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TECHNOLOGY MANAGEMENT IN SPAIN

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Introduction

Spain is not an underdeveloped country as far as the use of technology is concerned. Visitors can see high speed trains commuting between Madrid and Seville, use a fairly advanced communication system, see hospitals performing sophisticated surgery, etc. And yet Spain lacks the loosely coupled network of interrelated knowledge and technologies that characterizes technologically advanced societies. Any firm working in advanced development in Spain will be familiar with the problems of lack of infrastructure and the inability of Spanish enterprises to supply the knowledge required for advanced projects.

The period 1985-1993 was expected to be crucial for technological growth, since by then the country would have overcome the effects of the political transition to democracy. During this period, Spain was supposed to catch up with the more technologically advanced societies, bridging the gap.

Yet, in 1993 the gap has widened (1). In fact, in many areas of technology the world has progressed at a much faster pace than Spain. And since a country's ability to progress depends on the level of knowledge it has achieved, it will no longer be possible for Spain to bridge the gap in those areas. Attention now has to focus on technological areas that are still emerging and that can be tightly coupled with other country resources to produce sustainable competitive advantage.

In this paper, we start from the claim that Spain, using sensible approaches, has failed to achieve the expected qualitative leap in technology in the last ten years. We describe the political situation and argue that the failure may be due as much to structural causes as to mishap. Measures that are otherwise considered standard and are widely accepted in technological development may not be strictly applicable to Spain (2). Some will say that the result of applying these standard approaches has been marred by the political situation. But we maintain that politics is as much part of the environment as the economy. An approach that fails because of politics is not taking one important fact into account, namely that life is complicated and that politics is a fact of life.

During these years, hundreds of companies have embarked upon technology development plans, with mixed results. Many good managers whom we interviewed complained about «not enough market», «lack of critical mass», etc., giving these as reasons for the lack of success. Such explanations are almost always associated with the failure to really get to grips with the root problems. We believe that many of the people responsible for these initiatives were competent and conscientious managers. In the early 1980s, however, the required quantum leap in technological development was something quite new to many Spanish companies. Faced with an uncertain situation, many resorted to mimicking the behaviors of other (internationally recognized) successful companies, despite the fact that those behaviors were designed for completely different environments.

In this paper, we expound the school of thought (3) that sees technological growth as being similar to a process of evolution by natural selection. In a nutshell, the environment is populated with entities (firms) that are all striving to succeed. The technology (knowledge) that these firms possess becomes their genetic material; it is what gives rise to their competitive capabilities. A process of continuous improvement (learning) is under way, gradually improving the competitive characteristics of firms. Chaotic situations are at the heart of the most dramatic innovations, which are naturally compatible with the continuous improvement process. This framework explains –better than any other we know– the reasons for some of the behavior observed in Spain's technological position.

In light of these ideas, in the last section of this paper we present a somewhat different approach –one that we have tested in our work for the regional governments– based on developing knowledge and creating markets. It is an approach that we hope would yield better results in a country such as Spain.

1. A global perspective

It is difficult to obtain reliable data on the status of technology in Spain (4). Although the way technology is generated by universities and public research bodies has been fairly extensively documented (5), technology generation in companies and, in particular, the link between business enterprises and the above-mentioned public institutions has yet to be studied.

The impression gained from studying a large number of specific cases (6) is that the two systems follow separate paths, each guided by the interests of its local agents, rather than by usefulness criteria established through a process of communication.

This is not the proper place to review in detail the technological status of different industries in Spain. However, we will attempt to sum up the main characteristics of the environment in which technology management has taken place in Spain over the last 8 years. Most of what follows has been gathered through direct interviews with leading Spanish or multinational firms operating in Spain.

The 1970s left Spain with the remains of an autarkic system. The old system had been designed to develop heavy industry: iron and steel, shipbuilding, basic chemicals, etc. Many of these industries were maturing rapidly at the time of their initial growth in Spain. As a result, most of the publicly owned companies (managed at that time by INI, «Instituto Nacional de Industria», the largest industrial conglomerate in the country) were suffering heavy losses and had a poor technological structure. When the Socialist government took office in 1982, there was an urgent need to modernize industry.

