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## TOWARDS A BETTER UNDERSTANDING OF THE CONCEPT OF DESIGN

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# TOWARDS A BETTER UNDERSTANDING OF THE CONCEPT OF DESIGN

*VERS UNE MEILLEURE COMPRÉHENSION  
DU CONCEPT DE DESIGN*

*HACIA UNA MEJOR COMPREENSIÓN DEL CONCEPTO DE DISEÑO*

Linda Acosta Salgado, Ph.D. Student<sup>1</sup>

*ERPI (Équipe de Recherche sur les Processus Innovatifs)  
Université de Lorraine  
Nancy, France*

Laure Morel

*ERPI (Équipe de Recherche sur les Processus Innovatifs)  
Université de Lorraine  
Nancy, France*

Isabelle Vérilhac

*Pôle entreprises & innovation, Cité du design  
Saint-Étienne, France*

## ABSTRACT

The word “design” is a concept that is becoming increasingly popular in the scientific literature, in the industry and in people’s daily lives. Despite its importance, however, there is no consensus about its meaning. Whether in theory or in

practice, there are multiple and diverse definitions, which should be made consistent to facilitate exchanges and collaboration between all stakeholders. This article seeks to identify and compare existing design concepts in the scientific literature. It is interpreted through the types of design proposed by van Aken (2004):

object design, plan design and process design. A bibliometric study of the word “design” were employed. The results of this study show that the concept of design has evolved over time from an object-design and process-design perspective to a plan-design and theorisation-of-design perspective.

**Keyword:** bibliometric study, design research, concept of design

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1. Corresponding author: [linda.acosta-salgado@univ-lorraine.fr](mailto:linda.acosta-salgado@univ-lorraine.fr)

## RÉSUMÉ

Le mot «design» est un concept qui devient de plus en plus utilisé dans la littérature scientifique, dans l'industrie et dans la vie quotidienne des individus en général. Cependant, malgré son importance, il n'y a pas de consensus sur sa signification. Aussi bien

en théorie qu'en pratique, il existe des définitions multiples et diverses, qui devraient être cohérentes pour faciliter les échanges et la collaboration entre toutes les parties prenantes. Cet article cherche à identifier et à comparer les concepts de design existants dans la littérature scientifique. Une étude bibliométrique du mot «design» a été

réalisée avec la prise en compte des trois types de design proposés par van Aken (2004) : design objet, design plan et design process. Les résultats de cette étude montrent que le concept de design a évolué au fil du temps, passant d'une perspective de design d'objets et de processus à une perspective de design de plan et de théorisation du design.

**Mots-clés :** étude bibliométrique, recherche en design, concept de design

## RESUMEN

La palabra "diseño" es un concepto cada vez más popular en la literatura científica, en la industria y en la vida cotidiana de las personas. Sin embargo, a pesar de su importancia, no hay un consenso sobre su significado. Tanto en la teoría como en la práctica, existen múltiples

y diversas definiciones, que deberían ser coherentes para facilitar los intercambios y la colaboración entre todas las partes interesadas. Este artículo busca identificar y comparar los conceptos de diseño existentes en la literatura científica. Con este objetivo, un estudio bibliométrico de la palabra "diseño" fue realizado. En el análisis se tuvo

en cuenta los tres tipos de diseño propuestos por van Aken (2004): diseño de objetos, diseño de un plan y diseño de procesos. Los resultados de este estudio muestran que el concepto de diseño ha evolucionado con el tiempo, pasando de una perspectiva de diseño de objetos y de procesos a una perspectiva de diseño de un plan y la teorización del diseño.

**Palabras claves:** estudio bibliométrico, investigación en diseño, concepto de diseño

## INTRODUCTION

The civil society has gradually positioned design at the crossroads between art, science, technology and the digital humanities, among other fields, and is in total connection with today's world (Flamand & Delpech de Saint Guilhem, 2015).

As a discipline, the notion of design has been studied within a rigorous culture and a reflective practice (Cross, 2007), linking different areas of knowledge, audiences and technologies (Koskinen & Krogh, 2015; Lloyd, 2017; Pries-Heje & Baskerville, 2010).

Design is a subject of interest for most industrialised countries, searching for a differentiation strategy (Kotler & Keller, 2012). It has a growing value on the world market and its contributions are increasingly understood, recognised and valued (Stevens, Moultrie, & Crilly, 2008). The principles of design appear capable of solving the major challenges of the 21st century, whether social, cultural, environmental or economic (Brown, 2012). Firms with a strong integration of design concepts and methods experience sustained growth, commercial success, increased innovation and strong robustness in performance, while also supporting national competitiveness (Beltagui *et al.*, 2008; Danish Design Center, 2003; Moultrie, Clarkson, & Probert, 2007). However, there are very few firms able to integrate design theory into practice; the vast majority of them are characterised by the quality of their products, by the intense service and/or competitive pricing. Competition based on these criteria leads companies to experience lower profits at an unhealthy level (Stevens *et al.*, 2008).

Design research, in contrast to scientific research, is characterised by the development of prescriptive rather than descriptive theories, because the nature of design is action-oriented (Koskinen & Krogh, 2015; Pries-Heje & Baskerville, 2010). Design research and the scope of research topics show that design is a strong and diverse research field that is widely applicable and broadly inclusive (Lloyd, 2017). Furthermore, the increase over the last few years in the number of scientific journals and conferences addressing this topic confirms its importance (Cross, 2007; Driver, Peralta, & Moultrie, 2011; Gemser, De Bont, Hekkert, & Friedman, 2012; Lloyd, 2017). However, the body of knowledge about design appears to remain fragmented and dispersed across many disciplinary fields (Romme, 2003).

The word design does not have a unique and shared definition among languages and over time. Several authors have shown that its meaning in theory and practice has evolved over many periods (Held, 1970; Simon, 1996; Yagou, 2015). Furthermore, the definition of design depends on the language used. In the English language, "design" means simplicity and functionality, whereas in the French language it means aesthetics or style (Burdek, 2005; Latour, 2008). In addition, this word could be used as a verb and as a noun, each with a number of different meanings and usages (Galle & Kroes, 2014).

