CERAMIC SECTOR. TRADITION AND INNOVATION

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ABSTRACT

Innovation may be defined as those technologies, products, or services that are newly created or generated by modifying existing ones, which the end-user detects as valuable. On the basis of this definition, it is proposed to review those innovations that have become milestones, while also including certain others which, though they were economically unsuccessful, have meant a new way of understanding the ceramic product.

Some significant advances of the past are briefly reviewed as precursors of the ceramic product as it is understood nowadays: ceramic wainscoting, dry cord (cuerda seca)*, arris* (arista) *tiles, semi-dry pressed products, stencils, screen printing, single-fire glazes. A number of innovative products and techniques are then presented and analysed chronologically from different points of view: production process stage, innovation provided, or area of the company particularly involved in the innovation (design, technology, marketing).*

Finally, some reflections will address the requirements that a product or service must satisfy in order to become an innovative product. In particular, aspects relating to its own gestation, appropriate adaptation to the personality of the company, or the transmission of its values to the target group.

1. OBJECTIVES AND METHODOLOGY

To speak of innovation at this time seems appropriate for the particular situation that not only the ceramic sector, but the entire international scenario is going through. Particularly noteworthy characteristics of this time, though this list is not intended to be exhaustive, include the following:

- Globalisation, mainly of goods, services, and currency, though not so much of people
- Sufficient maturity of the information technologies to allow instant communication of any type of data, images, plans, texts, certificates, etc. between distant points. Thus, this phenomenon has led to a "democratisation of knowledge", enabling consumers to obtain exhaustive information on the goods they consume or intend to consume.
- Degradation of the environment, principally by human causes
- Increased proximity of the roles traditionally assigned to men and women
- Search for social well-being. Although we still live in an individualistic world where personal satisfaction rules, in our close environs a still incipient current of social solidarity has sprung up that will undoubtedly advance firmly.

All these facts that surround us, which have reached us at such dizzy speed, oblige us to adopt a watchful attitude towards their consequences and the new opportunities and threats they bring with them. It is for this reason that this presentation seeks to review some of the milestones that the Spanish ceramic sector has produced in the last twenty-five years, with a view to learning from their deficiencies and virtues, in order to further an innovative attitude in our sector.

First, to conduct the study, a database was prepared that included the advances or proposals that have characterised these recent years, exclusively considering those that have been generated in Spain or have had a clear repercussion in our surroundings. Those innovations have not been considered whose differentiating features from the others were fundamentally formal, i.e. as a combination of chromatic, graphic or geometric attributes or reliefs. This approach has responded to the need to limit the study, which was therefore focused on the types of innovations proposed in the Oslo Manual, though it is obvious that the foregoing features will continue to play an important part in product differentiation and, therefore, in the user purchasing decisions in certain market segments.

The main source of information used has been a survey of professionals with extensive experience, encompassing all sectors in the cluster ceramic, as well as those related to different activities in their organisation (businessmen, technicians, researchers, etc.). Each was asked to indicate between five and ten sectoral advances that, in their opinion, were especially noteworthy and, as far as possible, foreign to their field of activity. The results of the surveys were classified by subjects and the number of times that they had been mentioned, with a view to selecting the one hundred most highly valued advances. Finally, experts in the field relative to the identified advances were surveyed in order to confirm the

evaluation, and the information needed to limit each advance chronologically and conceptually was completed using the extensive available literature, which included the proceedings of the successive Qualicer conferences, the records of the Alpha de Oro Awards by the Spanish Ceramics and Glass Society[1], as well as different scientific publications and literature sources.

This collection of data has allowed us to classify the innovations in a series of categories arranged in chronological order, in order to set out in a general way the characteristics displayed by innovation in the ceramic sector.

2. BASIC CONCEPTS OF INNOVATION

2.1. WHAT IS INNOVATION?

Though there are a great number of definitions of innovation, all share some common concepts: value perceived by the user, the inclusion of products, services or values, and novelty or a high degree of improvement. Taking all these elements, we believe that an accurate definition of innovation might be as follows: *Innovation is the implementation of a new product (good or service) or process or one with a high degree of improvement, or a new method of commercialisation or organisation applied to business practices, to the workplace, or to external relations, which is perceived by user as an increase in value.*

This definition, based on the third edition of the Oslo Manual (2005)[2], extends the concept of innovation used in the previous manual of 1997, including the so-called soft innovations, such as organisational and marketing innovations. In the previous editions of this manual, innovation was solely technologically focused and in view of the most noteworthy success stories, it has been established that even though this type of innovation continues to be necessary, it is not the only path to success. This extension of the innovation concept is not new, since in the 1995 edition of the Green Paper on innovation (European Commission, 1995[3] it was stated:

> *"... It is this **global approach** which lies behind, for example, the success of Swatch watches. In practice, this amounts to four simultaneous innovations in:*
>
> - *conception (reduction in the number of parts);*
> - *production (assembly of the housing in a single part);*
> - *design (new concept for the presentation of the watches);*
> - *distribution (non-specialised sales outlets).*
>
> *Research, development and the use of new technologies - in a word, the **technological factor** - are key elements in innovation, but they are not the only ones. Incorporating them means that the firm must make an organisational effort by adapting its methods of production, management and distribution..."*

In the same sense, it may be appreciated how the Organisation for Economic Co-operation and Development (OECD) defines the different types of innovation, as follows:

Product innovation is the introduction into the market of a good or service that is new or that provides a substantial improvement in regard to its characteristics or desired use. This includes important improvements in technical specifications, components and materials, incorporated software, ergonomics or other functional characteristics.

Process innovation is the implementation of a production or distribution method that is new or that provides a substantial improvement. This includes important improvements in techniques, equipment and/or software.

Marketing innovation is the implementation of a new method of commercialisation that provides important improvements in product design or presentation, or its localisation policy (positioning), promotion or price.

Organisational innovation is the implementation of a new method of organisation applied to business practices, the workplace, or the company's external relations.

Finally, the Oslo Manual of 2005 establishes that even though R&D plays a key role in the innovation processes, it also needs **highly qualified personnel, interactions with other companies and public research institutions**, and an **organisational structure** that **fosters learning** and the **exploitation of knowledge**[4]

It is important to note at present that the perception of value by the client, understood in a broad sense (user, distributor, constructor, specifications writer, etc.), is essential for innovation to be involved, so that this label should not be applied to those products or services that have not been demonstrably approved by the public through their purchase. This may occur for different reasons, which depend on numerous factors, but we may simplify reality by just pointing to two reasons:

1- The product or service has not been appreciated by the user, which means it has not been designed according the user's needs and/or desires.

2- The product or service has not been communicated with sufficient clarity to the consumer

The first reason for failure could stem from a lack of syntony with the environment and the user. Note, in this sense, that the traditional business focus based on putting what one makes on the market without listening to the target user is at present destined to fail. However, this apparently simple premise displays intrinsic difficulties, the most significant possibly being that in most cases the user does not know what he or she would like. For that reason, breakthrough innovations have rarely arisen from the responses that users provided. The story is told that Henry Ford once said, "If I had asked the people what they wanted, they would have replied: faster horses".

The second reason implies that the consumer has not been made appropriately aware of the new product or service, which in some cases does not even travel beyond company walls, so that there is strictly speaking no innovation, but invention. The foregoing allows the conclusion that it is as important to have a

bright idea and develop it suitably, as it is to transmit it to the public so that it may be understood and assimilated.

