A knowledge-based development model: the research chair strategy

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Abstract

Purpose – *The purpose of this paper is to introduce a model for the knowledge-based development (KBD) of a region using a research chair strategy at Tecnológico de Monterrey, to describe its impact and to propose its use in organizations that generate scientific and technological knowledge, especially research groups, in a university environment.*

Design/methodology/approach – *The approach employed in this research evolves around a strategy for setting up research chairs (research groups headed by a lead investigator) which is a type of action research methodology whose steps are: planning a research program which is clear, focused and with an impact on regional development, implementing it, observing the corresponding processes and results, and reflecting on them. The components of the KBD model include human and intellectual capital (research professors and research students), research products (journal articles, conference papers, books and patents), research funding, entrepreneurial spin-offs emerging from the research capacities, and research-based learning and education. Measures of performance for each of these components are explained and quantified for the KBD at Tecnológico de Monterrey. Management and technological issues are analyzed in deploying and implementing the research chair strategy, especially the method proposed for evaluating research chairs. An overall assessment of the approach is given based on the results of five years of operation. The internal and external impact of the model and its computer implementation are also analyzed and assessed.*

Findings – *This paper concludes that research outcomes at universities, research centers and institutes may be organized around a knowledge-based model and a knowledge-information computer system that supports the model. These serve the organization by disseminating knowledge assets, by solving economic and social needs in different regions, and by creating value for researchers and for the organization.*

Originality/value – *The paper describes a knowledge-based model that proved useful for a university case. It can be adapted by organizations that generate knowledge and need to leverage it, not only for their own benefit but also as an engine of economic development for target regions. The model is supported by a knowledge-information computer system and has been running for five years.*

Keywords *Knowledge management systems, Knowledge economy, Knowledge organizations, Research*

Paper type *Research paper*

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Introduction

Universities today are playing a new role in the development of the economies of their countries (Etzkowitz, 2001). Knowledge and intellectual capital are now the bases of a new source of wealth for organizations and are engines of economic and social development. Competitiveness at both institutional and national levels is constructed from technological innovations that provide better products and services in traditional or emerging markets. Thus, universities have embraced new challenges for preparing qualified professionals and generating scientific, technological and innovative knowledge, as well as in the creation of new knowledge-based companies and the upgrading of existing ones in their regions (Matthiessen *et al.*, 2006).

University rankings

In addition, universities compete among themselves. This is especially true of research universities, whose standing is often measured by rankings calculated periodically by organizations such as *US News*, *Newsweek*, *The Times* of London and the Shanghai *Jiao Tong* (Zuckerman, 2004). Rankings are used by universities for attracting the best students and faculty, as well as for obtaining research funding from government and industrial sectors, foundations and other agencies. The rankings are calculated from weighted indicators that yield a general score, with research evaluation as an important component. Typical research indicators are the quality of journal articles and number of paper citations, faculty awards, student graduation rate, research expenditure and, nowadays, the number of start-up companies generated by the research and development activities of the professors and students. To measure a publication's scientific impact, there are indexing services that provide valuable statistics about article and patent citations, and abstracts and impact factors. Thompson Scientific's Web of Science (www.thompson.com/), for example, keeps proprietary databases of papers and patents published in a selected set of journals and conferences; articles and journals are ranked through an impact factor based on the number of citations. Scopus is another institution that provides indexed statistics of scientific publications (www.scopus.com). CiteSeer (www.citeseer.org/) and Google Scholar (http://scholar.google.com/) provide this service without charge, obtaining their information through automatic Web data extraction. Patents are available through public databases such as the US Trade Patent Office and Google Patent.

Value of knowledge

However, relying only on the epistemic value of scientific publications does not seem to be sufficient, especially in current economies. Government, industrial and academic officials want to see the economic value of knowledge generated by public and private investments in research and technology. Therefore, other measures of the economic impact of knowledge have been proposed. These include the number of technology-based spin-off companies, the number of jobs requiring technical skills created, the contribution to the gross internal product of the region, and royalties for universities and professors. Research evaluation has created the need for a knowledge-based model that makes evident the intellectual capital and knowledge assets available in the organization, combined with computer information systems that allow the integration of data, information and knowledge for the calculation of research indicators for strategic planning, investment analysis and competitiveness (Martins-Rodriguez and Viedma-Martí, 2006).

The Tecnológico de Monterrey knowledge-based model

This situation is well understood at Tecnológico de Monterrey, a multi-campus institution of higher education that has decided to play a more active role in the economic and social development of its local regions by following a strategy based on the knowledge-based approach, which is described in this paper.

The paper is organized as follows:

- the research background that is relevant for this investigation is discussed;
- the knowledge-based development model is presented, with its components and the measures of performance for each component;

" Knowledge and intellectual capital are now the bases of a new source of wealth for organizations and are engines of economic and social development. "

- the research chair program is explained, with an analysis of its managerial and technological aspects;
- an overview of the impact of the knowledge-based model within the organization and on the local region is presented; and
- the results and conclusions of five years of model operation are presented.

Research background

An action-research methodology was used for designing the knowledge-based model described in this article (Reason and Bradbury, 2004). The main focus of action research is on the capacity of people to analyze and reflect on their own activities. Kemmis and McTaggart suggest that: ''Action research should have four cyclical phases: Planning – defining the problem and organizing research practices; Acting – implementing plans; Observing – collecting data; and Reflecting – revising actions and outcomes, and planning new actions derived from what has been learned.''

The authors of this paper were responsible for the planning, design and deployment of a research chair strategy and a knowledge-based model built around the research chairs. A meta-level analysis and self-reflection on the work was conducted by applying action research methodology to the research strategy. A KBD model has been proposed for a university case and for adapting it in organizations that generate scientific and technical knowledge.