Most definitions of the word design focus on three attributes: process, plan and result. Design refers to a process, which follows a predetermined plan and gets a result (Friedman, 2003). For van Aken (2004) these attributes represent three types of design: object-design, plan-design or process-design. An object-design defines the characteristics of the final result; it can be a product (tangible or intangible) or a service. A process-design defines how the production of the result is carried out and a plan-design defines a strategy for implementing the object-design (Pries-Heje & Baskerville, 2010).

The gap between theory and practice is discussed in academia and industry (Zhiqiang & Rhinehart, 2004). However, despite the increase in design research, there is no consensus on the definition of design (Heylighen & Nijs, 2014). Moreover, most firms lack a "design touch", and those who integrate it into their activities do it only partially (Direction Générale des Entreprises, 2017).

Following Romme's (2003, p. 569) assertion that in "collaboration and exchange between theory and practice, design can only be effective if there is a common framework available that facilitates interaction and communication between both of them", three questions emerge. First, are there conceptual differences between the notion of design that companies have, and the one used in scientific literature? Second, can the identification and understanding of these differences provide insights to improve the relationship between design theory and design practice? Third, can a clear conceptual relationship between design theories increase the adoption of design practices by companies?

In this article, we have chosen to focus on the first two questions. Consequently, this research aims to identify and evaluate existing design concepts in the scientific literature. The ambition is to contribute to a better understanding of the concept of design. To do so, the notion of design is evaluated by considering the types of design introduced: object-design, plan-design and process-design. These three types of designs are considered to cover the interdisciplinary aspect of design practices. A bibliometric study of the word design and its use in the scientific literature (across disciplines and through several periods) is used to execute the work.

In the next section, the research methods used to clarify the concept of design from a scientific standpoint is explained. Then, the third section shows the results of the bibliometric study. Finally, the results are discussed in a fourth section leading to the conclusion.

## RESEARCH METHODS

Bibliometric studies are a set of methods used to examine large quantities of bibliographic data and scientific publications (Cobo, López-Herrera, Herrera-Viedma, & Herrera, 2011a). This approach provides objective criteria for: evaluating the research importance and impact; recognising the main scientific actors; assessing scientific progress; identifying new research fields; and other functions (Gauthier, 1998; Martínez, Cobo, Herrera, & Herrera, 2015; Taylor, 2013; University of Leeds, 2014). Due to the large number of documents from various disciplines over a long period of time (1931–2016), the bibliometric method appears the most relevant to help identify the concept of design in the scientific literature.

### Bibliometric Data Collection

The bibliometric methods are a useful aid in conducting a literature review as they can guide the researcher to the most influential works and objectively map the field of research before even starting the review process (Perna, 2017). Moreover, bibliometric studies provide a systematic, transparent and reproducible process of analysis (Zupic & Cater, 2014).

There are two main approaches to explore an area of research: performance analysis and science mapping or bibliometric mapping. The first seeks

to assess the research and publication performance of individuals and institutions, and the second aims to discover the conceptual structure and dynamics of scientific fields (Golsby-Smith, 2007; Martínez *et al.*, 2015; Zupic & Cater, 2014). Hence, the scientific mapping method was selected for this study because it describes the conceptual, intellectual and social structure of specific disciplines, domains and research fields.

For this study, the Scopus database was chosen to gather the data. Scopus is the world's largest multidisciplinary bibliographic database of peer-reviewed research literature; it has been under development by Elsevier since 2004 (Regolini & Jannés-Ober, 2013). The data were retrieved from Scopus in May 2017 by including all types of documents that contained the word "design\*" in the titles and author keywords. The time span considered was from the oldest documents referenced by Scopus up to documents published prior to 2017. The research equation was the following: (TITLE ("design\*") AND AUTHKEY ("design\*") AND (PUBYEAR < 2017)). The asterisk was used to search for all variations of the word used (plural or past participle).

## Scientific Mapping – Co-Word Analysis

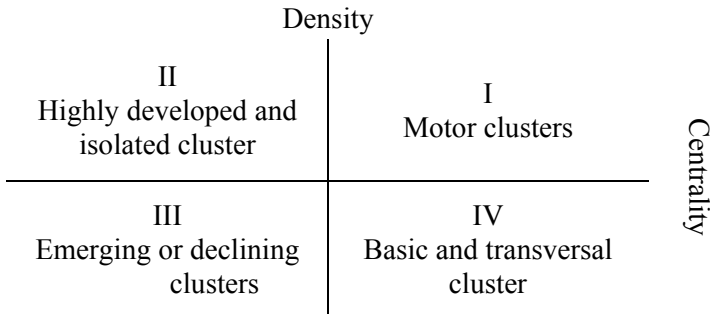
The scientific map analysis is a spatial representation of how disciplines, fields, specialties and articles or authors are linked together (Cobo *et al.*, 2011a). This representation seeks to visually display the conceptual structure of a field and its scientific evolution (Martínez *et al.*, 2015; Zupic & Cater, 2014). A scientific map can be constructed with various types of techniques, mainly the correlation of citations (co-citation) of documents and word correlation analysis (co-words) (Cobo *et al.*, 2011a).

Co-word analysis is a technique for content study and is used to construct a measure of similarity (Cobo *et al.*, 2011a), where the unit of analysis is a concept and not a document, an author or a journal (Zupic & Cater, 2014). For this reason, this technique was selected for the study. This technique uses the words of documents (titles, keywords, abstracts or complete texts) to establish relationships and association strengths. The result is a network of themes from a corpus of documents. All this allows for the representation of the conceptual field of a domain and helps understand its cognitive structure (Cobo *et al.*, 2011a).

The retrieved data was analysed and visualised with SciMat (Science Mapping Analysis software Tool). This is the most complete software for bibliometric mapping studies, because it allows for data processing, bibliometric analysis, mapping and visualisation (Taylor, 2013). SciMat is built around three modules: (1) The Knowledge Base module where the data is imported and pre-processed; (2) the science mapping module where the data reduction, analyses and mapping are carried out; and (3) the visualisation module where data visualisation and interpretation are performed (Taylor, 2013).

The results can be visualised through multiple techniques, such as the strategic diagram, cluster network, evolution map, and overlapping map.

