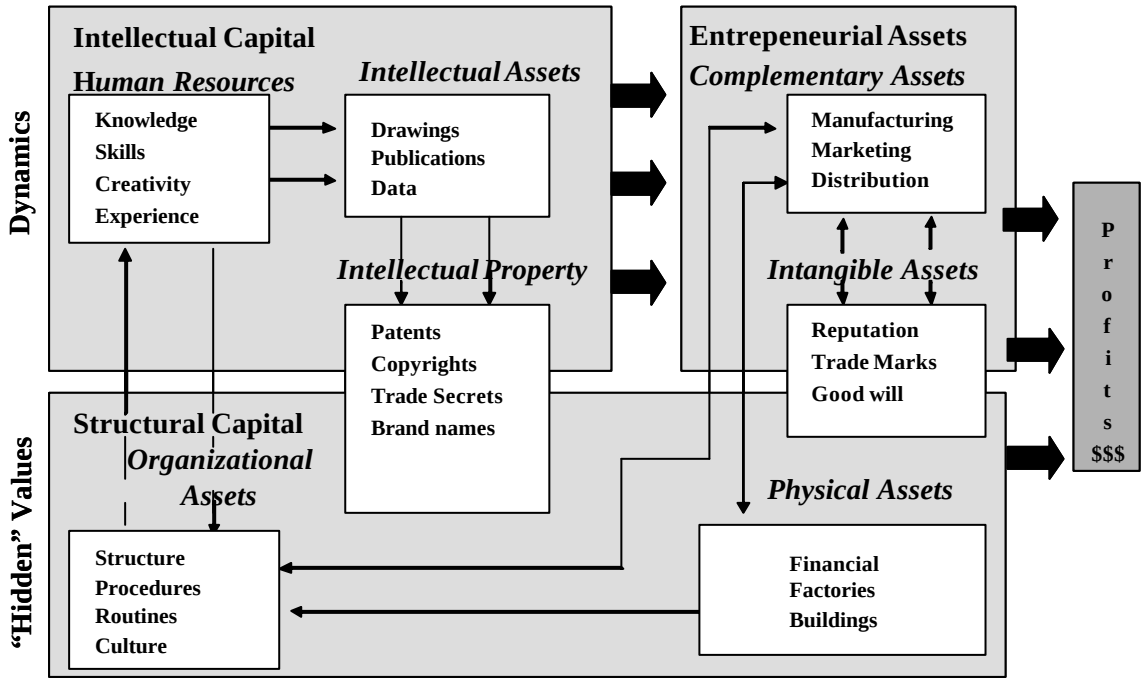

Figure 1. The components of intellectual capital (Grindley and Sullivan, 2001)

The life force contained in the concept of intellectual capital is constituted by **human capital**, which is the generator of all the value derived from the innovative potential of the organization. Human capital consists of the knowledge base and the institutional memory for each relevant matter. In a knowledge-based enterprise (which an R&D center effectively is), human capital will contribute with the greatest portion of the enterprise's market value (Martí, 2000). At an individual level, the wide concept of human capital includes the abilities and experience of employees, contractors, suppliers and other related persons in solving the clients' problems. This wide conception of human capital calls attention to the importance of overcoming the traditional conceptions of human resources administration that are deeply rooted in the institutional milieu of our country. In the traditional view, there is an inward vision that places serious limitations on the positive development of human capital, starting from the premise that the human capital is, to a large extent, of a tacit nature and is not the property of the firm (Westberg and Sullivan, 2001). This stresses the importance of encouraging and motivating employees to encode their knowledge, for only in this way can the firm obtain intellectual assets that will be its property, constituting an advantage for the firm[‡].

There are two aspects that must be underlined in relation to the importance of human capital. First, human capital in itself is not completely useful if it does not have adequate infrastructure and organization (structural capital), and a market (client capital) to commercialize the contributions of its personnel. In order to benefit from the qualities of human capital, people must be physically located so that they capitalize on skill, aptitude or piece of knowledge and be provided with sufficient tools to assure that their contributions are sustainable. Secondly, the institution must define its vision and the strategy to be used, otherwise the firm is moving forward blindly, unable to direct or motivate human capital to use its capacities in order to crystallize this vision.

