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# Sequential Application of Indicators in Degrees of Intellection for Systematic Information Analysis

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## Abstract

The aim of this paper is to define the architecture of the information analysis towards a proposal of methodology on systematic information analysis.

First, the author shows the dimensions that state the architecture of information management. Second, the work explores the concept of indicator, as the measurement of the relation between data, and presents the results of a theoretical study of the scales that determine the analytical procedure of information from a systematic perspective. Third, the hierarchical architecture of indicators is reviewed from the literature taking the classification of scientometrics indicators as reference standard to its projection on extended metrics of information.

The paper suggests from the review that the analytical progress of sequential application of indicators, based in a hierarchical architecture: (1) is the main guarantee to ensure a methodological systematisation of analytical procedure; (2) may be defined as the systematic order of intellection: (3) and allows a rigorous, integral and exhaustive information management in organisations.

**Keywords:** Information analysis, indicators, knowledge management, scientometrics, datametrics.

## Introduction

Information analysis is the nuclear process of information management. The results from the analytical processes are integrated into scientific research processes, they help with taking decisions in any sphere of human activity, and they provide the necessary knowledge for designing the strategy of organisations. For this reason, having a methodology that validates analysis as an integral information management instrument is a matter of huge importance.

In this work we will be looking primarily at information analysis from a systematic perspective. We are referring to a point of view that is not exposed to the dynamics of organisations. Irrespective of the sphere in which it applies, analysis must be qualitatively unconditioned and rigorous in accordance with universalisable methodology principles. Analysis obtains its systematic element from the scientific nature of its procedure: measuring. The starting point of this concept may be found, for example, in work by Lafouge, Le Coadic and Michel (2002): “There are no sciences or technologies that do not have precise measurements”.[1]

We measure information and want to find out how many ways the measurements can appear in analytical practice considering a perspective of progress in the results. We refer to these *progressive ways of considering information* as *modes*, and analytical activity as a whole constitutes an absolute mode that at the same time describes the trend towards progressively more complex ways of treating information.

Indicators constitute the measuring element where the progressive complexity of analysis appears. Several recent studies (Mrosek, Balsillie, & Schleifenbaum, 2006; Potts, 2006; Rakel Øvstedal, Lid, & Terje Lindland, 2005; Hong Liu, Hsiewn Ou & Huan Ting, 2005; Do Santos, Crispim, Noualhetas, Macacini, & Gomes, 2005) about analysis of sustainability, development, or technical applications, offer examples of the effectiveness of indicator systems in organizations.

We understand that the analytical architecture of the information is associated with the sequential structure of the application of an indicator system. The order of implementation associated with the order of intellection that describes the analytical progress of a indicator system constitutes its guarantee as a suitable measuring, analysis and control instrument, while providing homogeneity and methodological systematicity to the integral information management process in organisations.

## Prior Specifications: Approach to Analytical Architecture

To define the information analysis architecture, we need to identify and describe the structure of the dimensional contents that must participate in its design. The framework issue that we need resolving is: What are the dimensions that we must consider in the design of the information analysis architecture?

We can define the elements that participate in the problem we are faced with in terms of information management in organisations. We have observed which spheres are involved:

1. The absolute framework is analysis.
2. Information is the subject that we analyse.
3. The object is the entity that participates in the informational universe: the organisation.
4. The relations between organisations, in which we are involved, are inter-(ob/sub)ject.

Information and analysis are types of relations as much as regions of communication and transmission structured in the form of a synapse. The organisation is the common denominator agent presented for the analysis of the information on the set of the given relations. The relation between organisations is presented to us as a dimension where a complex interaction of activities, interests and strategies converge (Figure 1). Analysis therefore falls on a system of relations arising from the interaction of systems.

A parameter of the relation between organisation and information corresponds respectively to each of the spheres involved as dimensions: strategy, system, method and process (Table 1). If we analyse the organisation as an object, viewing the dimensions revealed during this work, we can synthetically state that:

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[1] Later on we find: “Demonstrating a regularity, i.e., a constant quantitative relation, is the spirit that pervades all quantitativists” (Lafouge, Le Coadic and Michel, 2002).