In this study, the strategic diagrams and the evolution diagram were used because they allow for the detection of the evolution of the cluster or theme (group of references) over different periods of time. It supports the study of new and transient elements, as well as elements shared in two consecutive periods (Cobo *et al.*, 2011a).



**Figure 1. Strategic diagram**  
(adapted from: Cobo, López-Herrera, Herrera-Viedma, & Herrera, 2011b).

The strategic diagram shows the themes detected in each period in a two-dimensional space (Alonso, Gago, Martínez Aires, Dolores, & Martínez Rojas, 2015; Callon, Courtial, & Laville, 1991):

- Centrality measures the strength of the links of a defined theme with other themes. This value can be understood as a measure of the importance of a theme in the development of the entire research field.
- Density measures the strength of the links that connect the words describing the topic of the search. This value can be interpreted as a measure of the development of the theme.

Figure 1 shows the structure of the four quadrants of a strategic diagram where the clusters are distributed. Cobo and Herrera describe them as follows (Cobo, López-Herrera, Herrera-Viedma, & Herrera, 2012):

- Motor clusters: themes that are both well developed and important for structuring a field of research.
- Isolated clusters: themes are well developed, but are of marginal importance for the field.
- Emerging or declining clusters: themes are both weakly developed and marginalised.
- Basic clusters: themes are important to a field of research, but are not developed.

## RESULTS

In this section, the results obtained from the bibliometric study are presented (Acosta, 2017).



## Characterisation of Scopus Research

The search in the Scopus database was conducted during May 2017. A total of 145 902 documents were found. According to a visualisation of the publications per year (Figure 2), two types of research growth can be seen: a linear curve between 1930 and 1966 and an exponential curve between 1967 and 2016. Based on this information, six different partitions were built, selecting consecutive groups of years: I (1931–1966); II (1967–1976); III (1977–1986); IV (1987–1996); V (1997–2006) and VI (2007–2016). The first period is 35-year long, due to the small number of documents identified. The subsequent five periods are each 10-year long.

The increase in publications containing the concept of design is consistent with the growth of scientific publications in general. However, over the entire time-frame of the study, less than 1% of the documents registered in Scopus each year use the concept of design (Figure 3).

For each period, types of documents, language, origin and scientific domains were evaluated. The results for each dimension based on the data available are presented in Appendix A. The following results were obtained (Appendix A):

- Types of documents: many of these documents are journal and conference articles (95%). Articles are most representative in the early periods. Over time, conferences and other types of documents began to appear and to gain in importance.
- Language: English was the most frequently used language for written documents (88%). However, the amount of literature in Chinese has increased in recent decades.
- Origin: All continents increased their production of scientific papers. However, the distribution over continents has changed. North America was a major producer of scientific content in earlier periods, followed by Europe. Currently, the major producer of publications is Asia, followed by Europe and then North America. In Europe, the United Kingdom was the largest producer of content related to design during the early periods (periods I, II and III). It continues to be the first producer but it is no longer dominant. The domain is also covered by other European countries such as Germany, France, Italy, The Netherlands and Spain.
- Scientific domains: in the early period, Scopus classified most articles as “other” (75%); this category can be understood as unclassified. Also, the second category associated with design is medicine, with only 17%. From the second period, articles are classified in several domains and the unclassified decreased to 24.9%, whereas mathematics, computer science and engineering are at 29.3%, 17.3% and 10.4% respectively. The current distribution keeps design associated with the knowledge domain from engineering (30.3%) and computer science (19.4%). Meanwhile, the “other” classification remains fairly high (17.6%).

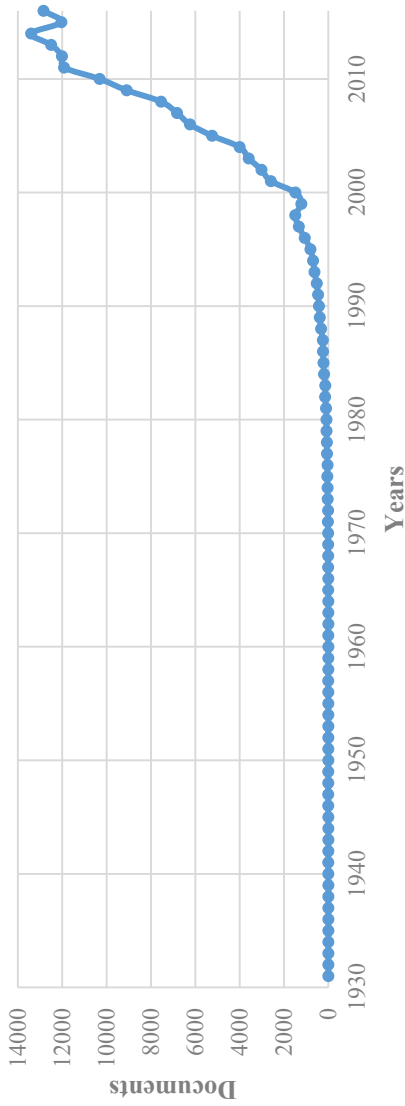


Figure 2. Scientific documents containing the concept of design per year

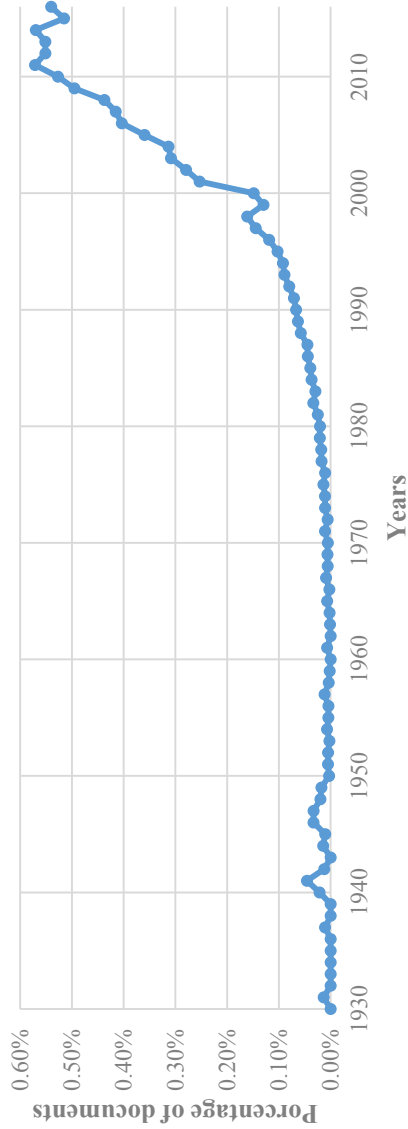


Figure 3. Percentage of scientific documents that contain the word design over the total publications registered in Scopus by year

## Clarifying the Concept of Design in the Scientific Literature

In order to understand the concept of design in the scientific literature, the 50 most cited articles from each period were selected and downloaded, knowing these items may have a stronger influence than those less frequently cited (Chai & Xiao, 2012). This allowed us to collect the raw data in order to select and extract the relevant information for this analysis. It permits us to calculate the similarity of concepts and position this information in a map to visualise it.