- **Structural capital** permits the creation of wealth through the transformation of human capital's work (Martí, 2000). It is defined as the enterprise's structural capacity of using human intellect and innovation to achieve objectives. Structural capital is the support or

[‡] Full encoding of knowledge is not always advisable, for it is strategically convenient to keep certain intellectual components secret and this can be more viable when the tacit character of the information is maintained.

infrastructure that the firm provides to its *human capital*. It includes both direct and indirect support, including both physical and intangible elements (Figure 2). Thus, structural capital basically consists of physical assets and structures that comprise an organization. It includes factors such as quality and scope of information systems, images of the firm, databases, organizational concepts, and documentation.

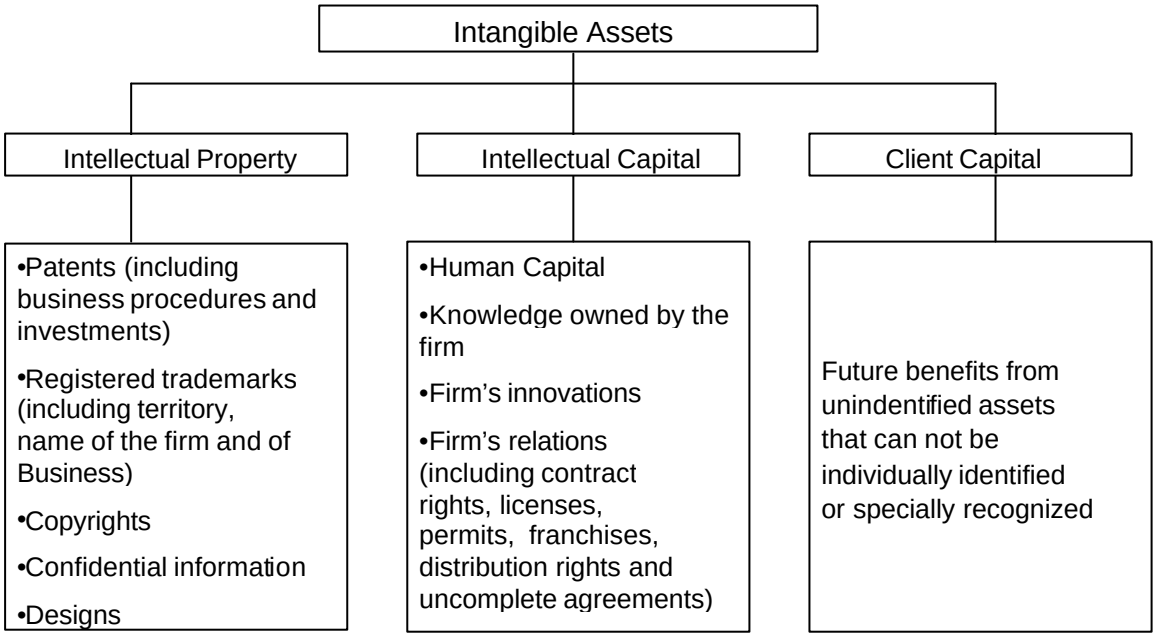

Figure 2. The integration of intangible assets in an organization

Edvinsson and Malone (1998) conceive structural capital as being composed of three types of capital: organization, innovation, and process.

- Organizational capital consists of systems, tools and operative philosophy that favor the flow of knowledge through the organization, and outside of the supply and distribution channels.
- Innovation capital is the capacity to renovate in combination with innovative results; the results are protected by intellectual property titles or are in the form of other intangible assets and talents required to take new products and services to the market.
- Process capital is constituted by work processes, techniques and programs that improve the efficiency of operations and service provision.

Structural capital also includes the *complementary entrepreneurial assets* necessary to convert an innovative idea into a sellable product or service. They are the assets of the firm that are used to create value in the commercialization process. For knowledge firms, their entrepreneurial assets complement the innovations developed by human capital. These complementary entrepreneurial assets often include industrial installations, distribution networks, lists of clients and the relationships with them, supply networks, service forces, complementary technologies, trademarks, and organizational components.

Client capital (or clientele capital) comprises the information related to the past, present and future clients of the firm and, of course, includes the relations the firm maintains throughout the value chain, which are of central importance for the value of the company[§]. Aspects such as trademarks, image, prestige and social visibility are also included.