The process required to generate innovation has two important characteristics: it is complex and uncertain[5]. The complexity comes from the great number of agents taking part, from the company management that can drive or at least to allow its development to the final audience that will evaluate how good the innovation is, across all the company areas: R&D, design, marketing, etc. On the other hand, uncertainty, i.e. not knowing beforehand whether an invention will work in the market, provides the most uncomfortable constituent of the entire process, since most people and companies feel "surer" if they can control the processes and know "what is going to happen". Nevertheless, to judge by what we have seen thus far, we will need to learn to live with this uncertainty and try to handle it as best we can in order to minimise the risks.

2.2. METHODOLOGIES FOR INNOVATION

When an organisation decides to tackle an innovation process it does so with a pragmatic objective: that of profiting from the effort made in order to achieve competitive advantages in its market. When it comes to deciding how to attain that objective in the most beneficial possible way, it needs to evaluate the situation of both the own organisation and that of possible competing organisations.[6]

Two key aspects will condition the ease with which an innovation can be made profitable: imitability and the availability of complementary assets[7]. The first refers to the ease with which the innovation at issue might be imitated or replicated in the market, and will depend on the level of legal protection that is established (e.g. patents) and on the complexity of the competences required to develop it. The second aspect considers the company resources needed for market implementation, which include the manufacturing processes, distribution channels, marketing and the means for disseminating the innovation in the market.

Simplifying these variables, assigning them just two states, we can draw up a table that presents four possible scenarios (Table 1), each of which would require application of a different strategy in order to increase and/or to prolong the duration of the innovation's profitability.

The theoretical models of innovation management posit the adoption of three basic types of strategies[8]:

a) BLOCKING: the main objective being to thwart competition from new organisations that could enter the market. For example, by developing own manufacturing technologies and even taking legal actions to defend the developed patents.

b) ACCELERATION: aimed at keeping competitors at a distance. For example, by constantly updating the product range and doing so more quickly than the competition.

c) ASSOCIATION: in order to cooperate with other organisations, jointly taking advantage of every partner's complementary assets. For example, this might be the case of a producer without a commercialisation channel

or of a company that wished to supply a complete product range without it having any specific means of production.

The strategies recommended in each scenario (Table 1) differ and may even require a combination of several strategies or the progressive modification of a strategy depending on market circumstances or evolution. The table presents the most frequent strategy, and gives other combinable or consecutive strategies in brackets. For example, in a situation of a readily imitable innovation that, however, requires a hardly accessible technology, ASSOCIATION with another organisation that has the required means would allow a strategy to be established to ACCELERATE product development in the market and avoid competition with other organisations that could readily imitate it.

		COMPLEMENTARY ASSETS	
		Readily accessible or hardly determining	Hardly accessible and highly determining
IMITABILITY	Readily imitable	ACCELERATION (ASSOCIATION)	ASSOCIATION (ACCELERATION)
	Hardly imitable	BLOCKING (ACCELERATION)	BLOCKING (ASSOCIATION)

Table 1. Innovation methodologies

Another fundamental concept in the application of these theories is the so-called "dominant design", which is defined as the set of features that the market recognises and demands in a product and which, once the supply has been standardised, will be the prevailing design in the market. The experts agree that once the dominant design has been consolidated in the market, organisations need to adopt new strategies to address the strong increase in competition which, for instance, may include specialisation in certain market segments in order to orient the innovation towards manufacturing processes in order to reduce costs, foster the brand image, etc.

Paradoxically, the ceramic tile sector has for many years mainly reproduced a product concept that is quite consolidated (impermeable rectangular piece fixed by adhesives), which has evolved, however, in a slow but continuous way till now, progressively updating the definition of the dominant design accepted by the market (e.g. porcelain tile, larger-sized tiles, etc.). Despite this and even though there is an additional formal constituent that can help avoid the stagnation of the dominant design, it should not be forgotten that it will be increasingly difficult to continue like this in order to maintain the differentiation in regard to other producers with lower costs, in increasingly saturated markets.

Though the application of these theories may be rather ambiguous in certain situations, there is a clear consensus that the worst situation for the development of innovations is that in which high imitability coincides with great accessibility to complementary assets (such as the case of the ceramic sector in regard to technology), since under these circumstances the benefits obtained are particularly ephemeral, limiting the profitability of the effort made. Further, it should be noted that the ACCELERATION approach tends to encourage the market to become more quickly defined and the dominant design to become consolidated earlier, making it more difficult to prolong the benefits obtained from the innovation effort.

3. EVOLUTION OF INNOVATION IN THE CERAMIC SECTOR

When we were considering the evolution in our sector, we needed to make some decisions aimed at bounding the study and establishing the limits within which we would move. The first bound was the time frame, so that the conclusions drawn might help companies take the decisions that they currently needed to make. That boundary has therefore been set in 1984, when the single-firing technology for the floor tile manufacturing process began to become mature and it began to be applied to earthenware or wall tile.

This milestone, which required comprehensive changes in manufacturing technology and body and glaze composition and, of course, in the manufacturing process method, may be considered a watershed innovation that initiated a new technological cycle[9].

On the other hand, the study is solely confined to the advances that have been generated or adopted by the Spanish industry. This frame also includes the products or processes that have been unsuccessful and therefore cannot be considered innovations but rather just inventions, since we believe they can provide a better perspective of this evolution. In contrast, those have not been included whose implementation in Spain has been insignificant or is still incipient.

Although, as mentioned, our analysis begins after the implementation of the single firing process, a brief review follows of those innovations, in the most current sense of the word, that have allowed us to enjoy the situation we live in today. As Isaac Newton wrote to Robert Hooke in a letter: "If I have seen further it is by standing on the shoulders of giants". We will begin our chronicle with that summary.

3.1. HISTORICAL INNOVATIONS

It is difficult to summarise in such a brief space the most significant advances in ceramic floor and wall tiles, because mankind has used ceramics for constructive purposes since the dawn of time. On the basis of the studies of J.L Porcar[10], V. Estall i Poles[11], and E. Granjell[12], among others, we have chosen the milestones that, in our opinion, have allowed ceramic tiling to evolve.

It was during the Palaeolithic Age that clay was first used to join the raw materials for construction, such as branches, canes, or tree trunks. In the Neolithic Age, when mankind evolved from a nomadic life to more sedentary one, this primitive system evolved towards a more elaborate use, in what is now Iraq (7000 BC) by a walling technique, which consisted of making a sliding form in which the clay was shaped, mixed with straw or other plant fibres. Adobe appeared a thousand years later (6000 BC), involving independent (parallelepiped) clay products dried under the sun, which constituted the first prefabricated construction components.

Finally, in 3000 BC, the use of fired brick became widespread. That was when ceramics appeared as the first synthesis products used by humanity. Well-conserved rests have been found in that same geographic area, displaying a very rich use that combines the relief with polychrome glazes. The gate of Ishtar built

by Nebuchadnezzar II about 600 BC, or the archer frieze and the lion frieze in the palace of Artaxerxes II about 500 BC, are good examples.

In the 11th century, in present-day Iran, a new form of cladding known as wall tiling (alicatado in Spanish) began to be used (al-laqatt = pliers) in which glazed ceramic pieces were trimmed with pliers to produce small pieces called *aliceres* (small glazed tiles), which were used to compose the facing. This technique came to the Spanish peninsula possibly via a route through Egypt and North Africa, and it was during the Nazari period, which lasted until the 15th century, that great mastery was achieved in wall tiling, witness the tilings in the Alhambra.