A total of 300 documents were imported to SciMat. In this software, the keyword author was normalised by combining singular and plural forms and grouping different terms related to the same word. A keyword list of 2 760 keywords, defined by the authors, was obtained for the analysis.

SciMat incorporates a wizard to configure the analysis, where the user can choose the methods and algorithms to apply in each step of science mapping (Cobo *et al.*, 2012; Martínez *et al.*, 2015). The selection of criteria in the present study was based on recommendations found in the literature (Alonso *et al.*, 2015; Cobo *et al.*, 2012; Van Eck & Waltman, 2007) and led to the parameters in Table 1.

<b>Step</b>	<b>Parameters</b>
Periods	All periods (6)
Unit of analysis	Author's words
Data reduction methods for all periods	Minimum frequency (2)
The kind of matrix	Co-occurrence
Network reduction methods for all periods	Minimum frequency (1)
Normalisation measure	Equivalence index (Callon <i>et al.</i> , 1991)
Clustering algorithm	Simple centres algorithms (Cobo <i>et al.</i> , 2011b)
Maximum – minimum network size	6 – 3
Measures for the longitudinal map	Evolution map – inclusion index Overlapping map – inclusion index (Cobo <i>et al.</i> , 2011a)

**Table 1. SciMat configuration of wizard steps**

To understand what is happening in each period and to deepen the different clusters and their relationships, SciMat proposes a strategic diagram per period and an evolution diagram of all periods. Each cluster represents a thematic network in which the keywords and their interconnections are linked; the name of the cluster corresponds to the most important keyword in the thematic network (Cobo *et al.*, 2011a). The cluster size is proportional to the number of documents associated with it and corresponding citations (Martínez *et al.*, 2015). The clusters from each period were analysed individually. The relationships between clusters, the topics of the internal network of each cluster and the related documents (title and abstracts) were taken into

account. By comparing all results by periods, an evolution of the concept of design is established.

### First period (1931–1966):

This period comprises five clusters (Figure 4). Most of the themes in this cluster are positioned in quadrants II and IV. Only the “human-relation” cluster was placed in the quadrant I. Although this cluster has few associated documents in its network (due to its size), it is the most important and developed research theme.

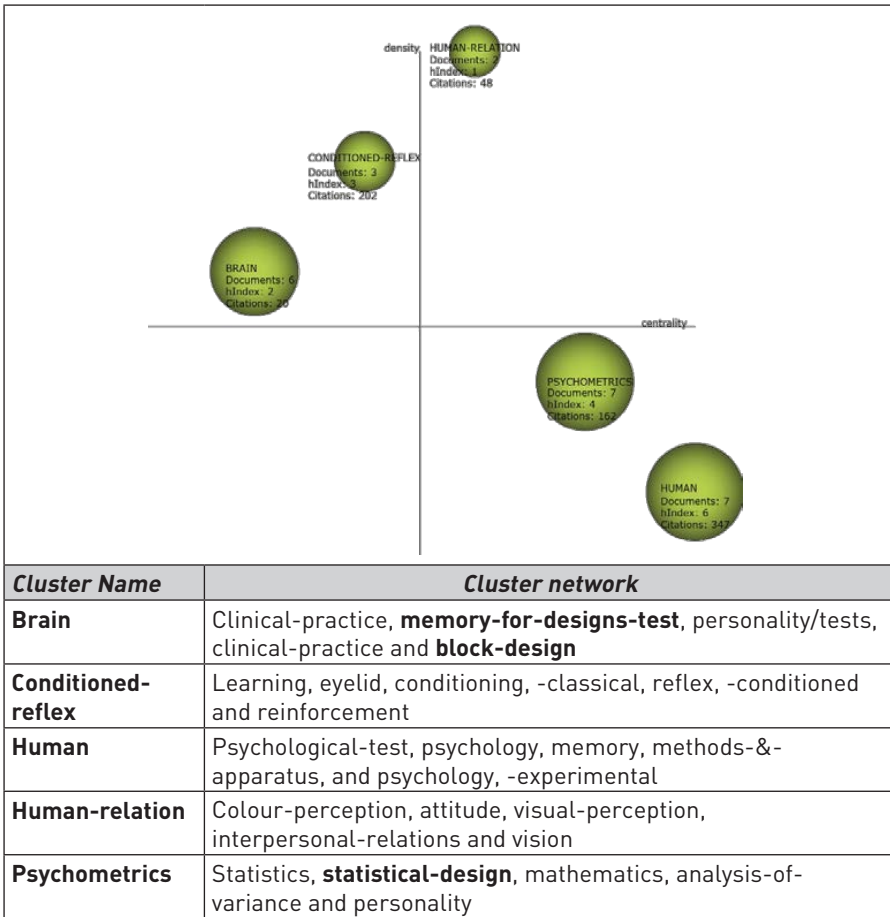


Figure 4. Strategic diagram and cluster names for Period I (1931–1966)

The word design was not part of any of the cluster names during this time period. This means design was not a central word in any network. However, in the word network of two clusters (psychometrics and brain), three terms that contained design were identified: statistical-design, block-design and memory-for-designs-test.

## Second period (1967–1976):

The second period has nine clusters, which are located in quadrants I and II (Figure 5). The motor clusters in the upper right of the diagram form a diagonal that can be interpreted as a specialisation located in the diagram forming a diagonal. The themes of the emerging or declining clusters are scattered and their size is not significant. The statistical-methods cluster is the most important theme of this time period, given that it links the largest number of documents. This is located approximately in the centre of the diagram, but with a great part in the motor clusters.