Knowledge management methodology

A Knowledge management methodology was also followed for describing the processes and products of the KBD model (Liebowitz and Beckman, 1998; Liebowitz, 1999) and the computer based knowledge and information theory that supports its implementation (Aguirre *et al.*, 2001; Robles *et al.*, 2006). This involves the creation of a knowledge-based corporate memory, which stores and distributes information and knowledge that is relevant for the operation of an organization. Corporate memories are classified according to the capture and distribution mechanisms that are used to build the memory, which may be either passive or active. Active capture and active distribution involve a corporate memory called a knowledge pump. In this research, the KBD model and the computer knowledge and information system that supports it are viewed as a knowledge pump (Cantú *et al.*, 2005b), involving active capture and active distribution.

Knowledge-based development models of various types have been proposed, analyzed and criticized elsewhere (Carrillo, 2006b; Raza *et al.*, 2006). Raza *et al.* write: ''The diversity of human cultures requires holistic and socially sensitive perspectives of development, which also take into consideration the critical relationship of human values and their impact upon the global economic development.'' These authors analyze the impact of information and communication technologies (ICT) on the globalization of knowledge-based development and the concept of social capital within the cultural context of human groups, and consider the role of ICT in the growth of the economies of countries outside the industrialized world.

In this research, cultural aspects are briefly discussed. However, since ICT is very important in deploying the KBD model, careful attention has been paid to the implementation of a knowledge and information computer system, which has become a key ingredient of the knowledge development strategy.

The Tecnológico de Monterrey case study

Tecnológico de Monterrey was founded in 1943 by Eugenio Garza-Sada as a technical university based on his own experience as a student at MIT. His idea was to provide technically-qualified professionals to the growing industries that had emerged in the early twentieth century and were consolidating in the 1940s and 1950s mainly in Monterrey, but also in other regions of Mexico. Research and graduate programs were introduced in 1985 through the creation of approximately 20 applied research centers, 20 master's programs and five PhD programs with a close interaction with industry. In 2001, the Monterrey Campus committed to accelerating its transformation into a teaching, research and entrepreneurial university, emphasizing research areas in the knowledge economy.

Today, Tecnológico de Monterrey is a private university system comprising 33 campuses in various cities of Mexico, as well as a virtual university system with coverage in Mexico and Latin America, and 12 liaison offices in the USA, Canada, Europe and China. All the campuses of the Tecnológico de Monterrey university system are accredited by the USA's Southern Association of Colleges and Schools (SACS). There are approximately 60,000 full-time undergraduate students and 12,000 graduate students, of which 400 are PhD students. The number of faculty members is approximately 8,000, of which of the order of 3,000 are full-time and 1,200 hold PhD degrees. The Institute has research cooperation with more that 50 universities worldwide.

The work described in this paper focuses on the transformation of the Monterrey Campus, which currently reports an enrolment of 16,000 undergraduates, 2,500 master's and 170 PhD students, as well as 650 full-time faculty members, of which approximately 350 hold PhD degrees. It is made up of the schools of: Engineering, Business, Information Technologies, Medicine, Public Management and Humanities & Social Sciences. The different schools are accredited by the corresponding national and international agencies.

The knowledge-based development model

The knowledge-based development model proposed in this research consists of six components:

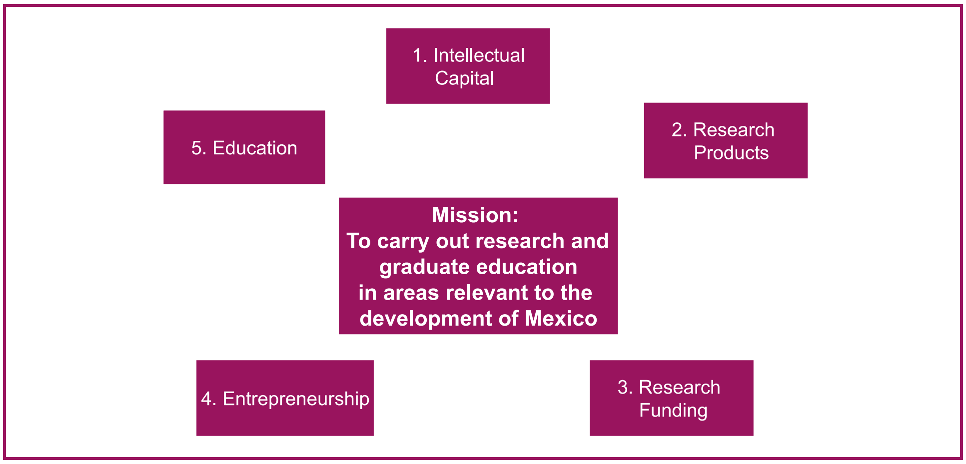
1. an institutional mission, which is the central and guiding element;
2. social, human and intellectual capital;
3. research products;
4. research funding;
5. entrepreneurial initiatives; and
6. the education model.

These main components of the KBD model are displayed in Figure 1.

Institutional mission

The institutional mission establishes the *raison d'être* of the university and provides the strategies for achieving its goals. One of these strategies emphasizes carrying out research, development and innovation relevant to the economic and social development of Mexico

Figure 1 Knowledge-based development model



and its different regions by focusing on niches of knowledge on which the university is to concentrate in order to develop research and entrepreneurial capacities. Among the knowledge disciplines on which Tecnológico de Monterrey has decided to focus are: biotechnology (food and drug discovery), information technologies (software development and wireless communications), engineering design (automotive and aero-spatial vehicles), health (cancer and cardiology diagnosis and treatment), and natural resources (water, air, forests, energy, materials, construction). Figure 2 shows the priority areas of focus and specialization.