Edvinsson states that client capital *is the probability that our clients will continue to work with us.* The fact that determines whether clients will continue to work with a firm is the degree or capacity of the firm in providing clients with what they want, at the exact moment, the correct time, and at the best price. Together with the product or service, clients will get a solution to their problem and, therefore, become satisfied. In the relationship with clients, intellectual capital turns into benefit and profitability.

The client capital, in spite of its evident importance, is far from being efficiently administered. Many organizations do not know who their clients are (notably the R&D centers). Others do know, but do not treat them as goods that generate value; on the contrary, clients are treated as adversaries who must be overcome in negotiations (Stewart, 1997).

II. Intellectual Capital Management

In general terms, management has been understood as an intervention with the firm purpose of achieving a controlled change in the state of a system (Negroe, 1981). The structure of the management process resides in decision-making, planning, information collection, correction and execution of plans deriving from process, so that the system in question does not lose its strategic sense (Terán, 2003).

[§] Despite having good quality, being innovative and easy to acquire, many products and services that have been put on the market have not been sold. These products remain unsold because the market does not accept them. Without market acceptance, the generation of value will not provide benefits to the firm.

The interest in intellectual capital that began to manifest itself throughout the world is one facet of the search for more intelligent methods of firm management. According to Sullivan (2001), the management of intellectual capital is related to the following elements:

- The vision the organization has of its future and the strategy for achieving its objectives.
- An internal definition of intellectual capital and its internal function as precursor of the fulfillment of vision and strategy[**].
- A clear definition of the functions of generation and extraction of value.
- Value extraction mechanisms.
- Systems to routinely administer and manage the intellectual capital of the organization, including the definition of decision processes with respect to the management of intellectual assets, work processes, and generation of information systems.

In the final instance, the management of intellectual capital refers to the development of techniques to facilitate the planning and execution of activities that aim at optimizing the processes of generating and extracting value from the knowledge of an organization.

The creation of value is related mainly to activities concerning the human capital of the firm. These activities aim at creating new competencies through research, learning or knowledge acquisition. This generation of new knowledge must be linked to its conversion into innovations that provide commercial value. Creating value activities include training, education, research, innovation, development of relations with clients, organizations and individuals, and management of values and culture.

The extraction of value leads to the achievement of the level and the degree of value required to reach the strategic vision and objectives of the firm in the long term. It is centered on valuation, decision processes, databases, filtering and selection, conversion mechanisms (Figure 3), and asset management systems and instruments.

As can be observed, intellectual capital management, an emerging field in full development, has clear strategic and operative strategies. In relation to the latter, the

[**] Skandia, for example, has defined intellectual capital as "the possession of knowledge, applied experience, organizational technology, client relations, and professional skills that allow competitive advantage on the market". (Edvinsson and Malone, 1998).

identification of processes that generate value has acquired special relevance in the context of its operation in a value chain or sequence of operations that aim at forming intellectual assets.

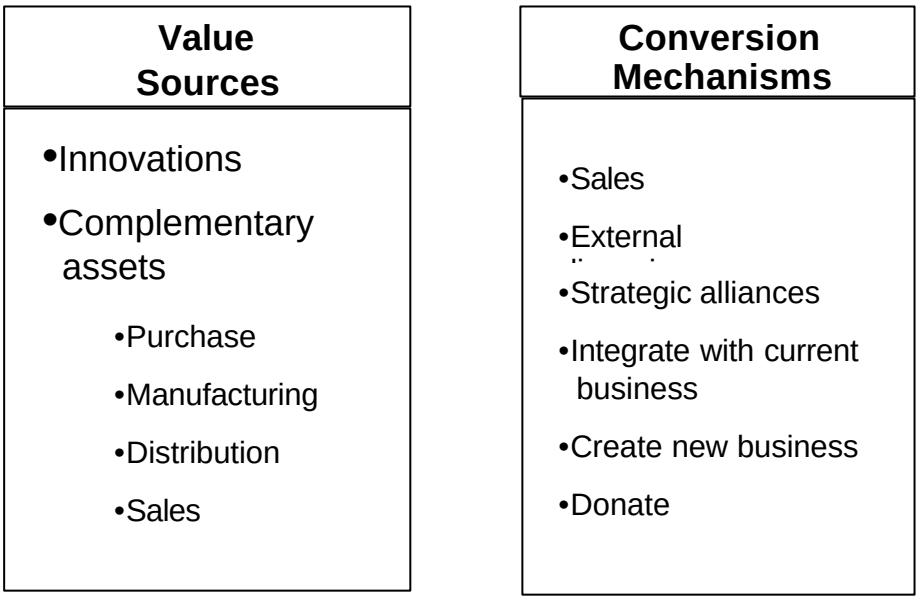

Figure 3. Value sources and conversion mechanisms (Sullivan, 2001)