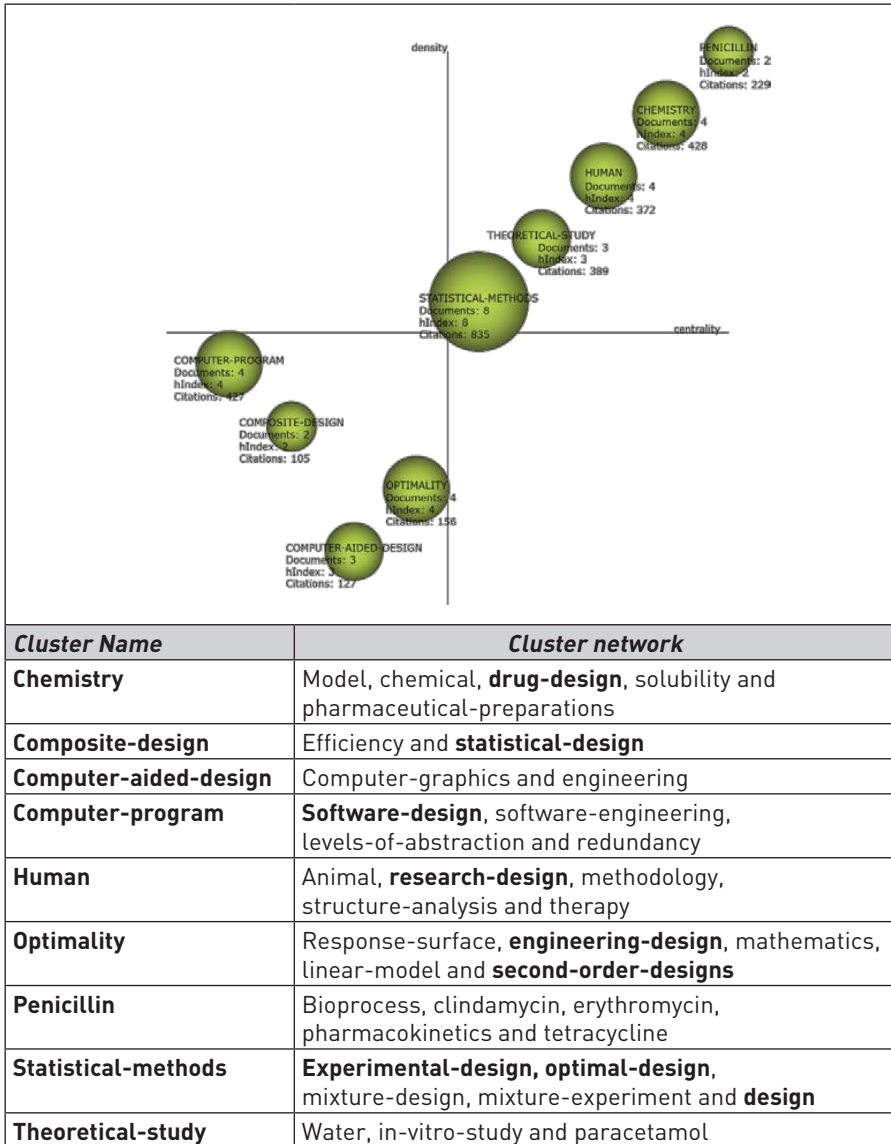


Figure 5. Strategic diagram and cluster names for Period II (1967–1976)

The word design is part of the names of two clusters: composite-design and computer-aided design. These clusters are not considered important, due to the small number of linked documents. These two themes are located in emerging or declining clusters. In addition, if the word networks of the clusters are explored, it is possible to encounter ten words that contain the term design: drug-design, research-design, design, experimental-design, optimal-design, moisture-design, engineering-design, second-order-designs, software-design, and statistical-design. These words are from six clusters: psychometric, human, statistical-methods, optimality, computer-program and composite-design.

### Third period (1977–1986):

This period is composed of six clusters, which are scattered across all quadrants of the diagram (Figure 6). The “human” cluster is the most developed

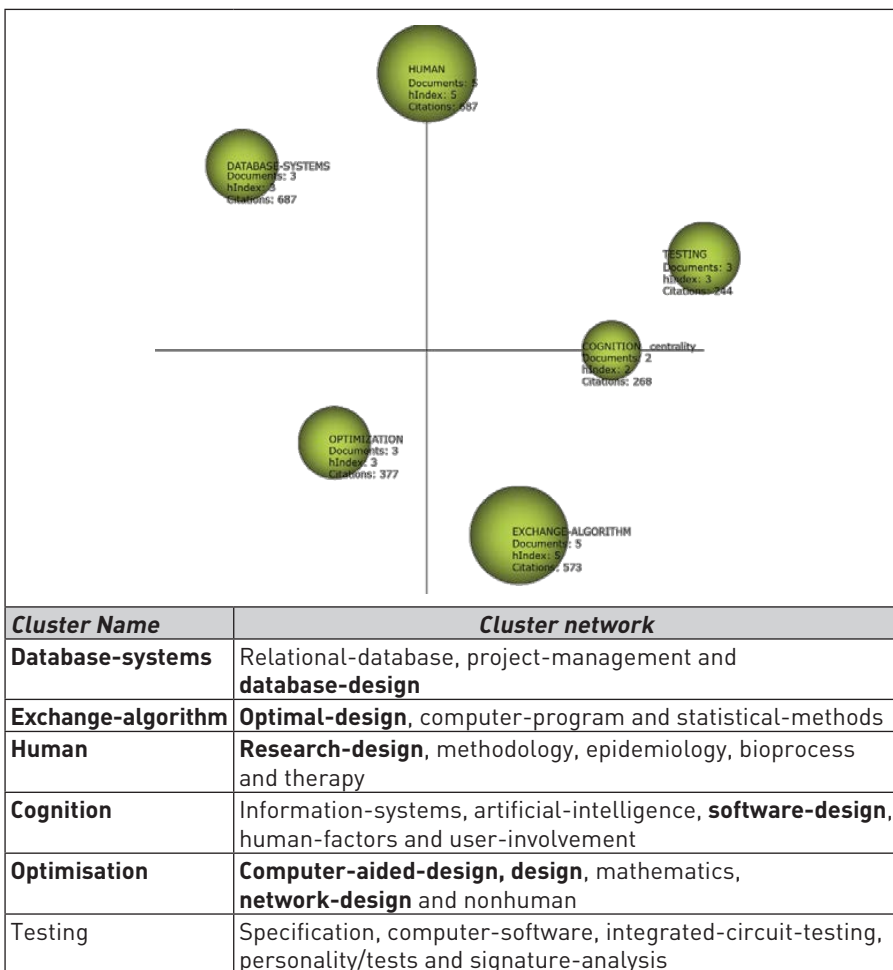


Figure 6. Strategic diagram and cluster names for Period III (1977–1986)