However, the issue of modernization faded into the background during the 1980s. During this period, Spain experienced an unexpected economic bonanza, which everybody now realizes was based on the sale of assets to foreign investors and on speculative operations. In pure theory, this should have been neutral as far as technology is concerned. But it was not. According to one high-ranking Spanish official, more than 50% of the research facilities in existence in 1985 among the many enterprises that were sold during the period 1985-1990 had been dismantled by 1992.

A summary of the background and main features of the current situation is as follows:

1. *The ’80s saw major sales of Spanish enterprises to international conglomerates*. We feel that, for the sellers, the main reason for the massive sales was concern about the future profitability of the companies. Behind this concern there lay, among other things, the feeling that few of the companies could compete worldwide, the high interest rates, the restrictive nature of the Spanish legal system, the strength of the trade unions, etc. For the buyers, a market of some 40 million inhabitants and access to a future EU from a less expensive country were reason enough to venture into Spain. It is difficult to find out what kind of investments were made with the money obtained from the sale by the Spanish owners. Few obvious alternative productive investments have occurred as a result of those transactions.

2. *Economic «growth» has been based to a large extent on zero sum speculative operations, mainly in real estate, and very little asset creation has taken place*. Land was made scarce by the local authorities, and prices soared. Increases in real estate prices were spectacular during this period. In 1990 a house could sell for up to six times its 1985 price. The losses accrued by the last owner have not yet been realized and real estate still has a high book value, but the market value has gone down steeply in the last year.

3. *The university system has placed an emphasis on traditional academic excellence, leading many academics to retreat into their ivory towers*. The practice of science in Spain is based mainly in the universities (the vast majority of them state-owned) and CSIC («Consejo Superior de Investigaciones Científicas»). Patterned on the French system, CSIC suffers heavily from the «official science» syndrome. Many of CSIC’s institutes live in isolation both from industry and from teaching. The result is that the flow of knowledge between CSIC and society is scarce, both in terms of applications and in terms of learning.

4. *Deals with foreign technology providers have been based on the exchange of real market opportunities for technology promises*. Many technology transfer deals were made in the ’80s. The assumption was that advanced technology would be transferred in exchange for markets. The firms involved often did not realize that once you trade markets, you lose them, whereas any technology that is exchanged remains with the transferring company, which normally retains its competitive lead. Many military purchases were supposed to provide technology, but failed to do so.

One of the best examples was the purchase of a number of F-80 fighter planes (7) in the early ’80s in a contract worth over 3 billion dollars. The deal included big promises of technology transfer, some of them backed by premium prices. Joint production of parts for the planes was marred by the need to keep the final prices as low as possible, and in some cases only the low-level production processes were actually transferred. The whole project resulted in very little learning.

Two INI companies (Casa and Inisel) and the privately owned Ceselsa, among others, have had some successes, but there is little evidence of lasting gains in competitiveness in the international market. This is an area in which we feel that Spain exemplifies the failure of textbook strategies for technology transfer. Sensible measures were taken by competent people, but with meager results.

5. *The current depression is suppressing long-term investments in R&D, thus widening the existing technological gaps.* Since Spain failed to close the technology gaps in fast-growing technologies during the ’80s, the current depression can only serve to consolidate the situation. We believe that *the Spanish case shows that technology growth should take place when technologies are in their infancy.* It also illustrates a certain type of technology lock-in, characterized in Spanish firms by the phrase «critical mass». Spanish technology networks are too weak to sustain growth in fast-growing technologies. Efforts to develop new technologies face a delay until they come into operation. Since other countries keep going during the delay, only quantum leaps –«risky leaps» with a high risk of failure– can close the gaps. Obviously, this is unlikely to happen during a depression. Spending on R&D by Spanish firms has been cut dramatically in the last couple of years, making the outlook even worse.

6.*Efforts by central government have been shortsighted and oriented towards «popular» technologies*. The need to provide network infrastructure has led the government to invest in basic facilities. The «Centro Nacional de Microelectrónica», for instance, is intended to provide support for electronic chip development. But the investments needed to create infrastructure are enormous and very little can be accomplished by government projects on their own. What is more, in the search for maximum public impact, government initiatives have concentrated on «popular» technologies. In a study of technologies in Andalusia (PINTA), the authors recommended providing infrastructure in Electronics, Robotics, Optronics, Laser and Biotechnology. These were mature technologies at the time of the proposal and required extensive infrastructure that was very difficult to build up from scratch. A very substantial amount of public funds (8) goes into glamour fields such as space, high energy physics, oceanographic studies, etc., where Spain does not have any kind of competitive advantage.