III. Knowledge Management and Value Generation Processes

R&D centers should consider themselves as organizations based on knowledge; organizations where knowledge management and innovation are essential in providing greater effectiveness and flexibility to the processes of learning, creating, and translating knowledge into intellectual assets. Moreover, these management capacities have become critical in the present competitive environment, in which it is necessary to have responses and provide successful solutions to users and clients.

Knowledge management activities cover a broad spectrum, from those related to preparation and diffusion of scientific and technical reports, to those that support research personnel and the use of information technologies. These activities seek to generate the institutional capacity to creatively combine the stocks of knowledge (internal and external) on technologies, markets and operations that facilitate the development of business plans and R&D programs.

Hull et al. (2000) define the main groups of activities related to an adequate knowledge management. These groups offer a series of good qualitative indicators to develop knowledge management capacities and the design of policies and programs for their promotion:

Table 1. Knowledge management activities. Based on Hull et al., 2000

Knowledge management for innovation	Mapping of knowledge and competitive intelligence	Human resources administration	Intellectual property management	Information administration
To generate, maintain, share and manage experiences derived from R&D and other technical activities in order to constitute an institutional memory. Project management capacities from formulation of proposals, to transfer of results. Supervision and assurance of quality. Establishment of formal and informal mechanisms for communication between technical and non-technical groups. Establishment and support of gatekeeper networks.	Coordination of internal and external R&D capacities, strengthening of inter-organizational relations and recognition of market demands. Analysis of innovation capacities. Definition of the relative position of internal capacities (benchmarking) and identification of opportunities. Overseeing of external standards and regulations. Identification and analysis of possible partners. Evolution of information systems to competitive intelligence systems.	Definition and implementation of motivation and reward systems for technical personnel. Management of interdisciplinary work. Ongoing training activities and career development.	Identification of intellectual assets. Development of specific strategies for the protection of the firm's own knowledge. Use of patent information to assess the relative position of the institution in specific technology fields. Development of technology transfer strategies. Administration of trade secrets and confidential information.	To guarantee regular access to databases. Development of internal mechanisms to classify and store information. Establishment of systems for the selective dissemination of information within the institution and towards clients and suppliers. Definition of information analysis and evaluation systems. Mechanisms for the use of relevant information in decision-making processes.

It is easy to reach a conclusion on the importance of adequate management of knowledge for R&D institutions, for they can only generate benefits from the commercialization of their ideas and innovations. However, as mentioned in the introduction to this work, the only way in which this type of organization can come to extract value from their knowledge is by translating it into intellectual assets that will be commercialized through one of the conversion mechanisms illustrated in figure 3.

IV. Intellectual Asset Management in Mexican R&D Centers

Under the aforementioned conceptual framework, an exploratory sample of public R&D centers was studied. A set of interviews was conducted with the directors of the centers. These interviews were directed with the purpose of identifying their main activities related to knowledge management and value generation. The centers chosen for this research were public, qualified as emblematic in terms of their orientation to relations with the productive sector. All centers have privileged structure (physical assets) in terms of modernity of equipment and possibilities of technological development in their areas of competence. Furthermore, these centers posses highly qualified human resources in science. Table 2 presents a summary of the characteristics observed during the visits to the selected centers, which have a clear vocation to technology development and transfer.