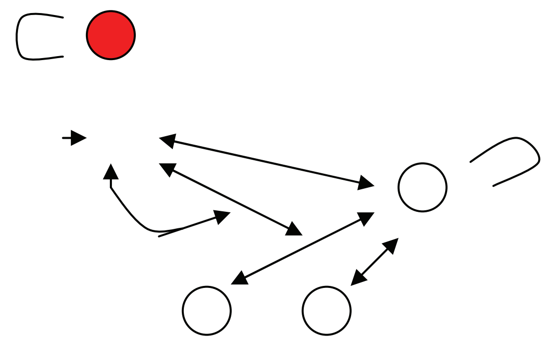

**Figure 1: Analysis falls on the set of relations**

a) The organisation appears as a fragmented complexity. We will name *strategy* to the orientation that determines the activity of the organisation in each fragment or sphere.

b) The organisation is a *system* determined by the tendency to raise the degree of complexity of its activity by the extent to which it is seen as a *system* of intellective progress.

c) The organisation is a living information subject. The heterogeneity of the information, that the organisation records, derives from the *methods* and *techniques* of information management used under or outside its control.

d) Objectively speaking, the organisation is a *process*: the feedback that describes its interest is reduced to its preservation and progress sustained through the cyclical management of information.

**Table 1: Elements, spheres of information management in organisations, characteristics, and dimensions of analytical procedures**

| Element | Sphere | Tendency characteristic | Organisation-information dimension |
|---|---|---|---|
| RELATION | Inter-jective | Fragmentation | Strategy |
| ANALYSIS | Absolute | Auto-intellection | System |
| INFORMATION | Subjective | Heterogeneity | Technique |
| ORGANISATION | Objective | Feedback | Process |

## Indicators and Information Measurement: Datametrics

From a systematic perspective, in the framework of information management, we consider the analysis and its instrument: the measurement.

The data that we have lay the basis for the information of an activity or phenomenon. The data are the result of the measurements of the constants or variables, corresponding to the parameters that describe this activity or phenomenon, and which we obtain on the basis of rigorous observation.[2] The analysis of the relation of these measurements allows us to explain the activity or phenomenon that we observe.

Sancho (2001) defines indicators as the parameters that are used in the evaluative process of an activity or phenomenon. We understand that the parameter is the variable element according to which the characteristics of any phenomenon are determined, and the indicator, in the technical sense given, is the instrument used to show the presence or to measure the intensity of the phenomenon. Given this, we can define indicator as the measurement of the relation between data represented by a phenomenon or activity.

The measurements have been expressed in the form of calculations, rates, indexes and indicators. According to a generic acceptance, all measurements are indicators. The indicator is found in the simple and first procedure of measurement for obtaining a piece of data. As Morgenstern (1970) states, the value of an observation depends not only on its one level of immediately recognised exactness, but also on the particular way in which the observation has been combined with others. The indicator itself is half way between the data and analysis proposals beyond the simple measurement that the piece of data represents. Rodríguez (2003) has recently suggested that data are simply obtained, gathered and selected whereas observations are made on the basis of a created design.

At the micro-organisational level, the design of indicators has played a critical role in strategy of enterprises. Precursors of this concept may be found in the work by Kaplan and Norton (1997). They show how the system of indicators acts as a set of tools for the management of organisations, albeit as a constituent part of what is known as a Balanced Scorecard (BS). BS can be defined as a system of inter-related objectives, measures, goals and initiatives that together describe the strategy of an organisation and how the strategy has to be achieved.

Examples of approaches to systematic application of indicators in organizations can be found in recent proposals. Pipe Methodology (2000), for example, describes a system of indicators as an integrated set of indicators structured as process relations and hierarchies of an organisation that, on the basis of the measurements of its different fields (customers, processes, people, impact and results) and consistent with the strategy and long term, offer, with the capacity for adaptation, a more complete vision of the state and expectations of the organisation.

In the sphere of information science, the metric and statistical analysis of information is the quantitative analysis of informational phenomena and is called informetrics. This was determined by the Informetrics Committee of the FID (International Federation for Information and Documentation) in 1984, with the support of such leading authors as Gorkova, Brookes, Egghe, Rousseau, Hood and Wilson, etc. According to this criterion, bibliometrics and scientometrics are established as sub-fields of informetrics, which is defined as the study of the quantitative aspects of information (Brookes, 1990) and as a set of techniques for the application of mathematical methods and models to the study of the phenomena of informative scientific activity, with the aim of determining the structure and properties (not the content) of information, through the definition of the regularities of the communication processes of this information (Setién & Gorbea, 1990).