7. *Most of the successful efforts have been made by regional governments,* mainly the Catalan, Basque and Valencian governments. Some regional governments have invested in technology parks (Catalonia and Andalusia). The Catalan technology park is located close to a major university, following accepted wisdom. Catalonia is now the most technologically advanced area of Spain. The Andalusian technology park has been located in Malaga, an underdeveloped area. The idea is that the park will foster economic development.

8. *Isolated islands of excellence have survived and developed, but there is a definite lack of a coherent technological infrastructure.* Food-processing firms such as Campofrío have developed substantial technology in their field. The food industry is probably the most technologically developed sector in Spain. Agriculture has increased its efficiency but does not hold much promise in an agricultural Europe. However, the main income-producing industries, and especially the tourist industry, are in sore need of technological development, and yet very little attention is paid to them.

9. *Lack of preparedness for the tougher competition resulting from EEC membership.* Spain’s EEC experience has been hurried along by the Government in order to boost its international prestige, and as the way forward for Spain. However, in the haste, much has been left open or imprecise.

Finally, to top everything, the feast of 1992 has drained resources and is leading to famine in 1993.

2. The role of the administrations

The two organizations mainly responsible for technology development in Spain are CYCIT (9) and CDTI (10). CYCIT administers research funds and CDTI acts as a business and technology development center. CDTI was originally created to act as a source of venture capital. The venture capital market was not developed in Spain and new ventures of a risky nature were difficult to promote. However, CDTI is a state-owned venture capital provider and has to rely on project evaluation in its money allocation process. Even if the allocation is made with the utmost care, it suppresses the selection process carried out by the market. Success in persuading CDTI to put up money for a project is certainly not equivalent to having a potentially successful project. This realization made CDTI gradually reduce its venture capital operations. Now, CDTI mainly monitors the European cooperation programmes, acting as a source of money for technology work in companies.

CYCIT also relies heavily on project evaluation to award money for research. Evolution and adaptation do not have much of a role to play in the system. As a result, funds tend to be awarded on the basis of how CYCIT feels about the projects, political priorities, and so on. For instance, a sizeable chunk of money goes to the Antarctic Programme, an oceanographic ship that takes scientists to the Antarctic for extended periods of research. Even if one accepts the importance of this type of work, the question arises as to the priority it should be given (or the effect it is likely to have) in the country’s long-term technological development. Perhaps instead of devoting resources to developing minisatellites (11), which are unlikely to generate competitive advantage, resources should be invested in areas that are less glamorous but better able to generate competitive advantage. It is therefore important to identify the technologies that can provide a competitive advantage, whether they be «new» or «old».

The Spanish Ministry of Industry has, in recent years, developed a fully integrated technology development plan. This plan could be taken as a guide to the administration’s point of view. It focuses on the following areas:

- Electronics and Software Plan (PEIN III)
- Automation of Advanced industries (PAUTA III)
- Research in Pharmaceutical Industries (FARMA III)
- Technological development in Biotechnology, Chemicals and New Materials (BQM)
- Technological development in basic industrial sectors (SBT)

Data show that some companies have carried out projects within this plan and that most of them have had over 500 employees. According to data provided by CYCIT for the years 1988-1991, the highest percentage of approved R&D projects were on Materials (23.39%), Space (14.68%), Computers (10.55%), Food (9.40%) and Robotics (8.72%). Government financial help for these projects ranged from 23.76 % (Materials) to 4.55% (Food).

If we take the applicants as a representative sample of companies wanting to get involved in technological innovation, the percentage of R&D financial needs that the companies require ranges from 3.98 to 22.53. These needs were satisfied with 50-60% of public financing.

As the reader will have noticed, government programmes only partly finance the projects. In a well developed market, a worthwhile project would find investors willing to put up the rest of the money. It is doubtful that in the Spanish market this is the case. High interest rates on money have led investors to hold liquid assets. Public debt in Spain has paid 13% in the last few years, roughly 8% after discounting for inflation, and this is a low-risk investment. In these conditions, risky projects would need expected rates of return of maybe 20% to be considered as alternatives. And this is all the more true of the high-risk initiatives required for a technological quantum leap. This raises the question of the suitability of partial financing, which favors large, entrenched enterprises with great lobbying capabilities and leads to public money being assigned to many state-owned, loss-making firms.