Social, human and intellectual capital

Social, human and intellectual capitals are based on faculty professors following a research career at the university and on students pursuing degrees at the PhD, master's and undergraduate levels, as well as the social network of researchers in the various disciplines all over the world (Liebowitz, 2004; Alvarado *et al.*, 2007). This social networking has been facilitated by existing ICT. Faculty development is a key factor of this component and has two sub-components: having faculty professors pursue a research track with encouragement to obtain external accreditations as researchers. For the former, the university has established a program in the last 15 years for hiring faculty holding PhD degrees from top universities. Currently, 35 percent of the research faculty has obtained their PhD degrees from top-50 universities worldwide. Tecnológico de Monterrey has established economic and academic incentives for those professors who obtain accreditation as national researchers from the National Council for Science and Technology. This accreditation is granted mainly on the basis of the number of journal articles in indexed and refereed journals published by the professor, the prestige and impact factor of the journal in the discipline, the number of citations and the graduation rate of PhD and master's students.

Measures of performance. The metrics to measure performance for this component are the percentage of faculty professors holding accreditation as national researchers. There are approximately 300 graduate-level professors holding PhD degrees. The goal is 100 percent. There are of the order of 250 research professors, of which 125 hold national researcher awards (50 percent). The goal is 75 percent. Figure 3 shows the growth of national awards in the past years.

Research products

Research products are the outcome of the research processes that take place within research groups. The main types of research products are refereed and indexed publications, such as journal articles and conference papers, books and book chapters from

Figure 2 Areas of specialization

Biotechnology
- **Food technology**
- **Drug discovery**

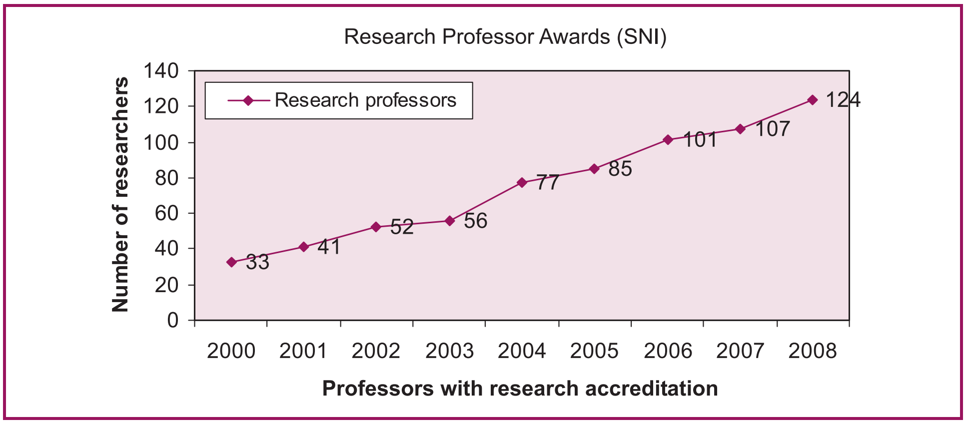
Information and communication technologies
- **Software development**
- **Wireless communication**
- **Cybersecurity and biometrics**

Engineering design
- **Automotive**
- **Aero-spatial**

Health
- **Cancer**
- **Cardiology**

Natural resources
- **Water, air, forests**
- **Energy, materials, construction**

Figure 3 Growth of researchers with national awards

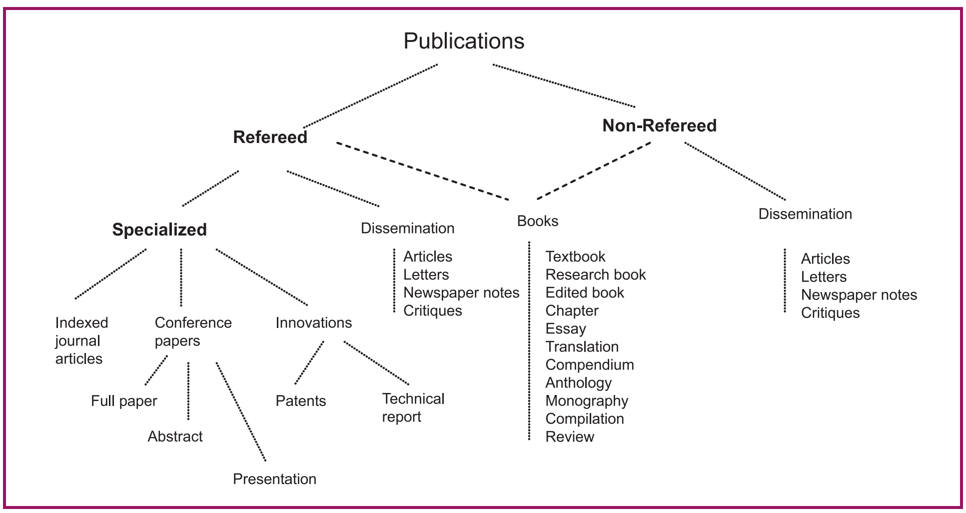


prestigious publishers, and patents for inventions. A taxonomy of the main products is displayed in Figure 4.

Measures of performance. The metrics to measure performance for this component are based on peer-review criteria. The main parameter is the impact factor of the journals in which research articles are published. The impact factor of the journal is calculated from the number of citations of the articles published over a period of time by articles of other journals. Conference papers are sometimes an intermediate step in preparing the publications of a journal article. The number of journal articles in the Science Citation Index published by Tecnológico de Monterrey professors has grown from two dozen per year five years ago to about 200 articles in 2006, and the average impact factor of the journals of publication has changed from less than 0.5 to of the order of 1.5.