With a view to lowering the cost of the expensive wall tiling process, two techniques appeared that simplified the process. The so-called *arista* (arris) or *cuenca* (hollow) technique consisted of stamping a relief, manually or with a press, in the surface of the earthenware tile, to keep the glazes deposited in the cavities from running together. On the other hand, the so-called *cuerda seca* (dry cord) technique consisted of drawing the design with a greasy pencil so that the oil would prevent the glazes from mixing together.

The year 1795 saw the creation of the Royal factory of Alcora by the Count of Aranda, who promoted a true innovation there by establishing certain clearly set timetables for the training of his workers. Some of these workers later moved to other towns, which led to high ceramic production. In 1840 Richard Prosser invented semi-dry pressing, which was quickly adopted by the English company Minton. In Spain, twenty years after that invention, Miguel Nolla established a factory, which bore his same name, dedicated to the manufacture of small-sized tiles with very low porosity, which became widespread after the Universal Exposition in Barcelona in 1888.

During the modernist period (end of the 19th and beginning of the 20th century) a true symbiosis developed between ceramics and architecture: Gaudi, Jujol, Doménech y Muntaner, Puig i Cadafalch, and others used ceramics as an indispensable resource. And it was then that true ceramic systems appeared, these being conceived by the architects in the earliest phases of the project. Not only did they work with two-dimensional ceramics, but the ceramics were perfectly adapted to the surfaces. It was during this time that stencils became widely used in tiling, largely replacing the manual decoration of previous times. This system allowed serial production of the pieces, lowering costs enormously and enabling a large numbers of users to be reached.

Firing underwent an important change when batch firing was converted to continuous firing, but the great leap occurred at the beginning of the 20th century when tunnel kilns were incorporated. Samuel Simon, from Manchester, patented the screen printing process in 1907, and he is usually considered to be the first to use a silk screen as a support or base for the template. This technique was adopted by the ceramic sector in the 1960s, and has reached great perfection. In the 1970s Italy incorporated the single-firing process, which was quickly adopted in Spain with the arrival of natural gas in 1980.

During that decade the ceramic sector experienced great expansion and that is the point of departure for our study.

3.2. ADVANCES IN THE STUDIED PERIOD

In order to analyse the advances generated within the framework of the Spanish ceramic sector after the implementation of the single-firing process, a grouping criterion has been defined, based on the following scheme:

- FIELD: As a function of the destination of the evaluated advance. This is divided into Material, Process, Product, and Organisation. The last head includes various activities, in particular, aspects related to commercialisation.
- TYPE: In relation to the main constituents in this field. For example, in relation to the Process, different process phases are considered as well as aspects related to the use of Energy, influence on the Environment, and process Optimisation.
- GROUP: Smaller groups are made in each TYPE as a function of the objective pursued by the advance. For example, in relation to Process/ Optimisation this is broken down into Process control and Automation.

The following scheme (Figure 1) shows the classification system used, detailing the divisions associated with the three levels of classification mentioned. In addition, Table 2 details the individual form of each advance.