Number of support staff per researcher in the business sector		*Unit labor costs in manufacturing industries 1990*	
Japan	0.7	Japan	83.3
Canada	0.9	Canada	128.6
Spain	1.8	Spain	118.9
France	1.8	France	97.9

OECD Industrial Policy in OECD Countries. 1991

Indirect labor gives an indication of the efficiency of the companies that received money. As far as the number of researchers compared with support staff is concerned, the above data show that Spain is in the same range as France, but that there is considerable disparity between these two, on the one hand, and Japan and Canada, on the other. The comparison of the cost of labor points to a clear blocking factor in technology development in Spain. All the indicators show that Spain has a low output per technology worker. To the inefficiency and low productivity of labor we have to add the indirect cost of a larger support staff, probably as a result of the bureaucratic nature of the system.

One of the problems lurking in the background is the difficulty of assessing the wealth-producing capabilities of the technology available in a country, or even an industry. Many procedures have been proposed, but in the national accounting system few figures are available for this purpose. Technology is basically an inventory, an asset that will produce income in due course, but there is an intrinsic delay between technology acquisition and wealth production. Economic agents have to be able to forecast accurately, since the delay blocks immediate response policies. Movements in technology inventories are not usually reflected in the available economic data, as these are centered on the measurement of flows, not of assets or technology levels, even though these form the basis of future flows, and therefore represent the capacity to create future wealth. As we have said, it is much easier to estimate technology flows than technology position.

When market signaling is weak and one has to rely on project evaluation techniques to establish patterns of technology development, many things can go wrong. In terms of our basic model, this is equivalent to abandoning natural selection as a way of deciding who should survive and who should not, and introducing the role of a (well intentioned) central planner. Our research shows a trend in many industries towards a decrease in technological assets accompanied by a loss of know-how or control over technology generation, which are equivalent in long-term strategy. In some industries the trend has been alarming. Data from studies of the software industry (13) in Spain show that the proliferation of ready-made packages, together with the standardization of the products offered and falling prices, have pushed many domestic developments out of the market; they have been replaced by imports of non-national products. From the flow point of view this may be insignificant. Not so from the asset point of view, because it leads to the abandonment of certain areas of knowledge, with serious consequences for the ability to create new products or services. Many other examples could be quoted, almost all with identical conclusions.

The success of project financing increases as we move down the scale from central government. The Catalan government, the Generalitat, has perhaps been the most successful in bringing about a quantum leap in technology. Its approach is based on evolutionary ideas. It stresses the development of infrastructure capabilities that have an impact on the performance of the global evolutionary system, either on the generation mechanism, the selection mechanism or the improvement mechanism. For instance, in order to develop the automibile industry, the Generalitat is building a multi-million-dollar car testing complex, one of the most advanced in Europe, that offers car designers and builders facilities in which to experiment with and improve upon their products. The Basque government is pursuing a similar path, with moderate success; it is heavily dependent on its steel and machine tool industry, which is trying to find a competitive position in the world.

The reason why local approaches are more successful that nationwide ones is perhaps to be found in the closeness of local government to the firms actually carrying out the projects, the greater proportion of private enterprises that apply for assistance, less bureaucracy, etc. (14).

As early as 1986 the authors were engaged in an attempt to diagnose the reasons for the stalling of what seemed to be very reasonable measures. An approach based on evolutionary ideas was developed and proposed to the Ministry of Industry. As a result, several new steps are slowly being taken, as we shall see in the following sections, most of them based on the general paradigm we have expounded here.

3. New approaches

We have seen how the classical approaches to technological development have been used in Spain without the success that was expected. A great number of factors can be used to explain these failures. However, such poor performance suggests that something is going wrong, especially considering that some very capable people have been involved in these efforts. *Our fundamental point in this paper is that the Spanish experience deserves in-depth scrutiny since it illustrates many of the weaknesses of the usual approaches*. For instance, we believe that providing companies with public funds for research has generated a demand for such funds independently of any desire for technological development. Therefore, we conclude that funds should not be geared towards this purpose, but more towards developing the infrastructure support system that is needed.