The success of books and book chapters is often measured by the prestige of the publisher, the number of copies sold and the corresponding citations. Patents have three purposes: to protect intellectual ownership and obtain prestige, to block competitors in specific niches of business and to pursue revenue from the licensing of an invention. The number of patents filed or published in one or more countries and the income from patent licenses are measures of innovation performance. Tecnológico de Monterrey has filed approximately 35 patents over the past three years. Most of the patents have been filed in Mexico, some in the USA and others in Europe through the Patent Cooperation Treaty (PCT). Approximately ten

Figure 4 Taxonomy of research publications



of those patent applications are being licensed to companies for commercialization purposes. Royalty contracts that benefit the university and the inventors have been agreed upon with different companies. Figure 5 shows the growth of patent filings.

Research funding

Research funding is needed for developing research capacities. This study analyzes the source and the destination of research funding. Sources of research income are of two types, internal and external. Internal funding is seed money allocated by Tecnológico de Monterrey to research groups in strategic and priority areas. External funding comes from government research grants, industry contracts, extension activities such as consulting and continuous education, donations and sundry other sources. The destination of research funding is as follows: increasing professor's research time by lowering the teaching load, granting research assistantships for paying student tuition and living expenses, and paying for laboratory equipment and materials, traveling and operation expenses.

Measures of performance. The metrics to measure performance for this component are based on the annual research expenditure, the percentage of research expenses with respect to total university income, and the balance between internal and external research funding. Figure 6 shows Tecnológico de Monterrey's research expenditure over the past eight years.

Entrepreneurship

Entrepreneurship is a means of getting value from a university's research products and intellectual capital. The entrepreneurial program at Tecnológico de Monterrey began during

Figure 5 Growth of patents filed by Tecnológico de Monterrey

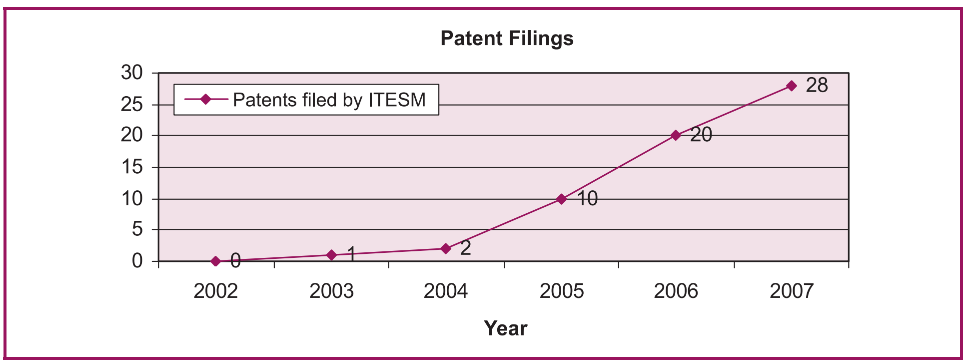
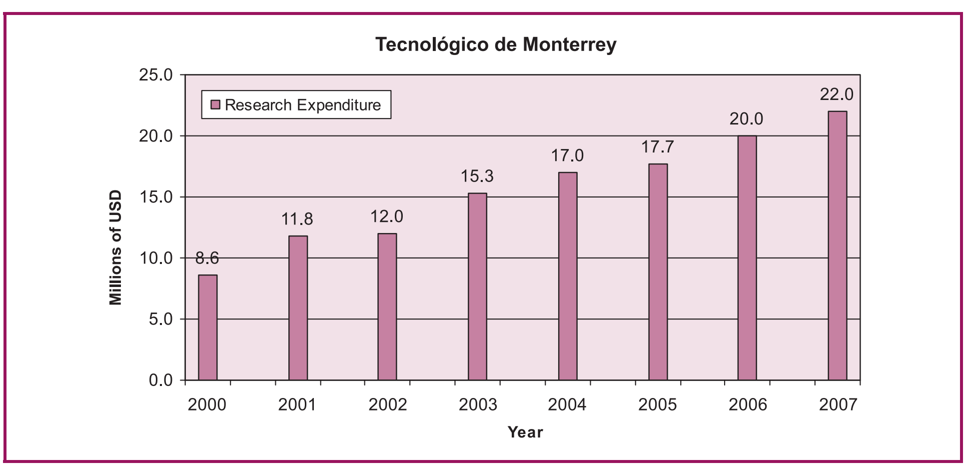


Figure 6 Growth of research expenditure at Tecnológico de Monterrey



> “A knowledge-based development model has been proposed for a university case and for adapting it in organizations that generate scientific and technical knowledge.”

the 1980s. Companies of various types were started by students and alumni at that time. Recent surveys indicate that 68 percent of university alumni have owned a company 20 years after graduation.

An incubator sub-program for initiating and accelerating technology-based companies from the research outcome of professors and students has been operating for the last few years. There are three stages in the incubation model: pre-incubation, incubation and post-incubation. In the pre-incubation stage, a business plan, which covers technologies, products and/or services, market, competitors, suppliers, prices, and costs is developed and business scenarios are simulated. During the incubation stage, a company is legally constituted, starts operations and generates its first revenues. At the post-incubation stage, managerial issues of sustainability, growth and expansion are treated. Over the last two years, emphasis has been placed on the incubation of companies based on technologies generated by research groups at Tecnológico de Monterrey. A model has been proposed through which entrepreneurial students develop business plans from the technologies developed by the research groups.

Measures of performance. The metrics to measure performance for this component are based on the number of technology based spin-offs either owned by professors or students, in which equity is shared by the university or the professors, or in which university-owned technology is licensed by a company. Other measures include the number of jobs and annual sales of those companies.

Education

Research must have an important impact on the education process at the graduate and undergraduate levels. Didactic techniques based on research-based learning (RBL) have been adopted by most of the research groups on campus. RBL and the entrepreneurial program are distinctive characteristics of the Tecnológico de Monterrey educational model. At the graduate level, emphasis has been placed on strengthening the doctoral programs offered by the university. PhD degrees are offered in the areas of Engineering, Information Technologies, Business, Public Management, Medicine, Humanities, Social Sciences and Education. A scholarship fund and a program of teaching and research assistantships have been established for attracting the best students in the country and in Latin America. At the undergraduate level, research professors are teaching courses and sharing their experience in a number of ways, including the following: international invited professors teach some of the classes, research projects are presented as class case studies, some of the students are co-authors of research publications, and students attend conferences organized by the research group.