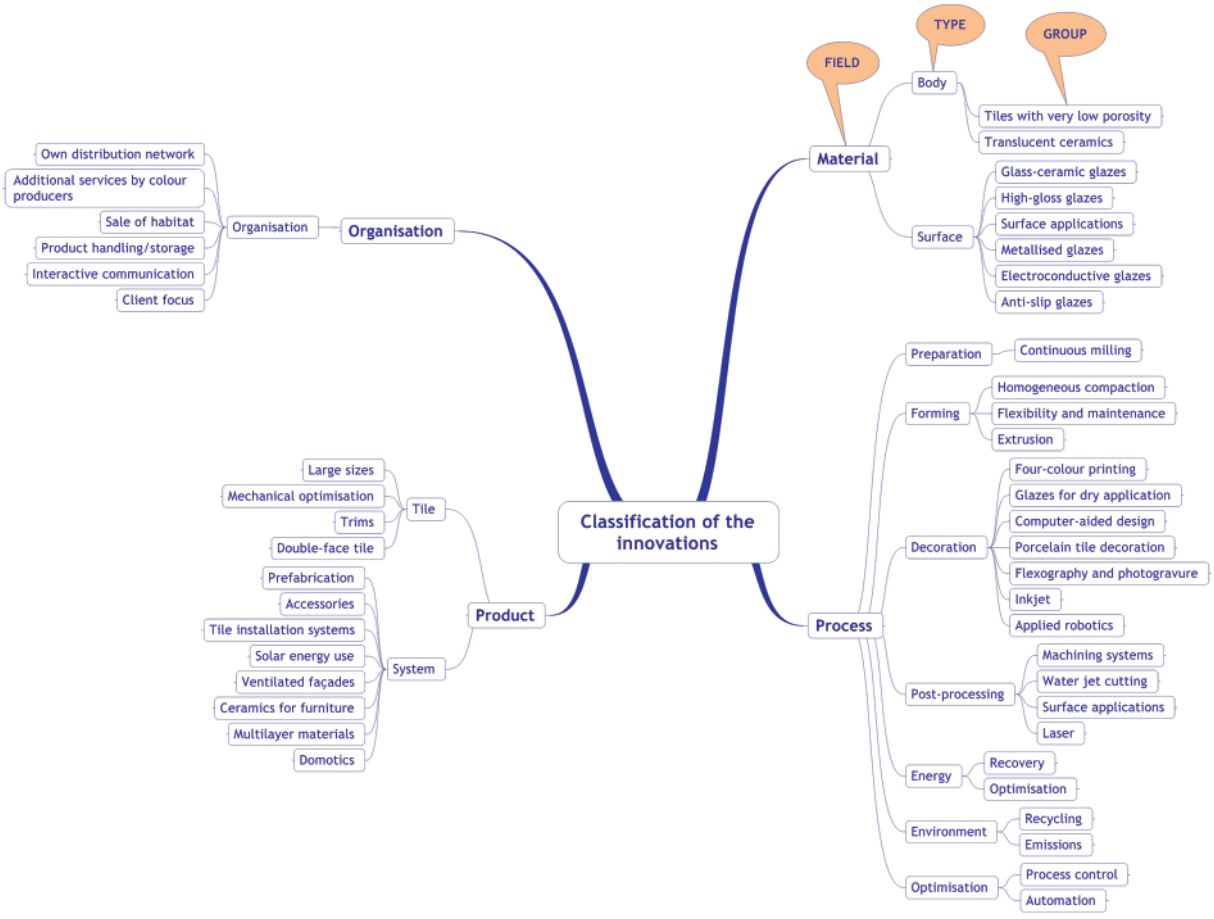

Figure 1. Classification scheme

FIELD	TYPE	GROUP	CONCEPT	INNOVATION	INNOVATION IN DEVELOPMENT	INVENTION
Material	Body	Tiles with very low porosity	Porcelain tile	1988		
			Red stoneware floor tile (<0.5%)		2000	
		Translucent ceramics	Glass-ceramic tiles		2001	
	Surface	Glass-ceramic glazes	Transparent matts (Ba)	1993		
		High-gloss glazes	Polishable glazes	1994		
			Imitation of polished surfaces	1996		
		Surface applications	Photocatalytic surfaces			1998
			Physical vapour deposition (PVD)		2002	
		Metallised glazes	Lustres (Ce-Zr)	1999		
			Metallised glaze (Fe-P)	2000		
		Electroconductive glazes	Radiant ceramic (heated)			2003
		Anti-slip glazes	Control of surface roughness	2003		
Process	Preparation	Continuous milling	Continuous milling	1992		
	Forming	Homogeneous compaction	Hydraulic press punches	1990		
			Adjustable spray-dried powder feed system	1995		
		Flexibility and maintenance	Interchangeable blades	1998		
		Extrusion	Extruded porcelain tile	2000		
	Decoration	Four-colour printing	Four-colour printing in screen printing			1987
			Four-colour printing in flexography			1996
		Glazes for dry application	Powders, grits, agglomerates	1988		
		Computer-aided design	Purchase of machines	1989		
			Product design	1990		
			3D digitisation and mechanical machining of relief	2000		
		Porcelain tile decoration	Soluble salts	1991		
			Double charge	1993		
			Dry colouring of spray-dried powder	1995		
			Dry decoration	1998		
			Decoration with spray-dried glaze	2000		
			Decoration in press	2005		
		Flexography and photogravure	Decoration by photogravure	1995		
			Flexography	1999		
		Inkjet	Printing with soluble pigments	2003		
			Printing with solid pigments	2005		
		Applied robotics	Robotics		2003	
	Post-processing	Machining systems	Diamond disc	1985		
			Media for polishing and rectification	1990		
		Water jet cutting	Water jet cutting. Purchase of machines	1991		
			Water jet cutting. Design	1992		
		Surface applications	Anti-stain treatments (fired clay, porcelain tile)	2003		
		Laser	Laser. Design		2003	
	Energy	Recovery	Gas recovery for preheating	1984		
			Cogeneration in spray dryers and dryers	1989		
		Optimisation	Increase of the solids content in spray drying	1985		
			Reduction of electricity consumption	1991		
			Optimisation of kiln operation	1992		
	Environment	Recycling	Wastewater and sludge recycling	1991		
			Total recycling of solid wastes	1996		
		Emissions	Reduction of gas emissions	1992		
			Flue gas treatment in frit furnaces (with cogeneration)		2004	
			Control of fugitive emissions in spray-drying plants		2006	

Table 2. Advances in the studied period

FIELD	TYPE	GROUP	CONCEPT	INNOVATION	INNOVATION IN DEVELOPMENT	INVENTION
Process	Optimisation	Process control	Bulk density as process variable	1985		
			Regulation of feed in the press	1993		
			Greater stability of spray-dried powder moisture content	1994		
			Control of decorating variables	1997		
			Reduction of firing curvatures	2001		
			Control of variables in continuous mills	2002		
			Reduction of delayed curvatures		2004	
			Minimisation of polishing cost		2006	
		Automation	Automatic spray-drying control	2000		
			Selection of pieces by artificial vision	2002		
			Automatic control pressing		2005	
Product	Tile	Large sizes	Sizes >50*50 stoneware floor tile	1992		
			Sizes >50*50 porcelain tile	1997		
			Ceramic sheets		2005	
		Mechanical optimisation	Lightweight tile			2000
			Tile for exteriors		2006	
		Trims	Pressure slip casting (steps)			2001
			Curved porcelain tile			2001
			Thermoformed tile		2003	
		Double-face tile	Double-face tile			2005
	System	Prefabrication	Meshing	1985		
			Prefabrication			1986
		Accessories	Mechanical fastening in panelled façades	1989		
			Glassy borders without biscuit	1995		
			Crosspiece for separation/fastening in panelled façades		2004	
			Joints for fastening			2005
		Tile installation systems	Thin-bed tile fixing	1994		
			Tile installation without adhesive		2002	
		Solar energy use	Photovoltaic cells on ceramics		2001	
			Modulated photovoltaic panels with ceramics		2003	
			Thermal solar capturing devices		2006	
		Ventilated façades	Ventilated façades	2002		
		Ceramics for furniture	Ceramic urban furniture		2004	
			Heated bench			2005
			Ceramics for furniture		2007	
		Multilayer materials	Ceramic insulation		2004	
			Translucent ceramic–Fibre cement		2004	
			Ergonomic floorings		2005	
		Domotics	Integrated sensors		2005	
Organisation	Organisation	Own distribution network	Own distribution network	1985		
		Additional services by colour producers	Design/development service	1987		
		Sale of habitat	Sale of ceramics with added value (tile installation, environments, etc…)	1993		
		Interactive communication	Interactive communication	1995		
		Product handling/storage	Self-guided vehicles (line/laser)	1995		
			Radio frequency	1996		
			Computerised automatic store	1997		
		Client focus	User-oriented design		2002	
			Universal design		2004	
			Custom decoration		2007	

Table 2. Advances in the studied period

The assignment of each advance to one of these categories is not always obvious, since an innovation may affect different fields. For this reason, in these cases it has been necessary to choose what is considered most significant or to separate the constituents into several fields.

In addition, each advance has been evaluated in order to identify those that have generated value (Innovations), those that still evolving (Innovations under development), as well as the advances that have not been implemented in the market (Inventions). Table 3 lists the 100 advances that have been considered most noteworthy, with their evaluation and a chronological reference related to the moment that they materialised in a significant way in the ceramic sector (in the case of Innovations) or associated with their dissemination (Inventions and Innovations under development).

Although the number of advances compiled in the initial information search exceeded the 100 presented in the table, it was considered necessary to reduce them to 100 in order to be able to analyse their evolution. For that reason, many minor advances do not appear in an individualised form, because they have either been placed inside a group with a broader concept (e.g. the concept decoration with spray-dried powder glaze includes the advances associated with the application technology and with glaze preparation and development), or have been discarded, even though they have been a necessary element in subsequent innovations (e.g. the sensorised roller for determining temperature gradients in kilns[13]).

4. ANALYSIS OF THE INNOVATIONS IN THE CERAMIC SECTOR

4.1. LEVEL OF IMPLEMENTATION OF THE INNOVATIONS

A count was performed to define the number of cases that have achieved success in the sector, that are in the development phase, or that have not been implemented, as a function of the typologies of Field/Type of the set of advances. Table 3 gives the results.

FIELD	TYPE	INNOVATION	INNOVATION UNDER DEVELOPMENT	INVENTION	GENERAL TOTAL
Material	Body	1	2		3
	Surface	6	1	2	9
Material Total		7	3	2	12
Process	Preparation	1			1
	Forming	4			4
	Decoration	14	1	2	17
	Post-processing	5	1		6
	Energy	5			5
	Environment	3	2		5
	Optimisation	9	3		12
Process Total		41	7	2	50
Product	Tile	2	3	4	9
	System	5	11	3	19
Product Total		7	14	7	28
Organisation	Organisation	7	3		10
Organisation Total	7	3		10	
General total		62	27	11	100

Table 3. Analysis according to the evaluation

As may be observed, a clear orientation is detected towards the Process field, which involves half the considered cases, especially related to the activities concerning decoration and process optimisation. In contrast, the innovations related to other activities included in field of Organisation have been the least frequent in the studied period. This observation is consistent with some reports on innovation in the Valencia Region[14,15].

These data do not allow evaluation of the probability of success in the innovation activities because, though it is apparently achieved in 9 out of every 10 cases, the inventions that have not triumphed, or have not even managed get outside the company, are either unknown or forgotten and, therefore, have not been mentioned by the experts surveyed or considered in the analysis conducted.