The probability of appropriation seems to be a major driving force behind the decision to apply for research and development funds from public sources. Technological development will only take place if companies foresee opportunities for profit in the market, but if, as is the case in Spain, the market is not well developed, then companies fail to read the signals that should trigger technological development. Consequently, firms do not engage in technological activity, since they do not see any market opportunities for themselves.

In this situation, which is the situation in Spain, we believe that efforts should be directed more towards creating markets that signal the desired messages for technological development. You have to create demand, rather than stimulate supply – this seems to be the lesson to be drawn from the Spanish experience. The evolutionary perspective makes it quite clear that the public sector should concentrate on developing the mechanisms that accelerate the evolution of firms by building up the infrastructure that enables these mechanisms to function efficiently. Attempts to alleviate the problem by applying technological development measures to particular branches of the technology tree entail making comparisons between the competitive capabilities of different companies, which for the public sector is difficult if not impossible to do. Many scientific plans lead to developments that are of little practical interest and cannot be applied to any industry's technological tree to produce competitive advantage.

In the following paragraphs we report on a new approach that has adopted the point of view outlined above, an approach that we have been actively involved in. The results are difficult to measure owing to tangled (political) events, but the evidence on hand suggests that this new approach could perhaps succeed where other approaches have failed.

To start with, we have to slightly revise and extend the notion of technology. Technology is too restrictive a concept to be used in a more comprehensive approach. We shall replace technology by *knowledge* [8].

Knowledge is essentially the capability to solve problems. As such it is an asset produced and stored in the human mind and can be originated and processed only by people. Knowledge is one of human beings' basic capabilities and is generated, consolidated and diffused by people. It is increased by learning and must eventually find an application if it is to give its bearers a competitive advantage.

The main reason for considering knowledge, rather than technology, as the primary asset is that many problem-solving activities that are part of the assets of a company are not technological, but belong to more general domains of knowledge. Knowledge can be of different types: abilities, technology, and pre-technological knowledge. Technology has two essential properties that distinguish it from other types of knowledge. First, it is formalized, in the sense that problem-solving abilities can be deduced from a basic set by the use of a formal language. Logical reasoning is the formalized language normally used for this purpose. Second, technology is action-oriented. It is targeted toward doing things rather than toward understanding things. Therefore, in order to become technology, knowledge has to be geared toward specific operational actions. Technology may arise from the pure generation of knowledge that we call science when science is transformed into specific knowledge that is capable of being applied and modified in a product, process or procedure that will be generated or used by the structure of a firm.

Other types of knowledge are just as important as technologies, however, and have some of the same properties. *Abilities* are unstructured, action-oriented knowledge: problem-solving that is performed consistently by an individual but that cannot be extended by using formalized tools. Many artistic abilities belong to this type of knowledge. And so do many managerial activities. Knowing how to buy or knowing how to manage projects are abilities that do not seem to be formalized enough to be technologies. Finally, there is pre-technological knowledge, which is capable of turning into technology but is not yet at the stage where this could happen. It is normally formalized to some extent, but its preliminary purpose is to explain or predict rather than to do. Most scientific knowledge falls into this category.

Technology management is thus a subclass of knowledge management, which is a concept that includes and subsumes what has previously been understood as technology management. Technology development is thus a learning process performed by human beings, and as such has been studied from the point of view of a range of disciplines from pedagogy to computer science. In order to better understand technology development, we need to have a better understanding of the learning process associated with it.

A central issue is the materialization of knowledge. If knowledge is to be transferred –and it will have to be if it is to be used by anyone other than the person who originated it– then it will have to be introduced into a channel of communication. Therefore, it has to be physically materialized in some way. The main materializations of knowledge are products (black boxes), procedures and descriptions in a formalized language. All of these assets represent the physical part of the **knowledge base** of the unit under study. Knowledge that is not materialized can be very important for the operation of the unit that possesses it and can be transferred by imitation or other means, but it is much more difficult to recognize, manage and develop. However, most knowledge is generated and accumulated initially at this «unmaterialized» level, in the minds of its bearers, and is only materialized, if at all, at a later stage.

Therefore, any company –or, in general, any economy– has assets that incorporate knowledge in different forms, which have to be distinguished and classified. Central to this approach is the degree of freedom of the knowledge. The more possibilities knowledge has and the more scope there is for applying it, the freer it is. However, the freer knowledge is, the less specific it is and, hence, the less power it has to solve a particular problem. All companies hold portfolios of each of these categories of knowledge. It is possible to identify in a company portfolios of black boxes, abilities, technologies and pre-technological knowledge.