Measures of performance. The Campus plans to increase the number of PhD students from 150 in 2006, to 300 in year 2010, to 500 in year 2015 and to 1,000 in the following decade. At the undergraduate level, in the August 2007 semester, there were of the order of 55 research chairs, with approximately 250 research professors teaching more than 5,000 students in 250 courses.

The research chair program

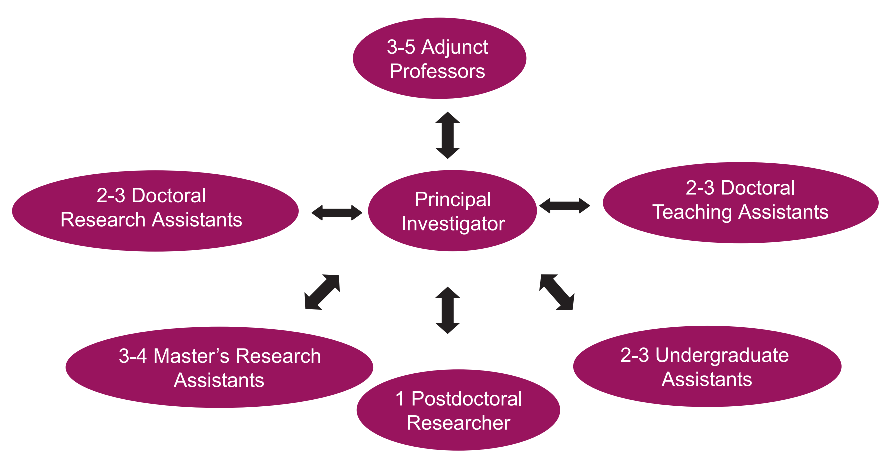
Having presented the knowledge-based model and the measures of performance, this paper goes on to describe the research chair program that is the means by which the KBD model has been deployed and implemented (Bustani *et al.*, 2006). The research chair program is an initiative that was designed to position the Tecnológico de Monterrey, Monterrey Campus as a teaching, research and entrepreneurial university in order to better serve the economic and social needs of the different regions of Mexico. A research chair is a group of researchers (professors, postdoctoral researchers, and PhD, master's and undergraduate students) specialized in a scientific domain and headed by a principal researcher.

A problem with research groups at Tecnológico de Monterrey in the period 1985-2001 was that it was very difficult to sustain a continued line of research because projects funded by companies were spread across multiple areas. Once a project was finalized, subsequent projects were not necessarily from the same line and the need to self-support a given center's operation obliged its directors and professors to take projects of very diverse types. The research chair program was designed to give continuity to research groups by supporting them with institutional seed money. The research chair strategy started in 2002 with an internal call for proposals that were assessed by an evaluation committee made up of internal and external referees. A research chair was granted to groups of researchers rather than to a single researcher. A research chair comprises of the order of 20 researchers led by a principal investigator, as displayed in Figure 7.

Selection of research chairs

The evaluation committee selected 25 out of 60 proposals by considering predefined criteria: research qualifications of the principal investigator and adjunct professors, enrolment of PhD and master's students, alignment of the project and the priority areas, international connections, feasibility of attracting external funding, potential for filing patents and inventions for future licensing, and external awards given to faculty members. The number of research chairs increased from 25 in the year 2003, to 40 in 2006, to 55 in 2007. Research chairs today include approximately one thousand researchers, including professors (300) and research students (700). They are classified in the following knowledge areas: new economy, which includes the fields of biotechnology; information technology and nanotechnology (or bio-info-nano for short); health, which includes cancer, cellular therapy and stem cell research, cardiology and medical engineering studies; resources for development, which includes water, energy, air, forests and housing technologies; economic, social and political studies, which includes employment, poverty, demography, border issues, democracy and North American studies; business studies, with technology-based company incubation, company fusion and acquisition, and base-of-the pyramid studies. Table I displays the areas and the number of chairs.

Figure 7 Research chairs for collaborative research



Note: 20 researchers per research chair

Table I Number of research chairs per area of knowledge

Knowledge area	*Number of chairs*
New economy: bio-info-nano	30
Economic, social and political studies	12
Resources for development	7
Humanities	3
Education	3
Total	55

Research evaluation

Research evaluation criteria based on international standards were implemented to measure research performance as well as the achievement of the stated goals (Martins-Rodriguez and Viedma-Martí, 2006). Evaluation is carried out along two dimensions: quantitative measures and qualitative assessment. Quantitative measures are classified in two groups: Essential Research Indicators and Special Innovation Indicators. Qualitative assessment is carried out by peer-reviewers analyzing ten aspects of research performance. Figure 8 summarizes the evaluation criteria.

Quantitative measures

Essential indicators take values from a 1,000-point scale. Publications are awarded 250 points without an upper limit. The type of publication includes refereed articles in indexed journals (25 points), refereed conference papers (5 points), books (25 points), book chapters (5 points) and patents (100 points). Published patents receive a high score in order to encourage researchers to transform the knowledge generated in technological innovations and to develop a culture of intellectual property. External awards are those granted to individual researchers by the National Council for Science and Technology, the National Academy of Science and scientific or professional associations (fellowships, prizes, etc). Researcher education includes both the graduation of students and the enrolment of students pursuing their degrees. Scores for student graduation are as follows: doctoral (30 points), master's (10) and undergraduate students (5). External funding scores 250 points should the research chair bring research contracts of amounts greater than or equal to the seed money received from the university.