4.2. CHRONOLOGICAL ANALYSIS ACCORDING TO FIELDS OF APPLICATION

Analysis of the chronological evolution of the total number of yearly innovations in all fields (Figure 2) evidences a clear increase, starting in the year 2000, which coincides with the progressive stabilisation of annual ceramic tile production, especially related to the innovations associated with the product (tile and system).

In addition, the figure shows there is a greater effort in innovations relating to the Process, the data on which present an oscillating but steady trend throughout the studied period. The remaining fields display noticeably less activity and a more sporadic character with the exception, starting from the date mentioned, of the Product field. This trend can be related to the increasing need for differentiation and/or redefinition of the Dominant Design through the incorporation of new functionalities and/or fields of application.

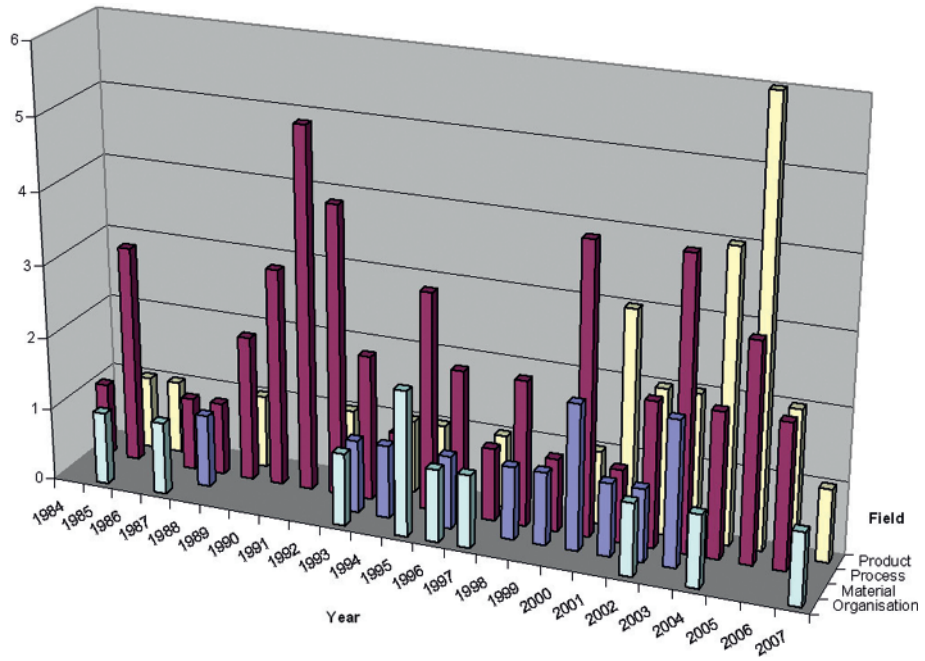

Figure 2. Chronological evolution of the number of innovations per year

4.3. INNOVATION IN THE MATERIAL FIELD

The number of advances in this field is quite small (Figure 3), as might be expected considering the long tradition of ceramic materials and the fact that the study does not include many of the previous developments associated with the implementation of the single firing process.

As Figure 4 shows, the most part is related to new types of glazes and surface applications, which have provided new aesthetic and functional developments. However, despite the small number of innovations related to the body, the enormous repercussion should be noted of the appearance in 1988 of tiles with very low porosity[16], which have not only led to notable changes in the definition of the dominant design accepted by the market, but also facilitated many subsequent developments in the Product field (tile and system).

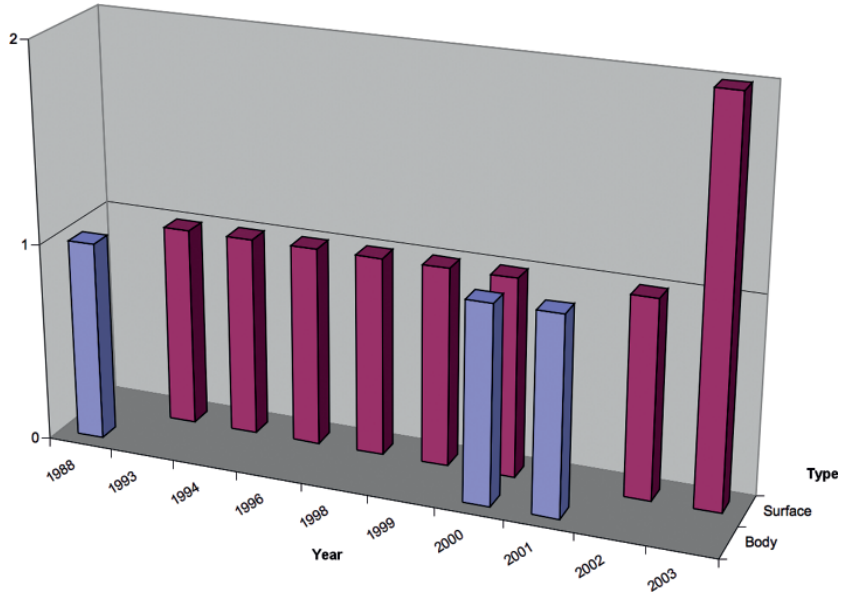

Figure 3. Innovations in the Material field

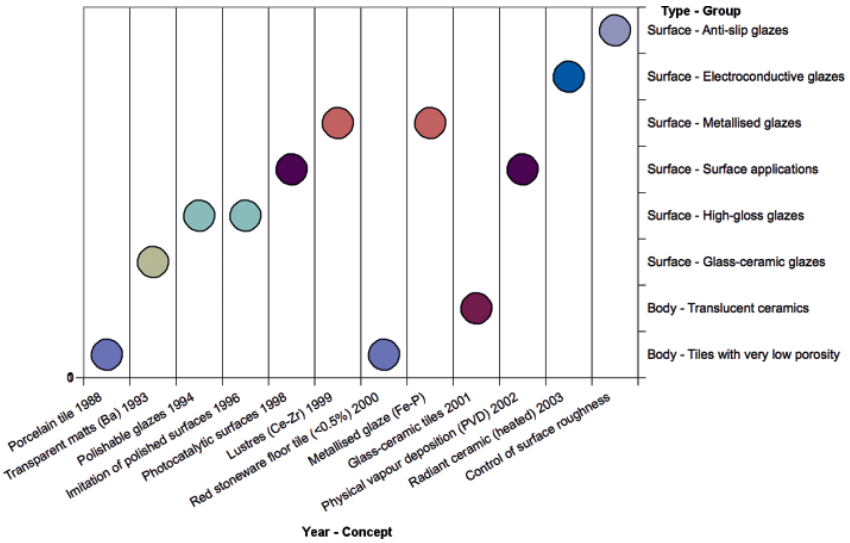

Figure 4. Innovations in the Material field

4.4. INNOVATION IN THE PROCESS FIELD

During the analysed period, unlike the foregoing case, the major focus lies on manufacturing technology and the process, 1 out of every 2 advances considered being related to this field. Owing to the large number of advances, the results are presented separately in terms of those associated with the manufacture stages (Figure 5) and those associated with the process (Figure 7).

It may be observed that most advances in the manufacturing stages are concentrated in the Decoration process. It should not be forgotten that aesthetic appearance is one of the features that some market segments recognise and value highly, in addition to being a factor that easily allows differentiation strategies to be developed.