Managing unmaterialized *knowledge portfolios* poses one basic problem. As unmaterialized knowledge is stored in people, it is not directly observable and its composition can only be inferred by deduction, either from observation of actual events or from experiments.

Our earlier comments about the available data indicate that we cannot expect much help from the normal data collection systems when it comes to evaluating the existing knowledge base, either in a firm or in an economy, for the purpose of knowledge development. Thus, one of the first tasks in knowledge management will be that of determining the types and qualities of knowledge contained in the knowledge base. This task we could call *knowledge inventorying.* Then, using *knowledge evaluation* procedures, we can determine the internal level of knowledge and compare it with the level of knowledge outside the economic unit that we are analyzing. This gives us a measure of the competitiveness of the existing knowledge. Finally, we can move on to *knowledge usage:* ways of using existing knowledge to secure competitive advantage for the economic unit.

The above process is static in that it looks for good ways of using *already existing* knowledge. Static analysis should be supplemented by showing ways of developing the knowledge base of the economic unit. The dynamics of knowledge lead to the study of learning processes. Some of the learning processes can be initiated externally by technology transfer actions, but in themselves these actions do not increase the knowledge base unless the action is coupled with the appropriate learning process.

There is only one possible way to evaluate the quality of the above approach: using it. In the following section we report on one project that has used the general framework outlined above to stimulate technological development.

The circumstances in Spain in 1991 provided us with two golden opportunities to apply our ideas about developing knowledge. Two major events were due to take place that would imply an enormous amount of problem-solving. One was the Barcelona Olympic Games and the second, the World Fair of Seville (EXPO-92). Both events, but particularly the second, were expected to break new ground, develop activities and gather unique capabilities to produce a unique result.

It was therefore a unique opportunity and we took advantage of it. We worked on projects related to both events [1], but since the work on EXPO-92 was more comprehensive, in terms both of resources and of time (15), that shall be the focus of our discussion here. The purpose of the project, which lasted two years, was to identify the knowledge generated in and around EXPO-92, and to propose ways of exploiting it to further the technological development of Andalusia.

First, we describe the methodology and findings of TecnoExpo 92. Second, we give an overview of what the project has done, or could do, to develop the state of knowledge in Spain.

4. TecnoExpo-93

The World Fair EXPO-92 took place in Seville, the capital of Andalusia. Andalusia is one of the most technology-starved regions of Spain, and the World Fair was conceived as a way of promoting change and chanelling resources and visitors into the region.

EXPO-92 was organized by the public company Sociedad Estatal Expo92 (SEE92), wholly owned by the Spanish Administration. SEE92 was put together by locating first-rate professionals in the various fields and giving them the mission to build “something unique”. For the institutional part of the Fair the approach consisted of scanning the world to see what kind of entertainment or exhibition capabilities were available. The country areas were left to the initiative of the individual countries. At one time, altogether several thousands of people from over 100 countries were working in the environment of EXPO-92.

EXPO-92 was conceptualized as a high-innovation entertainment product put together by materializing a fairly wide knowledge tree. Usually, one determines the scope of the exploration by locating the boundaries of the knowledge tree. In this case, the boundaries of the knowledge tree were easy to identify. Nothing was in place in 1981 and therefore everything that was to exist in 1992 would have to be created in the intervening period. Because it was a public body, SEE92 followed a careful contracting procedure. In order to identify the boundaries, the researchers’ first step was to create a database containing all contractual agreements undertaken by EXPO 92 and analyse all the outcomes and inward flows specified in these contracts.

The result of the analysis was a preliminary list of presumably existing knowledge. Then we began a validation and evaluation phase. After in-depth interviews over a one-year period, and after collecting the available evidence, the actual subproducts, black boxes, abilities, etc. were identified. More important still, the internal structure of the knowledge base was identified. Knowledge bases have sophisticated internal structures that can be represented in terms of constructs such as semantic nets. In our case, a simplified tree structure was used. One tree was associated with each of the different views of the knowledge base. The most important view was generated by the-so called «parts-of» relation, where each ability or knowledge was described in terms of the family of knowledge that it contained.

The typical difficulty at this stage is that a competitive evaluation has to be made *a priori*, before finding out about possible applications. This makes it possible to prioritize knowledge and thus simplify the subsequent evaluation task. If one does not do this, one gets bogged down in the details of the inventory.