Table 2.R&D Centers								
Characteristics	**CINVESTAV Irapuato**	**IIE**	**IMP**	**II-UNAM**	**CCADET - UNAM**	**CIMAV**	**CICY**	**UACh**
Technology orientation	Agricultural biotechnology	Energy generation Electric manufacturing	Oil Environmental engineering	Civil, environmental engineering and automation	Optics, acoustics, manufacturing	Materials, manufacturing	Biotechnology Polymers	Agriculture Agroindustry Zootechny
Project selection	Professors' initiative Response to academic calls	Joint definition with main clients (CFE and PEMEX)	Joint definition with main client (PEMEX)	Professors' initiative Response to academic calls Bidding	Professors' initiative Response to academic calls	Professors' initiative Response to academic calls	Professors' initiative Response to academic calls	Professors' initiative Response to academic calls
Competitive technological intelligence	Academic Little market evaluation	Area being formed jointly with clients	Specific department	Concentrated on leading areas	Academic Little market evaluation	Academic Little market evaluation	Academic Little market evaluation	Academic Little market evaluation
Evaluation mechanisms	Basically academic			Basically academic	Basically academic	Basically academic	Basically academic	Basically academic
Economic stimulus for personnel for technology transfer	Stimuli based on academic achievement	Performance premiums	Stimuli based on academic achievements	Percentage of royalties (40%)	Percentage of royalties (40%)	Stimuli based on academic achievements	Stimuli based on academic achievements	Not contemplated
Sources of income	Government agencies Research funds	Technological services Technical assistance	Technological services	Government agencies Research funds Technological services	Government agencies Research funds	Government agencies Research funds Technological services	Government agencies Research funds	Research funds
Technology management organization	Informal	Formal Decentralized	Formal Centralized	Formal Decentralized	Formal Centralized	Formal Centralized	Formal Centralized	Formal Centralized
Knowledge of their intellectual assets	Researcher valuation	Inventory of technologies without economic valuation	Incipient process, based on internal committee	Research valuation	Researcher valuation	Researcher valuation	Researcher valuation	Researcher valuation
Intellectual Property protection	Researchers' initiative	Researchers' initiative	Selective	Researchers' initiative	Researchers' initiative	Researchers' initiative	Researchers' initiative	Researchers' initiative
Technology transfer experiences	Little Few researchers involved	Support for technology acquisition	Works with technological partners	Little	Little	Little	Little Commercial success with agroindustrial firms	Isolated cases

CINVESTAV: Advanced Research Center

IIE: Electrical Research Institute

IMP: Mexican Oil Institute

II-UNAM: Engineering Institute, National Autonomous University of Mexico

CCADET-UNAM: Applied Sciences and Technology Development Center, National Autonomous University of Mexico

CIMAV: Advanced Materials Research Center

CICY: Scientific Research Center of Yucatán.

UACh: Autonomous University of Chihuahua

It is important to notice that the mechanisms to integrate a project portfolio derive mostly from the selection made by the researchers while answering calls from government agencies and research funds. Except in the cases of centers linked to large public enterprises (Federal Electricity Commission and Petróleos Mexicanos - the state petroleum company), there is little interaction with potential users of the research results in defining projects.

Also, there are no formal, systematic competitive technological intelligence activities, which means that evaluations of the environment are concentrated on scientific aspects with little attention given to the market and competition. The only center in the sample that has created a specific unit is the Instituto Mexicano del Petróleo (IMP - Mexican Oil Institute), which began to operate barely five years ago.

In general, in spite of their technological orientation, the centers have a strong tendency to manage an academic type, mainly oriented towards training human resources and contributing to knowledge in a sphere that is regional most of the time. For this reason, academic evaluation is, in most cases, based on traditional parameters (number of publications, citations, participation in congresses, etc.). Even the IMP has recently incorporated teaching at postgraduate level among its activities. The only center in the sample that does not present this academic biased profile is the Electrical Research Institute (IIE), which is defined as a support instrument for the acquisition of technology in the energy generating industry.

With respect to intellectual property protection, the Mexican R&D institutions have little experience. The case of obtaining patents is revealing (Table 3). A hasty explanation would lead to the conclusion this is due to inventions not being generated. However, this has no relation to the fact that scientific production published in indexed journals continually grew from 1990 (with an average growth rate of 11.6% from 1990 to 2001) to reach a figure of 4,948 articles published in 2001 (CONACYT, 2002). In 2001, for example, the SEP-CONACYT (Education Ministry – National Council for Science and Technology) "attended 5,228 students in its different programs; almost 725 graduated; 1,498 refereed articles were published; 1,694 books were published; 1,651 technological projects were generated; and 3,140 commercialized; similarly, 115,295 firms were attended and more than 125,000 services of different degrees of complexity were provided"[††]. All

[††] www.conacyt.mx/dacgci/descrpcion.html

the above was accompanied by applications for only four patents, corresponding to just one center, the Applied Chemistry Research Center.