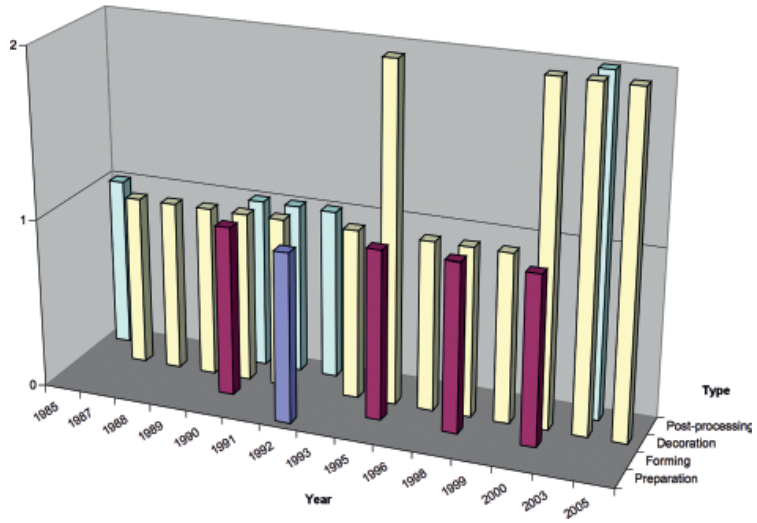

Figure 5. Advances in the Process (production stages)

Close examination of the advances related to the Decoration stage (Figure 6) shows there is a steady trend in the development of application technologies[17], in regard to both glazed products and porcelain tile decoration. In the first case, the advances can often be associated with technology transfer from other sectors, with initial attempts to apply four-colour printing that were unsuccessful due to the absence of sufficiently precise application means. In the case of porcelain tile, there is an accelerating trend in the development of various decorating techniques with a view to achieving differentiation in a product that initially displayed quiet a number of limitations in its aesthetic finish.

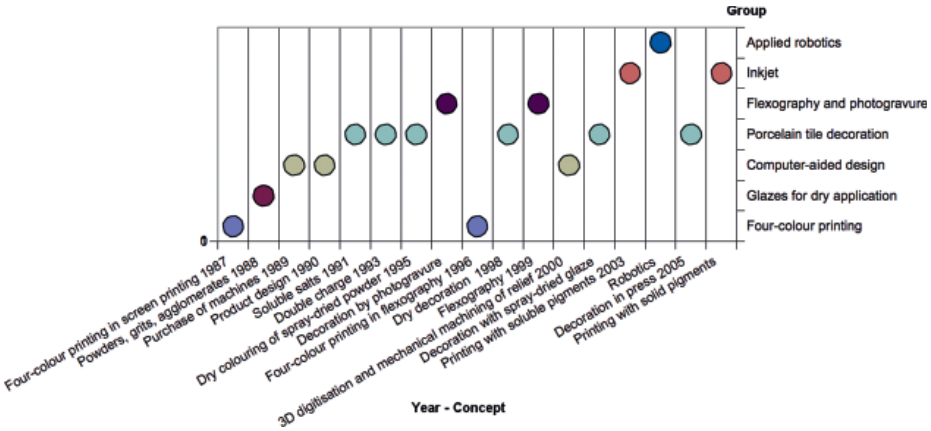

Figure 6. Advances in the Process-Decoration

In relation to the remaining activities related to the process (Figure 7), after an initial period coinciding with the progressive adoption of natural gas as fuel, in which the advances were directed at energy recovery and reuse, most of the efforts focused on optimisation of the production processes. In addition, continuity is observed in Environment-related activities, initially aimed at recycling liquid and solid wastes, and subsequently at controlling emissions.

Figure 8 shows that the advances related to the optimisation of the manufacturing process are mainly associated with actions targeting process improvement and control, a continuous trend being observed from the start of the period being studied to the present time. This trend has been rounded off, since the year 2000, with actions associated with the automation of the previously optimised processes[18], once the necessary knowledge had been generated, coinciding with the appearance of instrumental devices for control of the established regulating variables.

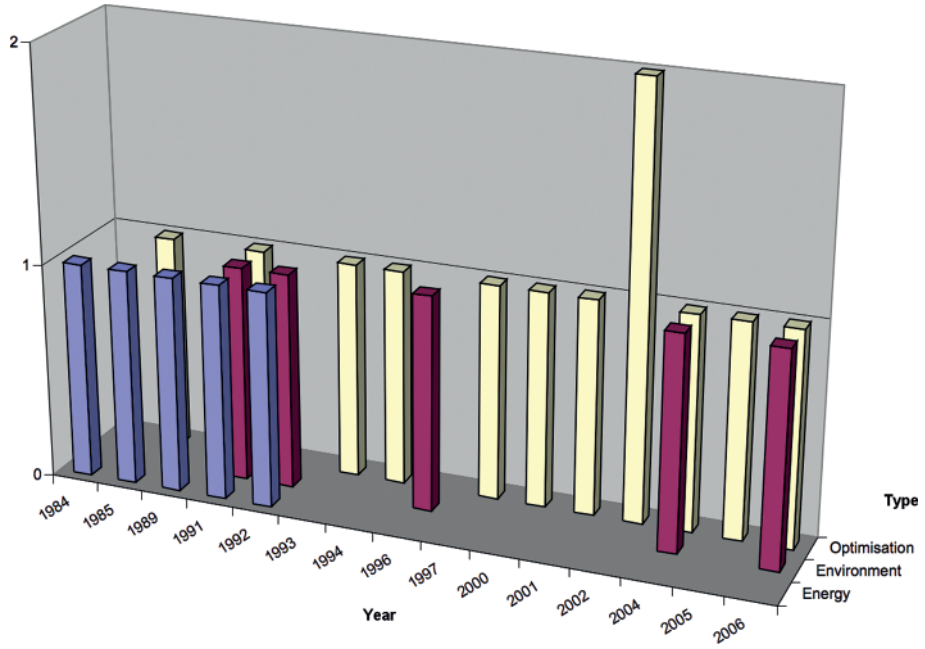

Figure 7. Advances in the Process (several)

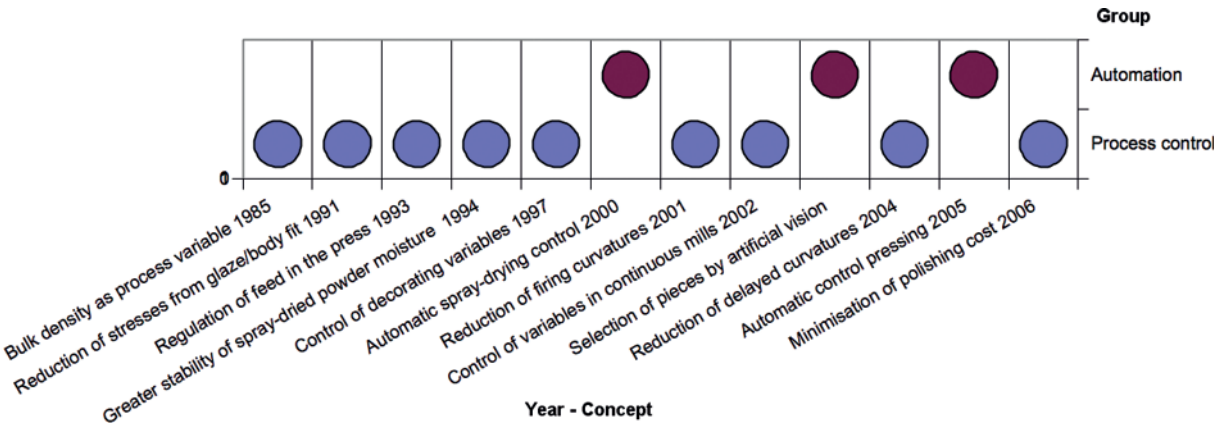

Figure 8. Advances in the Process-optimisation

4.5. INNOVATION IN THE PRODUCT FIELD

The activities related to this field constitute the second largest group of advances, after the production field, though it should be mentioned that it is also the one that exhibits the lowest percentage of success, since 25% of the recorded advances have not been implemented in the market. It has been divided into two typologies that reflect the advances related to modifications in the ceramic product (Tile) and those related to constructive applications (Systems), which in most cases also require non-ceramic elements.