In the scientific literature, as concluded by Peres (2002) and Gorbea (2005), in line with the analysis of Gorkova (1988), Egghe and Rousseau (1990), Brookes (1990), Tague-Sutcliffe (1992, 1995), Russell (1994) and Hood and Wilson (2001), informetrics is considered as the set of the

[2] We make the distinction between *phenomenon* and *activity* to characterise the presence or not of the organisation factor. *Activity* refers to an agent organisation: person, grouping, association, agency, company, etc, whereas *phenomenon* refers to the behaviour of a set of related elements, not necessarily organisations.

bibliometric, scientometric and webmetric disciplines aimed at the quantitative study of informational phenomena.

It is a criterion adopted by the majority of the scientific community. However, it should be understood, on the one hand, that this definition is restricted to the sphere of informational phenomena, and, on the other, that with regard to the relationship between metrics, the criteria that determine the definition of their competence should be defined.

The metric disciplines have in common the application of statistical and mathematical techniques to their spheres, complementing this application with expert knowledge on the subject. This knowledge appears in the creation of the specific indicators of application for each sphere.

If we can consider information, in a generic sense, as the object of quantitative analysis by informetrics, what do we do with the other metric disciplines that are also aimed at the quantitative analysis of information?

In our understanding, the meaning – that information provides to data – determines the sphere of its application. For this reason, if we want to obviate the sphere of the different metric disciplines, we must refer to a discipline that is aimed at the metric analysis of data. If we preserve the term of informetrics for informational environments, we must to define a metric macro-discipline *par excellence*. We propose the term *datametrics* to define this metric macro-discipline, which is defined as the set of analysis techniques aimed at information, irrespective of the form and sphere in which it is presented.

Datametrics groups together in one single methodological body the set of metric sub-disciplines. It is distinguished from the other metric disciplines in that it deals with the quantitative analysis of information without referring to any scientific sphere of specific application.

## Measurement Scales

We define measuring as the action of comparing a quantity, a physical magnitude, etc., with another of the same kind that is taken as a unit or template, from which we get a numerical value, with the aim of establishing relations or the deduction of conclusions.

Measuring is comparing with reference to a unit to obtain a numerical value. It is then ultimately, making the system of real elements that we are considering correspond with the formal system of numbers, counting. The number is the result of determining the times that the elements considered occur as a unit that form an aggregate or any of the abstract entities that result from generalising this concept.

In the scenario of measurement, we first depart in all cases from the perceptive establishment of the variables of the population, of the selected sample if necessary and of the creation of the measurements. Taking part in the measurement are the elements constituting the universe that we are measuring (population), a demarcated sphere and period (the sample), a unit of measurement (the parameter, understood as the variable according to which the characteristics of the phenomenon that describes the relation between the elements of the population are determined) and the measurement process itself (the calculation).

The measurement starts with the identification of the elements on the nominal scale (names or types). We have to define what we want to count. This *what* is the template unit object and may be a unit established arbitrarily or by agreement. If we want to count time, for example, we can do it according to the international unit of time, but also taking as reference the presentation of a fact or a phenomenon.

As Pardo and Ruiz (2002) state, the first measurement is nominal and consists of classifying in categories the subjects or objects that are to be measured, in such a way that all of the subjects or objects classed in the same category are equivalent with respect to the variable or property that is being measured.

The measurement is, by Lafouge, Le Coadic, Michel (2002), the compatibility of the elements on the cardinal scale (quantities). The variables, defined as each of the changing parameters used to describe an object, phenomenon or activity, may be numerical if they are represented by a numerical value or numbers or symbols if they are represented by a specific class label. An order ensues from the comparison that provides the relative position of the objects in the series that they form as a whole: ordinal scale.

In the debate on compatibility, the discussion that has arisen around the proposed economic measurement processes in four scales initiated by Stevens (1959), gathered by Churchman and Ratoosch (1959) and determined by Mattessich (1964) should be highlighted. According to this proposal, as showed by Rodríguez (2003), measurement is a procedure whereby symbols are used to represent a concept. These symbols or numerals are allocated according to certain rules that can be expressed through the nominal, ordinal, interval and ratio scales.[3]

The order of scales is also important. Ordinal measurement consists on allocating to the subjects or objects measured a number that allows them to be arranged according to the quantity of variable that they possess. By Pardo and Ruiz (2002) on the ordinal scale, "as well as the equality-inequality relation of the nominal scale being present, the numbers allocated enable us to state whether the quantity of variable that a subject or object possesses is bigger or smaller than the quantity of variable that any other subject or object possesses."