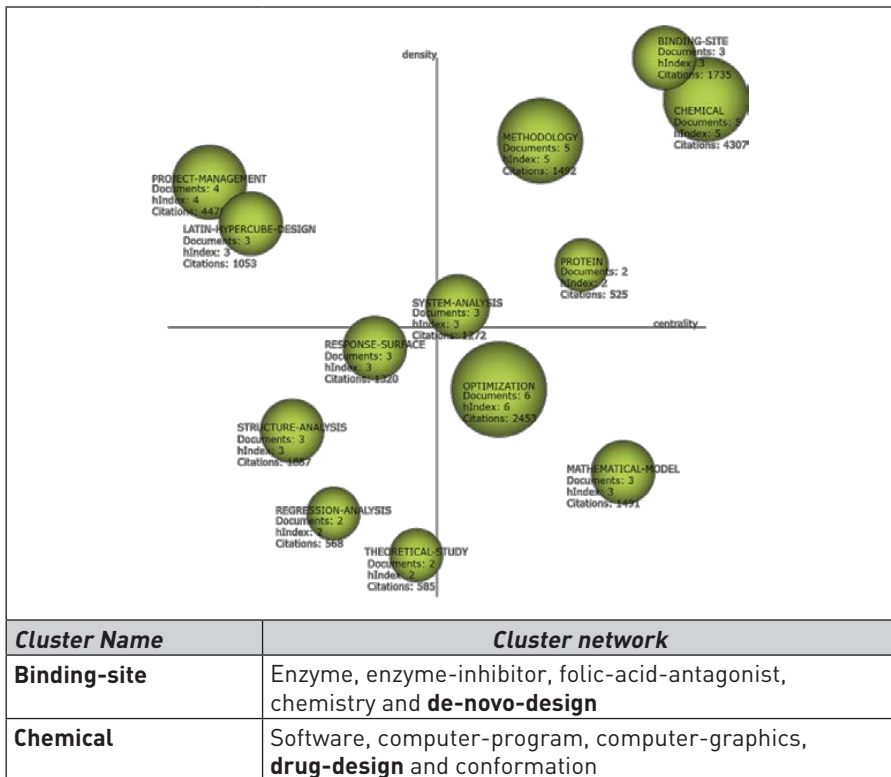
theme and one of the most important due to the number of linked documents. This theme is located between the highly developed and isolated cluster and the motor clusters. The cluster “exchange-algorithm” also links a high number of documents, but is located in the basic and transversal cluster.

The “testing” and “cognition” themes were placed in the motor clusters, but they are less representative as they link very few documents.

In this period, the word design is not part of the cluster name. However, there are seven occurrences of the term design (research-design, software-design, network-design, computer-aided-design, design, database-design and optimal-design) in five word networks of the following clusters: human, cognition, optimisation, database-systems and exchange-algorithm.

#### Fourth period (1987–1996):

In this period the themes increased considerably, and are scattered throughout the four quadrants (Figure 7). This period is composed of thirteen clusters: five motor clusters, four emerging or declining clusters, two highly developed and isolated clusters and two basic and transversal clusters. The “chemical”, “binding-site” and “methodology” themes are part of the motor clusters, but their importance in terms of linked documents is not representative. The theme with the most related documents is the “optimisation” cluster, which is located in the basic and transversal cluster.



<b>Latin-hypercube-design</b>	<b>Optimal-design</b> , computer-model, computer-experiment, entropy and interpolation
<b>Mathematical-model</b>	Risk-factor, controlled-study, <b>product-design</b> , <b>conceptual-design</b> and electrochemistry
<b>Methodology</b>	Human, <b>research-design</b> , clinical-trial, epidemiology and blood
<b>Optimisation</b>	Optimality, algorithm, <b>Bayesian-design</b> , <b>design-process</b> and computational-procedures
<b>Project-management</b>	Case-study, <b>design</b> , computer-software, <b>software-design</b> and software-engineering
<b>Protein</b>	Molecular, synthesis, comparative-study, magnetic-resonance-spectroscopy and <b>protein-design</b>
<b>Regression-analysis</b>	Age and performance
<b>Response-surface</b>	<b>Computer-aided-design</b> , <b>experimental-design</b> , <b>statistical-design</b> , information-processing and kriging
<b>Structure-analysis</b>	Theory, knowledge-representation and natural-sciences-computing
<b>System-analysis</b>	Computer-simulation, <b>creative-design</b> , control, knowledge-based-systems and value-engineering
<b>Theoretical-study</b>	Support,-non-US-gov't and <b>trial-design</b>

Figure 7. Strategic diagram and cluster names for Period IV (1987–1996)

This period is the first where the word design appears in the name of a cluster: “Latin-hypercube-design”. It is placed in a highly developed and isolated cluster. Also, sixteen words containing design were identified (de-novo-design, drug-design, optimal-design, product-design, conceptual-design, research-design, Bayesian-design, design-process, design, software-design, protein-design, computer-aided-design, experimental-design, statistical-design, creative-design and trial-design) in the word networks of eleven clusters: binding-site, chemical, Latin-hypercube-design, mathematical-model, methodology, optimisation, project-management, protein, response-surface, system-analysis and theoretical-study.