Thus, it was necessary to assess the competitive potential of the identified knowledge. To do this we developed an attractivity-positioning method, the CTA method [8]. The CTA method (Competitive Technology Analysis, which should perhaps be more correctly termed Competitive Knowledge Analysis) is designed to identify the manner in which knowledge (technology) should be managed in order to create a sustainable competitive advantage. The analysis works as follows:

1. Consider each item in the inventory of the knowledge base of the unit you are analyzing (company, economy, etc.).

2. Determine the internal level of this item of knowledge in the unit under study.

3. Determine roughly the environment in which the knowledge is likely to be used, i.e. the framework of services and markets that the unit is considering.

4. Determine the external level of the item of knowledge in question within each service or market.

5. Determine the competitive advantage in each case.

Measuring internal levels of knowledge is the first step in comparing the status of technology inside and outside the company. A wide variety of scales can be used for this purpose, but given the difficulty of obtaining precise quantitative observations, we settled for a simple five-level scale. This is not the place to explain the theoretical rationale of this scale; suffice it to say that it is based on the combination of knowledge's intensive and extensive aspects. The structure is very simple, as it is based on a distinction between two major areas: «knowing about» and «knowing how». Within each area, a further subdivision is made according to whether there is an ability to progress without help or not. This provides four levels of the scale, to which a fifth and final level, that of «universality», is added.

The result of evaluating the external level of an item of knowledge depends on how the environment is defined. There is no single way of defining the environment and a large part of strategy creation consists of redefining the environment within which each item of knowledge is to be used. The alternatives for defining the environment include:

1. An industry.
2. The market in which the company operates.
3. A geographical area.

When evaluating the external level of knowledge, we also recommend the use of a five-level scale, which the reader can find in [8]. Its structure is similar to that of the internal scale.

Now it is possible to compare the knowledge inside the company with the knowledge in the environment and so obtain a diagnosis that measures the competitive advantage to be obtained from a given internal level of knowledge. This method has been put into practice in some companies in order to diagnose and evaluate their technological competitive advantage. It was also the core method for analysing EXPO-92 knowledge (technology) creation and development.

Using the CTA methodology, we classified the findings into competitive (knowledge that is globally competitive), pre-competitive (knowledge that is competitive in Spain and similar to the rest of Europe) and non-competitive (knowledge that is similar to the rest of Spain). We then researched the key elements that needed to be developed in the industries of Andalusia in order to be able to coordinate these key elements with the competitive and pre-competitive technologies developed by EXPO-92.

To find potential uses for the knowledge, we used a decomposition-recomposition approach to the knowledge trees, trying to combine the knowledge in promising ways to form new products or services. The underlying idea is that the complete tree is associated with a competitive product (EXPO-92) and that, as we remove branches from the tree, we get less specific combinations of knowledge, some of them promising, some of them non-competitive. We developed a man-machine system to manipulate the knowledge in simulated evolutionary ways to produce potentially useful applications. At the same time, we developed procedures to identify knowledge that was in the process of extinction. Given the unique nature of EXPO-92, many items of knowledge were boxes that were quite specific to the product; the disappearance of the product meant the end of the product market and therefore the extinction of the knowledge.

The net result (16) of this exercise was:

a) A list of business areas that should be developed in order to expand and consolidate the existing knowledge;

b) Combinations of items of knowledge that could be structured as business units in order to supply a potentially competitive product;

c) A proposal to do the above not by subsidizing projects but by creating or maintaining markets for the new products.

The main point in some of the proposals was that if temporary markets were created, the providers of distinctive knowledge would have more time to achieve the take-off of the new services. In this way they would foster the development and creation of specific technologies that could become a key factor for the region.

One of the most promising ways to accomplish the above objectives was to create, on the site of EXPO-92, a new kind of «Educational Theme Park». EXPO-92 was a great demonstration of techniques for image projection and viewer involvement. Globally, the greatest accumulated potential was the knowledge about using new imaging techniques to convey educational messages to the viewer. The new product would be a «virtual reality park», aimed at exploiting a new approach to entertainment. Combining technological developments presented in EXPO92 with a different, more sophisticated approach to entertainment, the park was expected to have two main effects on the region.