Each research chair receives 150,000 USD per year for five years. Altogether, the campus is investing 20 million USD in the research chair program. Research chairs are ranked every month according to essential indicator values and the rankings are circulated among research chair members and university officers. An example is displayed in Figure 9. Names

Figure 8 Research evaluation criteria

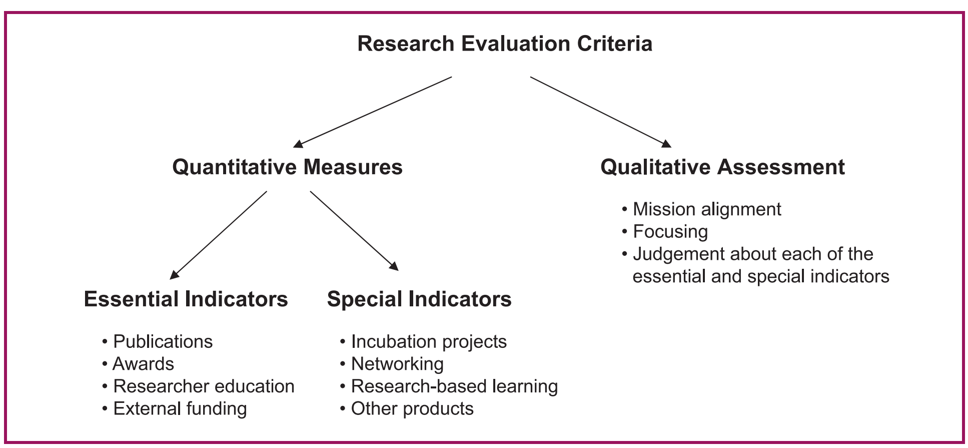


Figure 9 Ranking of research chairs by essential indicators

Tecnológico de Monterrey

Research Chairs Follow-up Indicators 1000

January 2003-December 2005	250	250	200	200	100	1000		
	Refereed	**External**	**External**	**Human**	**Other**		**Performance**	1000
								700
Name	**Publications**	**Funding**	**Accreditations**	**Resources**	**Products**	**Total**		0
Biotechnology	1170	144	460	226	100	2100		
Molecular Biology	500	752	140	221	100	1713		
Nuclear Physics	665	399	200	276	100	1640		
Thermodynamics	995	36	125	154	100	1410		
Electronics	470	128	250	363	59	1270		
Computational Complexity	415	293	210	279	41	1238		
Business Models	90	539	160	241	100	1130		
Astronomy	495	206	95	226	100	1122		
Industrial Engineering	355	245	135	269	100	1104		
Software Engineering	290	371	60	234	94	1049		
Operations Research	485	58	65	290	77	975		
Civil Engineering	60	587	40	165	95	947		
Artificial Intelligence	530	44	50	197	100	921		
Ethics	295	309	45	168	100	917		
World Trade	660	40	65	13	100	878		
Global Warming	190	440	40	78	100	848		
Sociology	295	231	150	70	100	846		
Sea Studies	50	656	30	30	58	824		
Philosophy of Science	250	18	105	40	100	513		
Literature	105	147	40	125	66	483		
History	210	4	50	108	100	472		
Geography	110	59	20	69	100	358		
Archeology	145	47	75	38	37	342		
Average	**370**	**240**	**111**	**163**	**86**	**970**		

and scores do not necessarily correspond to actual chairs to assure the privacy of information. The first column shows the chair name and the following six columns show the evaluation criteria scores, while the last column displays a color: medium gray means above the minimum, light gray means 1 to 30 percent below the minimum, dark gray means 31 to 100 percent below the minimum.

Special indicators measure other criteria of institutional interest, such as the number of incubation projects for launching spin-off and start-up companies, scoring 50 points for every project with innovation products, market analysis, a business plan, technology valuation and capital needs. Other special indicators embrace networking (250 points) and teaching impact through the use of research-based learning didactic methods in undergraduate programs (100 points).

Qualitative assessment

Qualitative assessment is carried out by peer-review every three to five years. Each principal investigator (PI) submits a five-page report highlighting the main contributions of the chair and makes a 30 minute presentation with questions and answers. Peer-reviewers evaluate ten aspects which correspond to the level of alignment of the research to the institutional mission and the focusing of the research in a sustained way. In addition, reviewers assess each of the essential and special indicators using a scale which is similar to the one employed by ABET for accrediting engineering programs. Each of the ten aspects receive a grade which may indicate a deficiency (D), a weakness (W), a Concern (C), or No-shortcomings identified (N). The list below shows the definition of each grade:

- *Deficiency*. A deficiency indicates that a criterion, policy, or procedure is not satisfied. Therefore, the research is not in compliance with the criterion, policy or procedure.
- *Weakness*. A weakness indicates that the research lacks the strength of compliance with a criterion, policy or procedure to ensure that the quality of the program will not be compromised. Therefore, remedial action is required to strengthen compliance with the criterion, policy or procedure prior to the next evaluation.
- *Concern*. A concern indicates that research currently satisfies a criterion, policy, or procedure, however, the potential exists for the situation to change such that the criterion, policy, or procedure may not be satisfied.
- *None*. There are no shortcoming identified for the research in this criterion, policy or procedure.

Grades are summarized and averaged along both the ten aspects and the number of reviewers. An overall numerical score is calculated and the chairs are ranked by this score. Then, the quantitative and qualitative scores are compared, a rank is assigned, differences calculated, deviations analyzed and decisions made in terms of budget increases, continuation with the same budget or finalization of financial support. Figure 10 shows an example of this procedure.

Alignment

The names listed in the first column of Figure 9 and Figure 10 describe the areas of knowledge on which research is carried out at Tecnológico de Monterrey. In order to receive institutional funding, a research chair must be aligned with the areas of the Institute's Mission, and therefore with regional development, otherwise, the researcher must conduct his/her research with funding from external sources.