### Fifth period (1997–2006):

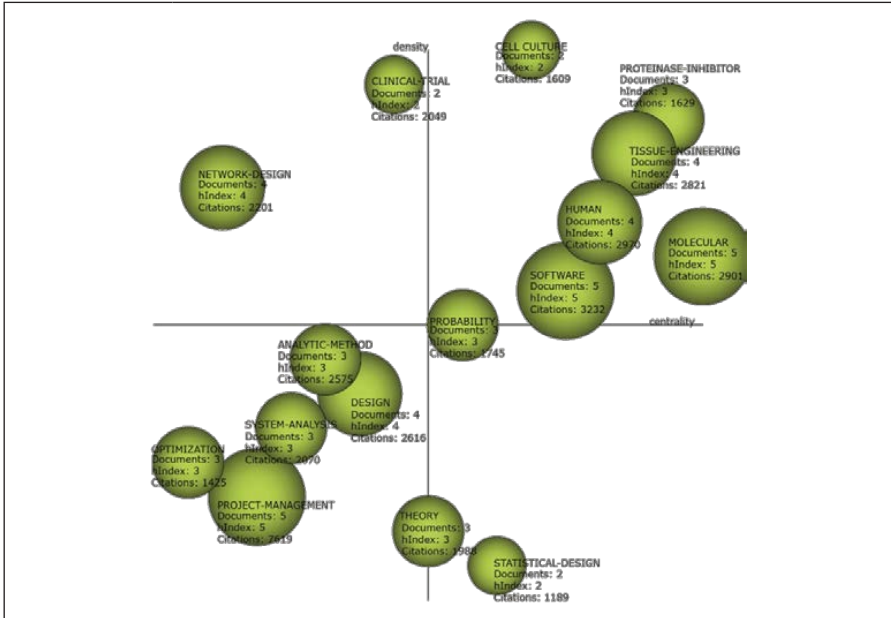
This period is composed of sixteen clusters scattered across the four quadrants of the diagram, but a large part was located in quadrants III and I, forming a possible trend line (Figure 8). Six themes for this time period are motor clusters, five are emerging or declining clusters, two are highly developed and isolated clusters and one is a basic and transversal cluster. In addition, two themes are between two quadrants (I–IV and III–IV).

The clusters with the most documents associated are “molecular”, “software” and “project-management”. The first two are motor clusters and the last one is emerging or declining clusters.

In this period, the word design appears in cluster names as “network-design”, “design” and “statistical-design”, which are respectively located in the highly developed and isolated clusters, emerging or declining clusters



and basic and transversal clusters. In addition, eleven words that contain the term design were identified: research-design, drug-design, epidemiologic-research-design, design-methodology, engineering-design, process-design, optimal-design, computer-aided-design, experimental-design, structural-design and product-design.



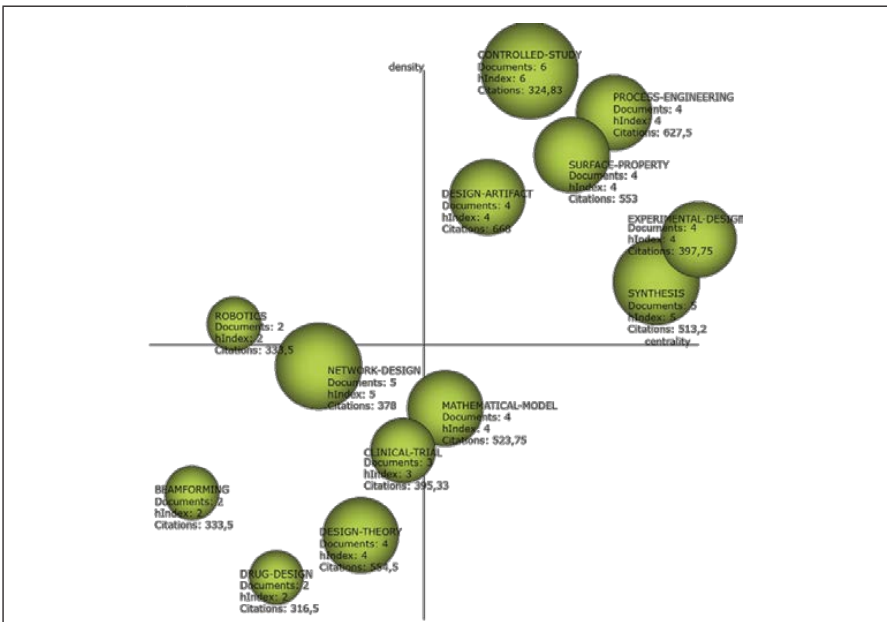
Cluster Name	Cluster network
Analytic-method	Process-design, mathematics, adsorption, extraction and nonhuman
Cell culture	Biomedical-engineering, cell-proliferation, culture-techniques, in-vitro-study and reproducibility
Clinical-trial	Research-design, methodology, therapy, hormone-substitution and ischemic-heart-disease
Design	Concrete, water, waste, stiffness and strain
Human	Age, middle-age, clinical-practice, bias-(epidemiology) and epidemiologic-research-design
Molecular	Animal, ligand, drug-design, HIV-protease-inhibitors and ligand-binding
Network-design	Design-methodology, computational-procedures, computer-architecture, integrated-circuit-layout and VLSI-circuits
Optimisation	Model, optimality, optimal-design, algorithm and evolutionary-algorithms
Probability	Statistics, industry, prevalence, reproducibility-of-results and strategic-planning
Project-management	Product-design, structural design, decision-analysis, electronic-commerce and societies-and-institutions
Proteinase-inhibitor	Binding-site, proteinase-inhibitor, docking, HIV-protease and proteinase

<b>Software</b>	Computer-program, chemical, simulation, computer-simulation and technology
<b>Statistical-design</b>	<b>Experimental-design</b> , protein, structure-analysis, sampling and process-engineering
<b>System-analysis</b>	Development, communication, problem-solving, <b>engineering-design</b> and product
<b>Theory</b>	<b>Computer-aided-design</b> , neural-network, synthesis, morphology and nuclear-magnetic-resonance
<b>Tissue-engineering</b>	Technique, controlled-study, biomaterial, bioprocess and porosity

Figure 8. Strategic diagram and cluster names for Period V (1997–2006)

### Sixth period (2007–2016):

This period includes thirteen clusters, mostly located in quadrants I and III, which form a possible trend line (Figure 9). Six clusters are motor clusters and seven are emerging or declining clusters. The “controlled study” cluster is a motor cluster and one of the most important, because it linked the largest number of documents.