If we claim that the values can be measured with a nominal (qualitative) or logical (quantitative) scale, the latter can be cardinal, where cardinal is further categorized as either interval or ratio, or simply ordinal. However, the question is, how can we measure the quantity of variable that a subject or object possesses without a cardinal scale?

Nominal, cardinal and ordinal scale is the natural order of measurement intellection that defines the order of sequential application of indicators for systematic information analysis. Interval and ratio scales are intrinsic to cardinal scale and previous to ordinal scale.

The range groups can be constituted in parameters identified qualitatively as differentiated entities. If we integrate the grading of the measurements of a set of variables relative to an object, they allow us to identify, distinguish and define it. This integration places us at an immediately higher level, i.e. offering the possibility to operate again on the basis of analysis of qualitative entities presented as variables, this time to establish the relation between contents, which leads us to the description of object identifier concepts.

Finally, based on these, we can establish the subsequent quantitative measures of approximation determining the dynamic networks of behaviour, as illustrated in Table 2.

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[3] Rodríguez (2003) shows how in some registers, such as subjective perception, when we deal with ordinal measurement, the order does not guarantee the equidistance between measurement values. For this reason, from the practical point of view, the lack of distinction between the ordinal scale and that of the interval measurement (existing between measurement values of the variable) means that many variables of an ordinal nature can be analysed as interval variables.

**Table 2: Operations, objects, scale, variable and operational result in the datametrical analysis phases**

| N/O | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| **Operation** | Name | Count | Value | Relate | Rationalise |
| **Objects** | Elements | Registers | Series | Contents | Networks |
| **Scale** | Nominal | Cardinal | Ordinal | 2nd Nominal | 2nd Cardinal |
| **Variable** | Qualitative | Quantitative | Degree, rank | 2nd Qualitative | 2nd Quantitative |
| **Operational result** | Identification | Number | Position | Concept | Dynamic |

## Systematic Dimension and Constitutive Sequences in Information Analysis: Modal Classification of Indicators. From Scientometrics to Datametrics

We are presenting the results of a theoretical study of the parameters that determine the analytical procedure of the information from a systematic perspective, in its heterogeneous definitions and practices. The objective was to define the modes of the systematic analysis of the information, through the study of the indicators, considered as a basic element for measuring the factors that condition the organisational activity. The nature, construction, standards, type, implementation and systems of indicators have been examined in order to propose a number of indicator classification criteria that are valid for the set of metric disciplines.

The framework issues that need resolving were: What are the modes of information analysis? What is the classification of datametric indicators according to the analytical mode? What relation is there between the analytical modes and the scales of measurement, the variables considered, the measurements used, the operational results with the type of indicators obtained? How is the relation structured between the levels and the analytical modes?

We propose that it is possible to synthesise a common hierarchical structure for the indicators from the modal point of view, however, in light of the dispersion of the specialisation of metric disciplines, it is evident that it is not easy to obtain it directly. How can we deduce it?

We will take scientometrics as a reference and will then assess the indicator type schema in relation to the object type information and its projection on datametrics. Our next step will be to classify the indicators according to level or representation or degree of universality of the phenomenon or activity that they embrace, depending on the type of information that they deal with and at the same time on the mode of datametric analysis within which their use is established. The result is the following common indicator classification:

1. *Quantitative indicators or indicators of the quantitative mode of the analysis* (also of activity): calculated in relation to the time, with a constant or between constants or variables of the same category or parametric nature and of the same universe as the phenomenon considered. Insofar as they are parametric portions, they provide formal information based on a descriptor of the dynamics of a system or of a specific totality. For example: birth rate, etc. They are activity or descriptive indicators of the status. Quantitative indicators are simple calculations and can be classed according to the sphere where they take place: demographic (annual population rise, death rate, birth rate, total number of males or females, percentages of age ranges, density, etc.), economic (GDP, income per capita), etc.