Figure 10 Quantitative and qualitative comparisons and decisions

Tecnológico de Monterrey

Comparison of Quantitative and Qualitative Scores and Decisions

	Score		Position			
Research Chair	Quantitative	Qualitative	Quantitative	Qualitative	Difference	Decision
Biotechnology	2100	11,4	1	1	0	Increase budget
Molecular Biology	1713	7,7	2	6	-4	Increase budget
Nuclear Physics	1640	7,4	3	8	-5	Increase budget
Thermodynamics	1410	8,5	4	5	-1	Continue
Electronics	1270	6,5	5	15	-10	Continue
Computational Complexity	1238	8,7	6	2	4	Continue
Business Models	1130	6,5	7	16	-9	Continue
Astronomy	1122	7,1	8	11	-3	Continue
Industrial Engineering	1104	5,5	9	18	-9	Reduce budget
Software Engineering	1049	8,6	10	4	6	Reduce budget
Operations Research	975	7,3	11	10	1	Reduce budget
Civil Engineering	947	7,4	12	9	3	Continue
Artificial Intelligence	921	6,7	13	14	-1	Continue
Ethics	917	3,5	14	20	-6	Terminate
World Trade	878	2,4	15	23	-8	Terminate
Global Warming	848	8,6	16	3	13	Continue
Sociology	846	6,0	17	17	0	Reduce budget
Sea Studies	824	6,8	18	12	6	Terminate
Philosophy of Science	513	2,7	19	22	-3	Terminate
Literature	483	7,6	20	7	13	Reduce budget
History	472	6,8	21	13	8	Terminate
Geography	358	2,9	22	21	1	Terminate
Archeology	342	3,9	23	19	4	Terminate

Focusing

One of the recommendations of the Organization for Economic Development and Cooperation (OECD) to its members is the need to focus and specialize, thus avoiding the dispersion of resources and efforts. Research chairs have thus been asked to focus their research efforts by identifying niches on which efforts and resources should be concentrated.

At Tecnológico de Monterrey, this focusing of efforts was achieved by asking researchers to classify their research by defining the following levels of specialization:

- area of knowledge;
- discipline;
- subject;
- research lines; and
- projects.

An area of knowledge may have several disciplines, but one must be selected; a discipline may embrace several subjects, but one or two must be chosen; within a subject there may exist many research lines, but a given research line should be supported by at least two researchers; within a research line there may be several projects, but each project must be executed by a team of three to five researchers. An example may clarify the focusing concept:

- Knowledge area – Biotechnology.
- Discipline – Pharmaceutical engineering.
- Subject – Drug discovery from indigenous plants.
- Research line – Bio-separation and molecule synthesis.
- Project – Drug and food bio-processing by synthesizing molecules from black beans.

Focusing has been a key factor for those chairs that have succeeded in the five-year evaluation.

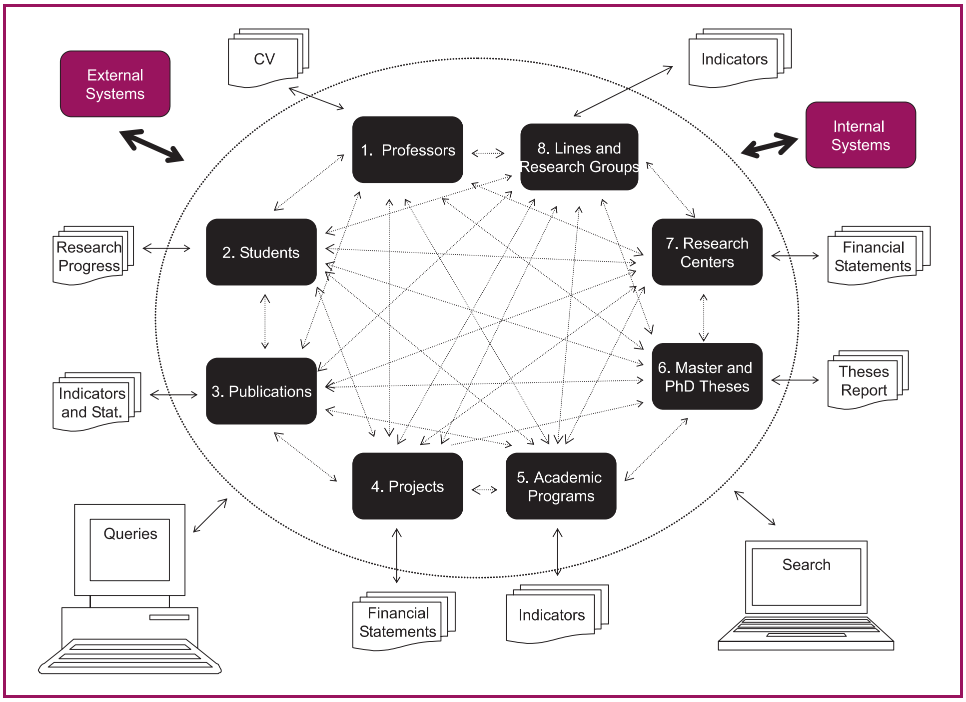
Managerial aspects

Management aspects of the research chairs are considered at two levels, internal – the research group interaction on campus – and external – interaction with companies, universities, and government and other agencies. Internal aspects include: invitation of adjunct professors, enrolment of PhD, master's and undergraduate students, administration of the research chair budget, teaching load of adjunct professors, internal meetings for research follow-up, general meetings of principal investigators to exchange experiences, planning of publications and traveling, reporting research results for ranking and evaluation purposes, and updating the web page. External aspects consider the transfer of technologies to companies and the government, the training of people in specialized areas of different disciplines, and the development of social programs for municipalities, state governments and the federal government.