As Figure 9 shows there is notable growth in the cases recorded since the year 2000, mainly related to System typology. The conception of the ceramic product is observed progressively to change from that of a building material to it becoming a construction system constituent, with advances associated with new product functionalities and/or the search for other fields of application for ceramic tile. It is in this field that the progressive need for differentiation has been evidenced with the greatest clarity in recent years.

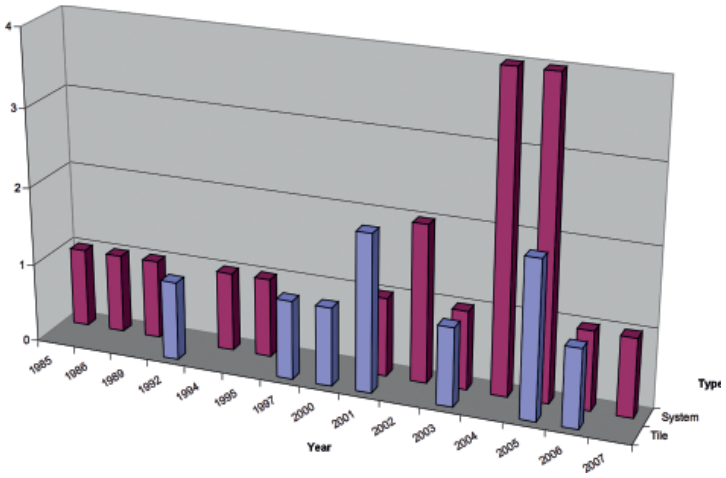

Figure 9. Product advances

Close examination of the evolution of the advances related to System typology (Figure 10) confirms the trend towards the development of new functionalities, in which the use of ceramics in ventilated façades stands out, as well as in other applications in indoor and outdoor environments.

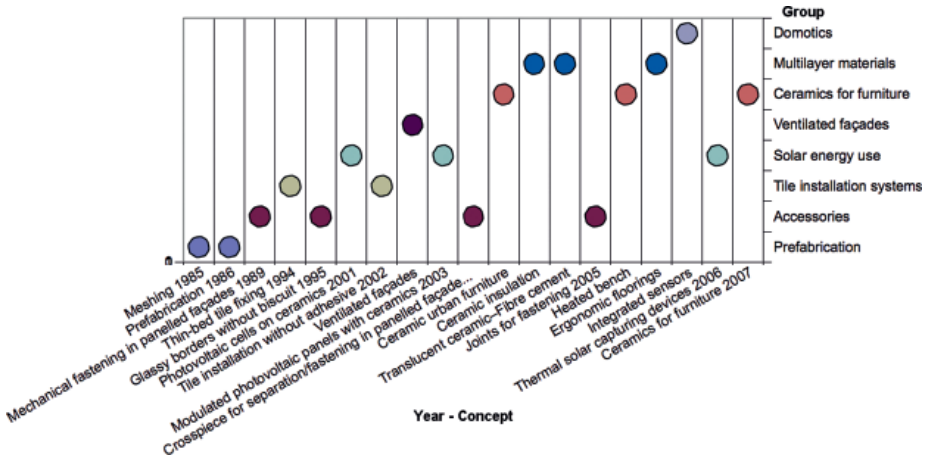

Figure 10. Advances in Product-System

4.6. INNOVATION IN THE ORGANISATION FIELD

As indicated previously, the number of advances in the Organisation field is the smallest of all the studied fields (Figure 11). This field, which until a few years ago was not clearly characterised in the frame of innovation studies, mainly due to its technological focus, is currently considered one of the most appropriate channels for innovation. It may be noted that this frame includes many of the activities needed to disseminate and generate value in the market and, therefore, to develop innovation.

In addition, the advances in the organisation field have a less collective character than the innovations of technological origin, probably because the required complementary assets are more specific, which causes them to be implemented in a much smaller number of companies.

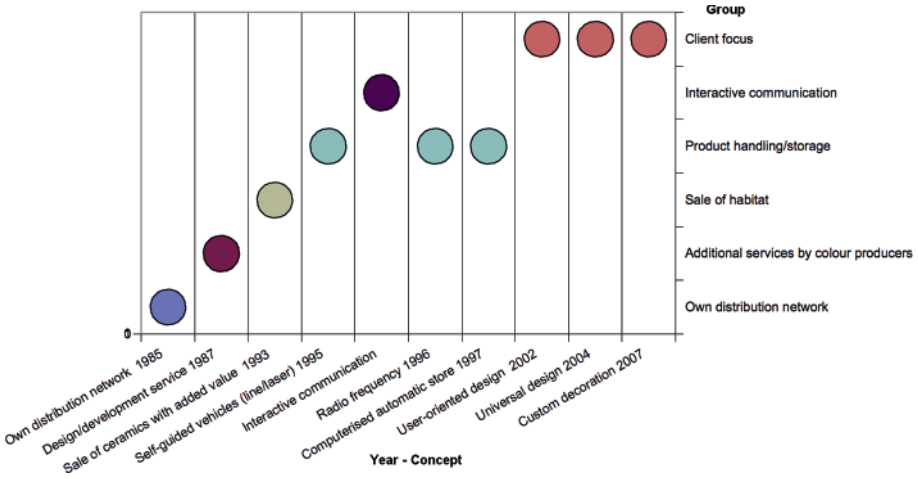

Figure 11. Advances in Organisation

4.7. NEW TRENDS IN THE INTERNATIONAL CONTEXT OF THE CERAMIC SECTOR

Parallel to the study conducted on the innovation process in the Spanish ceramic sector, information has been collected in regard to the most significant developments in the international context, in order to gather some insight into possible future trends. Some of the most noteworthy advances not yet found in Spain are included, as well as those whose implementation on a national level is still very incipient.

FIELD	TYPE	CONCEPT	YEAR
Material	Surface	Glazes with a nano-texture surface (self-cleaning)	2004
	Body	Ultraporous ceramics (humidity regulating)	2004
		Fibre-reinforced ceramics	2006
Process	Forming	Pre-compaction (presses, sheet)	2004
		Large-sized extrusion	2006
	Others	Green cutting	2002
		Mixed kiln (Convection-Microwaves)	2006

Table 4. Inventions/Innovations not yet developed in Spain

The principal focus observed in this context is also on technology and, in view of the small number of advances not yet implemented on a national level, it may be concluded that the Spanish ceramic cluster has a great capacity for rapid assimilation of outside innovations.