First, it would create a test and trial center for new «leisure technologies» that could become critical to the future development of the region. These technologies are at a very early stage of development in the world as a whole, and the opportunity to develop and experiment with some of them in a park of this kind would give Andalusia a clear competitive advantage in Europe. The park would generate a demand that would, in turn create a market in which firms could further develop their products.

Secondly, this virtual reality park would offer a type of entertainment that exists nowhere else in Europe. It would use technology to make people feel and understand different aspects of culture in a vivid, interactive way. Andalusian history, for instance, which is a rich source of tradition, could be presented to European visitors as a living experience. The park would adopt a differentiated approach to leisure, offering not only «fun» but also a powerful educational experience.

In addition, there was a technological strategy. The park would provide the necessary *market* for all kinds of knowledge that were in their infancy and needed time to mature. It would be a way to "pull" demand and create a market in which emerging firms or technologies could flourish.

The park opened in June 1993 but, owing to a variety of factors (recession, lack of money, etc.), it is a somewhat watered-down version of the original proposal. Only time will tell what results it will have.

The reader will detect in the above the outlines of a somewhat different approach to technology development. First, the scheme is not project-oriented. Everything hinges on creating and sustaining a market that gives appropriate signals to the participants. Creating a market is a complicated process and is not something that can be done in this way in all cases.

5. Conclusions

Having tried to bridge the technology gap with less success than expected, Spain is facing one of its biggest dilemmas in technological management and development: how to define its core competence as a country. The country as a whole needs a clarification of its targets and policies, and the Spanish Administration should be the driving force to achieve this. In this paper we have argued that actions should be oriented towards creating markets or other self-developing structures that can provide a systematic pull for Spanish firms. The markets should provide sustained competitive signalling to participants, in such a way that they can identify, and pursue, clear paths of competitive improvement.

If things continue as at present, most of the effort will be lost in random initiatives that do not yield any sustainable competitive advantage. In a country that uses, but does not develop, sophisticated technology management in satellites and high speed trains, and that has a large number of small and medium-sized firms struggling to find a competitive niche in a united Europe, there is an urgent need for concrete measures. Spain is mainly SMEs (17) and this should be taken into account in any technology development strategy.

Redefining Spain's core competence would create a pull for technological development in areas where Spain could compete as a front-line country. In this paper, by way of an example, we have presented an approach that hints at the advisability of developing the so-called «Leisure Technologies», which are an emerging field. EXPO-92 and the Olympic Games have demonstrated that the country can produce technology management and that a clear definition of its targets and goals could help it to make the necessary quantitative leap. □

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(1) Although the gap is very difficult to measure, all indicators seem to agree on this. See [6].

(2) See the work of Carlota Pérez in [2] on technology development. Although she is thinking mainly in terms of Latin America and her conclusions are therefore not totally applicable to a more highly developed country such as Spain, her analysis is very much to the point.

(3) See Holland [4] and Dosi [2].

(4) Yet see [3].

(5) See, for example, the titles in the Fundesco collection and the publications of CYCIT (Comisión Interministerial de Ciencia y Tecnología).

(6) IESE has been conducting a systematic case-writing programme on technology management for the last 20 years or more.

(7) The F-80 is a multipurpose plane manufactured and sold by McDonnell Douglas in the USA.

(8) For instance, according to CYCIT, in 1990, 20% of the total research budget was awarded to projects in Space and High Energy Physics.

(9) Comisión Interministerial de Ciencia y Tecnología.

(10) Centro para el Desarrollo Tecnológico Industrial.

(11) INTA (Instituto Nacional de Técnica Aerospacial) has a programme for minisatellite development and launcher design. Wholly owned by the Defense Ministry, INTA employs some 3000 people. It is a research institute but is trying hard to develop a personality of its own. Most of the personnel are civil servants.

(13) See [5] and the data from SEDISI, the professional association of software houses.

(14) Some of the effects explained above could probably be related to Michael Porter's national competitiveness model, as presented in [7]. However, we do not propose to pursue this line of thought in this paper.

(15) The project was carried out with the collaboration of Professors Andreu and Valor from IESE and Professor Alvarez de Toledo from ETSI, Seville.

(16) We do not have space here to give a detailed, step-by-step account of the work. Any reader who is interested can obtain a paper that describes the work in greater detail by writing to the authors.

(17) Taking an SME to be any firm with under 250 employees

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