In the case of institutes and research centers of the National Autonomous University of Mexico (UNAM), the situation is no different. Its academic personnel, consisting of 1,368 researchers and 1,006 academic technicians had accumulated, up to 2001, the publication of 38,948 articles (Scientific Research Coordination, 2002). However, the patents obtained by this institution have been decreasing. It is of note that in the years 2000 and 2001 there were no patent applications whatsoever.

Table 3. Leading Mexican institutions in patent applications 1996-2001 (CONACYT, 2002)

Institution	1996	1997	1998	1999	2000	2001
Mexican Oil Institute	16	15	14	25	8	18
National Autonomous University of Mexico	5	7	15	3		
Applied Chemistry Research Center	5	7	6	8	4	4
Electrical Research Institute	4	8		3		
CINVESTAV	4	3		4		
Metropolitan Autonomous University	4	3	3			
National Polytechnic Institute	4	6				
Autonomous University of Nuevo León	4		5			
University of Guanajuato			5			
Autonomous University of Puebla				3		
Optics Research Center				3		
University of Colima						4

The situation described above reflects the creation of centers with an eye to technology assistance and concentration of universities on conventional scientific activities that have left out the structuring of a portfolio of intellectual assets and effective value extraction mechanisms.

That fact that the R&D centers do not have a development strategy for intellectual assets would not be serious if this did not affect the fulfillment of their institutional mission. Practically all the public centers analyzed in the framework of this study declared that their mission includes the development of research related to solving problems of the productive sector. Furthermore, the Science and Technology Law explicitly states that one of the bases of State policy on this subject is “to incorporate technology development and innovation into the productive processes in order to increase the productivity and competitiveness required by the national productive apparatus” (Article 2, III).

Moreover, Chapter VII of the same Law establishes that “the Federal Public Administration agencies and entities and the public higher education institutions, in their

respective spheres of competence, shall promote technological modernization, innovation and development" (Article 39).

Article 40 establishes that "priority shall be given to projects whose purpose is to promote technological modernization, innovation and development linked to enterprises or entities that are technology users, particularly in small and medium enterprises. (...) In those cases in which the approved projects are successful and the exploitation of the technology developed produces dividends, total and partial recovery of the supports given will be considered".

As can be observed, the Science and Technology Law imposes the adoption of an application approach, at least for technological research and valuation of the knowledge generated, with the expectation of economic returns that will cover the costs of development. Article 50 II of the Law sets forth as basis for the establishment and operation of Scientific and Technological Research Funds, stating that funds "will be made up of the self-generated resources of the public research center in question and third party contributions may be received".

However, public centers are not prepared to face the challenges imposed by this Law. For example, the Centro de Investigación en Materiales Avanzados, S.C. (CIMAV), with a legal status that permits the generation of profits, has excellent achievements in its productivity in refereed publications, efficiency in the award of masters' degrees and continuity in the Postgraduate Excellence Register. But its indexes for the self-generation of its own resources is barely over 6% and for the generation of extraordinary income is 5.1%; each academic generated little over 41,000 pesos in 2002, each project that was invoiced represented an average of 55,000 pesos and each service given generated an average of 4,600 pesos that year [‡‡].

For its part, the Electrical Research Institute (IIE), a public center mainly linked to the electrical sector, defined its strategic market objective as "to consolidate the position of the Institute in present markets, and to enter others in which it has or could have a competitive advantage" [§§]. This Institute reports service sales in the amount of US$30,527.100. Out of this amount, only US$120,000 correspond to external services.

In the case of the Engineering Institute, a university center with a strong vocation for linkage with the productive sector, the situation is not very different. Even though this Institute has come to receive extraordinary income in comparable or even greater amounts than the regular

[‡‡] www.cimav.mx
[§§] http://gsidom.iie.org.mx/transparencia.nsf/MetasMercado

university budget in recent years, these amounts have fallen in both relative and absolute terms. This, to a large extent, is due to the fact that this Institute's linkage activity is highly concentrated on the provision of specialized services for four public entities: Petróleos Mexicanos (PEMEX), the National Water Commission, the Federal Electricity Commission and the Mexico City Government. Due to this concentration, with respect to services and some clients whose demand depends on the budget available from the government, the Institute has had to cut back its investments[***].