Analogously, a progressive focus is developing towards the organisation and product fields. In the first place, mention may be made of a company that, thanks to its association with the **W**orld **W**ide **F**und for Nature (WWF/ADENA), transmits to the user a feeling of collaboration in planet reforestation, since the company, which makes and markets ceramic products inspired by wood, is committed to planting trees in the Abisko Natural Park (Sweden).

Another example is that of a company which redefines the concept we have of ceramics as a rigid covering, and proposes soft and flexible coverings thanks to the use of very small sized pieces fixed on elastic substrates, which can be used to design furniture.

On the other hand, advances in new technologies not directly related to the ceramic sector may offer the possibility of contributing new functionalities to ceramics. In this sense, nanotechnology and biotechnology present themselves as the most active fields in today's scientific landscape.

5. CONCLUSIONS

We have analysed the importance of innovation in the first part of this paper, and have seen that it is a first-order strategic tool, which can provide the so highly sought-after differentiation with the competition. We have also seen the complexity of the process and one of its innate attributes: uncertainty. Some guidelines are put forward below, which may help implement it, and some of the errors are laid out that make this difficult.

Perhaps, as A. Cornellá and A. Flores[19] have stated, the most important constituent in all the innovation process is the creation of a group whose members have sufficient talent, energy, and capacity to work as a true team. Obviously, to attain that objective an appropriate corporate attitude will be needed and, therefore, the focus or understanding of the innovation process that the company has will be a determining factor in the desired value generation. This attitude will be the necessary frame without which hardly anything can be achieved. We will need to be move within this frame and this is where we will be able successfully to implement routines that expedite the process.

That team of people will need to devote time and money to generating innovative products. This, though obvious, seems not to be understood by a great number of companies, which expect innovation to materialise spontaneously. Therefore, the creation of stable multidisciplinary work groups with clear work times and the necessary financial resources for subcontracting experts, purchasing reports and developing prototypes, will act as a fertile field in which, with a little luck, innovation will be able to blossom.

We have already seen that observation of our environment can provide us with valuable insights into the changes that are occurring, as well as knowledge of the concerns and tastes of our present and prospective clients. In this sense the Oslo Manual states that "though R&D plays a key role in the innovation processes, it also needs highly qualified personnel, interactions with other companies and public research institutions, and an organisational structure that fosters learning and the exploitation of knowledge". Therefore, we shall need to try to watch from high vantage points in order to obtain and analyse all

the incipient manifestations of social, technological, and market movements, with whatever tools are available, in order to interiorise proactive attitudes that put us in an advantageous position. Only if we have watch resources[20]shall we be able to anticipate the changes.

The analysis conducted has highlighted the preponderance in previous decades of innovations based on processes and technologies in detriment to those based on commercialisation and differentiation. This trend, which was logical in a context of continuous growth in demand and the need to perfect manufacturing techniques, may no longer be the best strategy for the future owing the progressive saturation of the market and the strong increase in competition. That situation is already changing at the present time, evidenced by the progressive increase in the innovations related to Product and Organisation. These fields generally require more specific and less accessible complementary assets, while it is also possible to generate new market demands or segments that are initially easier to lead.

However, it should not be forgotten that the proactive strategies aimed at modifying the dominant design are generally expensive processes that take a long time, which are not always available to all organisations. In addition, it should be borne in mind that the external dependence on complementary assets (technology, design, glazes and raw materials, etc.) usually makes the value generated by the innovations ephemeral, given their rapid dissemination in the cluster and even internationally, which can make differentiation difficult. For that reason, some organisations could opt for defensive strategies, focusing their innovative capacity on manufacturing processes with a view to cutting costs, or focusing on specialisation in certain market segments, though this will be a difficult scenario with very intense competition.

Although the availability of complementary assets, which characterises the structure of the ceramic sector cluster, makes differentiation difficult in the frame of internal competition, it also provides advantages if we consider that the dissemination of the knowledge generated (internal or external) allows development of own incremental innovations and/or faster assimilation of those stemming from external suppliers, as the evolution of our sector has shown in the last few decades. An example is the use of processes based on four-colour printing, which have allowed spectacular diversification of the decoration processes. Figure 12 shows how different technologies for four-colour printing compete at the moment on the same stage, dynamising their development.

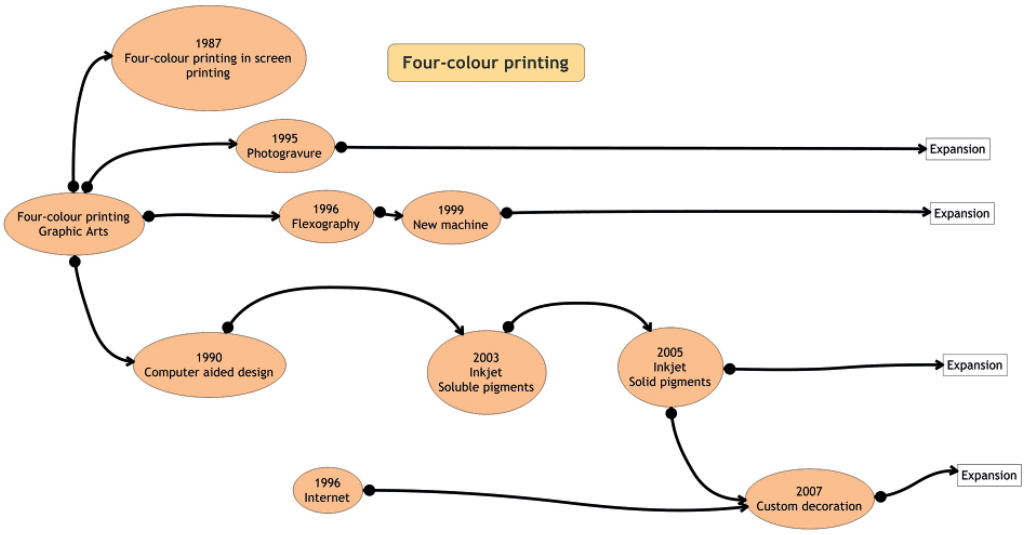

Figure. 12

In this sense, considering current globalisation, it should not be forgotten that there is not only competition between individual organisations that supply the same type of product or service, but that the differentiation in the market occurs in relation to other national or international ceramic tile producers, as well as to the sectors that supply substitute products for the same applications (natural stone, wood, etc.).

For that reason, several simultaneous, parallel innovation strategies might be required that will probably include cooperative schemes (ASSOCIATION) with organisations from the own ceramic cluster and with those from other complementary product sectors. The organisational innovations relating to the sale of the habitat in cooperation with other sectors (textile, furniture, etc.) are a clear example. This will require a change in the current conception of the ceramic tile as a finished product, for it to be understood as a building constituent that will only acquire its true identity in its definitive place of use, so that all the parts of the process that serve to put it there will be equally important.

We may conclude that there is no single solution for the innovation process, and even if there was, it would not be valid for all organisations. There are such a variety of clients and markets that the value set will need to be different in every case. Each company should evaluate its capabilities in order to decide what the best strategies will be for the given company to be able to differentiate itself in its target markets.

Yet, there are prime considerations that it would be advisable to take into account. Of particular note among these is the focus on new tile functionalities, the imperative need to recast our view of tile as a mere material and to conceive it as a building and habitat constituent, accepting, finally, that an uncommunicated product is a stillborn product. All these considerations can help extend the frontiers, to enable our sector to maintain the drive that has characterised it for over a hundred years.

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