2. *Qualitative indicators or indicators of the qualitative mode of the analysis* (also in 1st generation relational scientometrics): the result of the integration of different quantitative indicators relative to different groups of elements from different categories (for example, relational between territorial indicators: national, regional, local and economic indicators). In scientometrics, qualitative indication is derived from the impact indexes. The factor that endorses the quality of a scientific production is the impact that it has had on the scientific community (Maltrás, 2003). Generally speaking, datametric qualitative indicators work according to the referential information. And they are the result of the comparison of simple compatibilisations or the integration of simple indicators. Surveys are qualitative instruments or indicators inasmuch as they summarise user evaluations made on ordinal scales. There are other examples of qualitative indicators: the human development index, relational science-technology indicators based on citations, etc.
3. *Relational indicators or indicators of the relational mode of the analysis* (also in 2nd generational relational scientometrics). These are the indicators that require the presence of the element, the consideration of the significant content which distinguishes it as an element and not only its external relation with other similar elements of the same or a different nature. Although in scientometrics they have been established in the concurrence of terms index, in datametrics they have become more accepted and point to exhaustive analyses of cases although in their optimum theoretical approach they have to be extended to the whole evaluated universe. The different evaluations of behaviour, a phenomenon, an activity that we analyse are the values of the variable that leads us to the determination of a general concept. We do not limit ourselves to comparison but we orientate interpretation towards obtaining the definition of an aspect of the behaviour, phenomenon or activity indicated. For example: a set of synthetic indicators describes for us the interest a government has in R+D projects, which explains a certain tendency observed in the productivity of a country, or if we summarise the evaluations by users of the different aspects of a specific service we have an idea of its effective usefulness.
4. *Rational or elementary indicators* (also in 3rd generation scientometrics and relational patentometrics). The difference between a survey of opinions and a referendum is that the referendum is a rational indicator that quantifies the different forms of evaluation of the reality of a population whereas the survey is a relational indicator that is limited to determining the relation established between values. In the survey, we include evaluations on the basis of which we deduce a phenomenon, a reality, behaviour. In the referendum, we integrate constitutive elements of the reality analysed, the public and the result of their free decision as elements for measuring. We are not asked to evaluate a specific service, but the concept that is derived from the set of these evaluations and that mark a certain sociological tendency. Rational indicators draw the network of agents of a universe. In patentometrics, this type of indicator is known as third generation relational. The family of patents is an elementary indicator. Neither the citations which it refers to nor the key concepts that comprise the content of the accompanying reports are considered, but the patent is considered as an element that occupies a position on a map structured according to a network model. The significance of the patent as a synthetic information element is already acknowledged.

If we proceed to export the classification criteria of the indicators applied in the analysis of the scientific productive activity to the ones in the sphere of the activity in general of any organisation, we validate the passage from scientometrics to datametrics, homogenising and universalising the informational treatment; and, at the same time, in this passage we provide the sufficient methodological guarantees to a rigorous, integral and exhaustive information management in organisations.

As shown in Table 3, we can present the equivalence between categories of indicators, if we take Callon, Courtial and Penan (1995) as reference:

**Table 3: Equivalence of categories of metric indicators according to classification by Callon, Courtial and Penan (1995) and by the author**

| *According to Callon, Courtial and Penan (1995)* | | *According to author* |
|---|---|---|
| **Scientometrics** | | **Datametrics** |
| Class of indicators | Sub-types of indicators | Types of indicators |
| Activity indicators | Calculation of publications | Quantitative |
| | Calculation of citations | Qualitative |
| 1st generation relational indicators | Common key words and article set signatures<br>Citation networks<br>Joint citations or co-citations | |
| Indicators of relation between science and technology | Citations of articles in patents and between patents | Relational |
| 2nd generation relational indicators | Concurrence of terms<br>and relational analysis of content | |
| 3rd generation relational indicators | Exhaustive analysis of detailed elemental contents | Rational or elementary |

# Indicator Chart According to Analytical Modes

What relation do analytical modes maintain with the measurement scales, the variables considered, the measurements used, the operational results with the type of indicator obtained?