The Mexican Oil Institute (IMP) is the Mexican institution with the largest production of intellectual property titles, a fact that is not only due to its technological results but also due to the existence of a department devoted to the administration of this area[†††]. This highlights the importance of a specific organization to protect intellectual property in an institution. In spite of these achievements, the IMP still face problems in valuing its intellectual property in order to obtain better returns on the investments made to generate this asset. This Institute has recently created organic units to carry out technological intelligence functions, competitive benchmarking and estimates of the value of its intellectual assets. However, problems remain in articulating areas with the objective of having a coordinated decision making system in this subject and more effective commercialization activities aimed at a greater exploitation of the knowledge generated. At present, similarly to the cases described above, the IMP has a marked dependency: PEMEX is its main client for transfers, and services towards this institution represent 97% of the total sales of the Institute (IMP, 2002).

To summarize, the public Mexican R&D centers have barely reached the initial stages of their definition of intellectual property strategies. The intellectual assets portfolios are few and the generation of income arises mainly from the provision of specialized services to a small clientele, together with routine services of little technological complexity, low value added and little potential to generate resources that can be offered to a broader client portfolio.

It is easy to conclude that it is necessary to improve the approach to intellectual property and its management. Intellectual property should be understood as a process of construction of

[***] http://pumas.iingen.unam.mx/dir/diagnóstico2_2003.html

[†††] UNAM also had an Industrial Property Department in its Technology Innovation Center (CIT). The Department operated from 1986 to 1995, a period in which the patent applications of this institution grew substantially. The subsequent closure of CIT in 1997 and of the Linkage Coordination (which only operated from 1997 to 2000) coincides with the reduction to virtually zero of patent applications in this institution.

capacities that aims at institutional objectives linked to the consolidation of protectable intellectual assets.

Conclusions

According to the analysis carried out in this study, R&D centers in Mexico need to adapt themselves to the conditions of a new competitive and legal context and generate profound changes in their management styles. As a result, R&D centers will be able to improve their contribution to society and work towards the formation of intellectual capital that will strengthen them economically and administratively.

The intellectual capital approach does not simply refer to a mercantilist vision of R&D, for it has a strong relationship with more effective mechanisms for the management of knowledge and innovation that can help to increase efficiency and relevance of the activities conducted at these centers.

Mexico has accumulated considerable research capacities that generate growing academic results. Now the challenge is to translate these capacities into greater value for institutions and for the society in which they operate. The intellectual capital management approach can be a valuable tool for such a purpose.

Many R&D centers in Mexico have traced the goal of generating income derived from the commercialization of their knowledge. However successful cases have been an exception. The lack of institutional experience and orientation to solve specific problems of a client or user of such knowledge is expressed as an enormous obstacle in the fulfillment of this goal

One of the obstacles for the Mexican R&D centers to draw closer to the market is related to the relative importance of performance stimuli (such as the scholarships of the National Researchers' System[‡‡‡] and productivity bonuses), which have reached an important proportion of the salary perceived by researchers, which has meant that they give priority attention to projects that yield traditional academic results that are more appreciated by the groups that evaluate performance in order to assign those stimuli. Evaluation groups are normally made up of academic peers with no relationship with the industrial, social and market context in which

[‡‡‡] This system establishes economic rewards for researchers who fulfill academic requirements of productivity mainly expressed in the form of refereed publications.

research takes place. (Instituto de Ingeniería, 2003). Thus, with respect to intellectual capital management, these economic incentives for researchers become perverse.

It is also necessary to understand that the trend to complement competitive prices with factors not related to price, such as speed, quality and specific response to clients' demands do not only apply to manufacturing firms. Organizations that offer innovative services are also subject to these competitiveness criteria. Many R&D institutions in Mexico have opted for applying indirect costs in setting the prices for their services, in which they lose all competitiveness, as well as the traditional lack of speed of response resultant from bureaucratic decision-making processes that must be followed before signing a contract. The UNAM centers, for example, have to wait months in order to obtain the approval of the General Lawyer's Office before signing a commitment of this type [§§§].

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[§§§] There are institutes like those in the Health Sector that do not have the power to make technology transfer contracts, since this would imply alienation of the institutional patrimony.

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