Technological aspects

In order to facilitate the administration of knowledge from the research products of the various chairs, an integrated information and knowledge management system was developed on campus and has been operational since 2004 (Cantú *et al.*, 2005b). There is a set of modules and database histories in the system for storing and accessing information on various kinds of publications, theses, projects, professors, students, research chairs, research centers and graduate programs. The performance indicators and internal rankings of research groups are generated every month for follow-up research evaluation purposes. Figure 11 displays the architecture of the system.

Figure 11 Knowledge and information system: modules, relationships and reports



Impact of the KBD model

The KBD model described in this paper has guided the transformation of the Monterrey Campus from a teaching oriented university into a teaching, research and entrepreneurial university (Bustani *et al.*, 2006). This transformation is quantified by the measures of performance of the model. The external impact of the KBD model is discussed below.

The Knowledge City Project

Currently, Tecnológico de Monterrey is an active partner of the *Monterrey International Knowledge City Project* led by the state government of Nuevo León in coordination with local universities and the private sector. Although the knowledge city concept has been around for more that 30 years (Carrillo, 2006a), the Monterrey City project, which started in 2003, aims to transform the industrial focus of the city from a natural resource base (the production of steel, glass, cement, beer, petrochemicals, etc.) to a knowledge-based economy (software, biotechnology, nanotechnology, pharmaceuticals, etc). The Tecnológico de Monterrey, Monterrey Campus is playing a key role in this project and the knowledge-based development model has set the grounds for the Institute's intervention.

Every year, more than 300 research and development projects sponsored by industry, the government and other agencies are carried out by research groups on campus, most of which are organized as research chairs (Cantú and García, 2006). A small number of these projects are described briefly below.

The CAPRICO Project

The CAPRICO project was an effort to organize regional farmers who raise goats and commercialize goat milk for the production of goat cheese. Technologies (developed by the Biotechnology Research Chair with the support of the Biotechnology Center, the Food Technology Department and the Agricultural Business Center) for incorporating nutritional and cancer preventing components have added value to the commercialization of these products. A business model was also developed around the supply chain from raw materials – goat milk – to marketing and the export of products. Gathering investors from industry and the government was also part of the business model. For example, negotiations were made for the local government to invest 2 million USD in the project.

The Housing Project

The techno-domes construction system was a technology developed by the Design and Construction Research Chair using the infrastructure of the Design and Construction Research Center. The research group has designed fast construction methods utilizing materials at half the cost of current construction methods. The techno-domes system is used for house and building construction (schools, churches, offices) with all the facilities (electricity, water, cooling) and preparation for resisting earthquakes, storms and other natural phenomena. The technology has been licensed to various companies throughout the country for the massive construction of houses for low-income families. Also free-of-charge licenses have been granted to non-profit organizations such as CARITAS International for rebuilding houses that have been destroyed in recent years by hurricanes and earthquakes.

The Stem Cell Project

The Cellular Therapy Research Chair has developed methods and medical procedures by cultivating stem cells for preventing or restoring lost tissue functions in treating multiple sclerosis. In association with clinical research groups at the Medical School Hospital, researchers have treated patients at the terminal stage of this disease with promising short-term results. Patients whose life expectancy was estimated at three months at most have recuperated lost organic functions, gained quality of life and are still alive after several months.

The Wireless Project

Information and Communication Technologies have a long tradition on Campus. The Wireless Communications Research Chair has set up a strategic collaboration with NORTEL, the Canadian communications company that dates back to the early 1990s. There has been continuous sponsorship and support from the company to develop proprietary technologies for mobile wireless communications. More recently, in 2004, an association was signed with GOOGLE to establish a research chair on intelligent search engines sponsored by GOOGLE with matching funds from the campus. NIC Mexico is a company that was created by Tecnológico de Monterrey officers and researchers and is now responsible for managing the internet domains.mx in the country. In 2004, NIC Mexico began research to develop technologies for cyber security using cryptography, biometrics, speech recognition and related methods for user authentication.

Other Projects

These are just some of the projects that are being developed by research chair groups. There are many other projects in the areas of mechatronics, transportation, energy, water studies, laser technology, nanotechnology, optical communications, air quality, environmental studies, logistics, artificial intelligence and other engineering areas (Cantú *et al.*, 2005a). There are also research chair groups in the management, social and human sciences. In management science, they include groups working on new business models, family companies, competitiveness and benchmarking, the stock market and knowledge management. In the social sciences, there are research chairs in the demography and economy of the US border, democracy and citizenship, and public management. The area of human sciences includes research groups working on history, literature, ethics and the philosophy of science.

“A research chair is a group of researchers specialized in a scientific domain and headed by a principal researcher.”

Conclusions

The knowledge-based development model presented in this paper has proved useful in fostering the economic and social development of different regions in Mexico. The model is based on a research chair program and has been operational since 2003 with the support of organizational units that facilitate managerial functioning, computer knowledge and information systems. The authors believe that the model is inspired by human values and by an integral conception of the human being that depart both from the Marxist and the neo-liberal conception of economic development. Commitment to social development, especially to those with low living standards, is a characteristic of the program. It also involves the supporting of highly-talented individuals with economic limitations through an excellence scholarship program associated with the research chairs.

Although this paper describes the Tecnológico de Monterrey, Monterrey Campus experience, the authors believe that the model can be adapted for other knowledge-generating institutions under the following premises:

- Teaching and research universities generate scientific and technological knowledge.
- Social, human and intellectual capital (professors and students) are the real generators of knowledge and need an environment in which talent is nurtured.
- Models of organization for knowledge environments are needed for cooperative work.
- ICT-based tools that support the knowledge management processes are a sine qua non for successful implementation.
- Leadership and high-level management support is a fundamental element for the model's success.

Should these conditions be appropriately addressed, the authors believe that the knowledge-based development model described in this article may be adapted to other organizations with high probabilities of success.

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