The indicator chart (Table 4) offers a synthesis of the descriptive factors set out so far that determine their arrangement:

**Table 4: General chart of indicators and associated characteristics in relation to the analytical moments in datametrics**

| **N/O** | **0** | **1** | **2** | **3** | **4** |
|---|---|---|---|---|---|
| **Operation** | Name | Count | Value | Relate | Rationalise |
| **Objects** | Elements | Registers | Series | Contents | Networks |
| **Scale** | Nominal | Cardinal | Ordinal | 2nd Nominal | 2nd Cardinal |
| **Variable** | Qualitative | Quantitative | Degree, range | 2nd Qualitative | 2nd Quantitative |
| **Operational result** | Identification | Number | Position | Concept | Dynamic |
| **Measurements used** | Label | Simple rates and indexes | Complex indexes and indicators | Indicators and networks | Networks |

| N/O | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| **Information type** | Unit | Formal | Referential | Content | Element |
| **Information type code** | IU | IF | IR | IC | IE |
| **Indicators in scientometrics and patentometrics** | Elementary identifier | Activity | Impact and cocitations | Concurrences | Family of patents |
| **Scientometric indicator types** | | Quantitative | 1st generation qualitative and relational | 2nd generation relational | 3rd generation relational |
| **Datametric indicator types according to author** | **Descriptive** | **Quantitative** | **Qualitative** | **Relational** | **Elementary or rational** |

Until now, then, our classification of indicators is structured in table form according to the horizontal axis of the information-type, which involves the measurements used, the scales, objects and variables treated, from where the classification of the different types of analysis operable emerges, namely the different *modes* that will result from the progressive application of the indicators in the successive measurements: quantitative mode of the analysis, qualitative, relative, etc.

## Systematic Order of Intellection

The progress of information analysis is determined by the different analytical modes. When information analysis is assigned to information management procedures, it participates and stands on a philosophical framework that structures the final horizon of information and communication analysis in its reference to the intellective action: data, information, knowledge, knowing, culture, etc.

If we define *information* as the content abstracted from one or more pieces of data that become knowledge through the intellective process, which universalised (in society) is understood as knowing, and with this being the basic constituent of culture, and *communication* as the action or process of transmission of this information, the set results in an ascending structure, schematised as follows:

-----------►--- i n t e l l e c t i o n ---------------►

Information ----- Knowledge ----- Knowing ------ Culture

-----------►--- c o m m u n i c a t i o n -----------►----

**Figure 2:** Schema of the communicational intellective process

According to this explanatory structure, information is positioned as the structural nucleus from which intellection emerges before reaching culture through a communicational process.

## Conclusions

In accordance with the relational structure of parameters that we have described, the datametric indicators are classed and ordered in their application according to the mode that refers to the nature of their results: descriptive, quantitative, qualitative, relational and rational or elementary.

The analytical progress of sequential application of indicators, based in this hierarchical architecture, may be defined as the systematic order of intellection and is the main guarantee to ensure a methodological systematisation of analytical procedure

The proposed classification indicator criteria are valid for the set of metric disciplines. It enables us to arrange the analytical procedure according to the deployment in which the indicators apply and allows a rigorous, integral and exhaustive information management in organisations.

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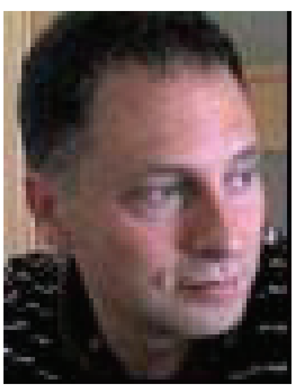
## Biography



Dr. **Victor Cavaller** was born in Barcelona (Catalonia, Spain) in 1965. He works as a Professor at the Department of Information and Communication Sciences of the Open University of Catalonia (UOC). He is also an Assistant Professor of Research and Development, and Marketing, Product Innovation and Development at the International University of Catalonia (UIC).

He received his Ph.D. in 'Information and Documentation in Digital Age' Program in the Department of Library and Information Science at the University of Barcelona (Spain) in 2007. Dissertation: "Matrix indicator system for strategic information analysis: application in a practical case". He holds also a Master in Applied Economic Analysis (IDEC-UPF, Spain).

He is President of the Catalan Society of Competitive Intelligence (www.scric.net) and Director of Interuniversitary Research in information Science and Technology (www.irist.eu).

His research interests include indicator systems, balanced scorecard, data analysis architecture, applied statistics, informetrics, technology watch, competitive intelligence, knowledge management, R&D&I.