<i>Cluster Name</i>	<i>Cluster network</i>
<b>Beamforming</b>	Covariance-matrix and <b>filter-designs</b>
<b>Clinical-trial</b>	Randomised-controlled-trial, <b>research-design</b> and satisfaction
<b>Controlled-study</b>	Human, methodology, cohort-study, cohort-analysis and medical-research
<b>Design-artefact</b>	Research, information-systems, <b>product-design, design-science</b> and structure

<b>Design-theory</b>	Business, case-study and human-computer-interaction
<b>Drug-design</b>	Genetics and <b>structural design</b>
<b>Experimental-design</b>	Optimisation, <b>Box-Behnken-design</b> , analytic-method, chemical and <b>statistical-design</b>
<b>Mathematical-model</b>	Computational-procedures, <b>computer-aided-design</b> , computer-simulation, problem-solving and theory
<b>Network-design</b>	<b>Design</b> , wireless, industry, production-management and work-conditions
<b>Process-engineering</b>	<b>Process-design</b> , technology, project-management, product and production
<b>Robotics</b>	Kinematics and <b>machine-design</b>
<b>Surface-property</b>	Water, dynamics, gas-chromatography, mass-spectrometry and surfaces
<b>Synthesis</b>	Chemistry, molecular, bioprocess, information-processing and robustness

Figure 9. Strategic diagram and cluster names for Period VI (2007–2016)

The word design is part of cluster names as design-artefact, experimental-design, network-design, design-theory and drug-design. The first two themes are motor clusters and the last three are emerging or declining clusters. In addition, in the word network of nine clusters (process-engineering, experimental-design, design-artefact, network-design, mathematical-model, clinical-trial, robotics, beamforming and drug-design), ten words that contained design were identified: process-design, Box-Behnken-design, statistical-design, product-design, design-science, design, computer-aided-design, research-design, machine-design, filter-design and structural-design.

The evolution diagram (Appendix B) was used in order to visualise the relationship between clusters in each period. In this diagram, two types of relationship lines are presented: solid lines and dotted lines. The first line means a thematic nexus and the second line means that the linked themes share keywords different from the name of the themes (Martínez *et al.*, 2015). The thickness of the line is proportional to the inclusion index, and the sphere size is proportional to the number of documents in each cluster.

## DISCUSSION

Results of the bibliometric study underscore the evolution of the concept of design in the scientific literature. Indeed, the bibliometric study of the scientific literature led or provided support to the identification of six time periods. In the early periods, the concepts were related to object-design and process-design, whereas in the last periods they were more related to plan-design and a theorisation of design. From a clustering-based perspective, the following changes are evident over time: an increase in the number of articles linked to design themes; an increase in the number of clusters named with the word design; an increase in the number of clusters that include the word design in

their network clusters; and an increase in the importance and development of clusters that include the word design.

In the last period, the word design is part of most clusters. These themes are motor clusters or emerging or declining clusters. In comparison to previous periods, the terms associated with the word design are not related to a result or a process. The terms related to the word design define it as a subject of study or a business strategy (Vinnakota & Narayana, 2014). Moreover, this period highlights the emerging interdisciplinary attribute of the concept of design. Indeed, the documents linked to the main clusters come from multiple disciplines.

On the other hand, in the evolution diagram it is evident that in the first periods (I, II and III) the relations between clusters of different periods are not so important in comparison with those of the last periods (IV, V and VI). Additionally, the number of documents associated with each cluster is less important in the first periods than in the last ones. This demonstrates a growth in the literature that includes the word design, and a diversification and strengthening of relationships with other notions.

In particular, among the notions related to design, the word “human” is the most important. This word was present in all periods, either as the cluster name or in the network of other clusters. In addition, it is the word that had more associated documents in each of the periods. The words “design”, “computer-aided-design” and “research-design” were present in all periods except the first, as part of a cluster or as a cluster name. This notion and others in the evolution diagram (network design, experimental design, software design, product design, etc.) demonstrate empirically that the notion of design has evolved with a strong relationship to notions about human, research and technology dimensions.

The results of the bibliometric approach make it possible to associate the meaning of the design concept with a process or its result. This is evident in the scientific articles of first period that used this term. However, the scientific literature in the early periods (I, II and III) was more focused on functional or technical aspects instead of on appearance. The current scientific literature at a high level merged into a notion of design associated with a plan or a strategy.

Additionally, on the basis of the evolution diagram, a trend in the definition and in the development of the notion of design can be identified. In the years ahead, it is likely the notion of design will be accompanied by words related to new technological developments such as robotics, with broad applications at a strategic level in the industry and oriented toward human beings.

## CONCLUSION

This article aimed to identify and evaluate existing notions of design in the scientific literature in order to contribute to a better understanding of this concept. A bibliometric study was used to understand the concept of design associated with three types of design defined by van Aken (2004): object-design, plan-design and process-design. This led to six time periods of evolution of this concept. In the periods I-III, the word design was accompanied by other terms. The union of these words defines the design as a process or as a result. This definition first appeared in psychology and later in medicine, chemistry, computer science and engineering. From Period III this word became important in the thematic network of project management, focusing on problem-solving and the development of products, processes and systems.

In the Period IV, the word design appears alone for the first time in the word network of the "project management" cluster. In the Period V, the word design is more important than in previous periods. Here, this term appears as a cluster and tag along with other clusters. For Periods IV-V, design is a plan or strategy, in addition to being a process or a result.

In the Period VI, the word design is represented in five of the thirteen clusters and is contained in the networks of most of the clusters. In this period, the importance of the design extends the types suggested by van Aken (2004). Design becomes the subject of study, as suggested by the "design theory" cluster.

Our main result clearly demonstrates that the acceptance of the term has evolved over time from an object-design and process-design perspective to a plan-design and a theorisation-of-design one. In theory, the notion of design seems to be expanding as this concept is studied or experienced.

The bibliometric study objective was to produce a broad perspective of the evolution of the concept of design by using a long time frame. This long period of time is also a limitation of this research, because it makes the study more sensitive to eventual modifications of the taxonomy used by Scopus to describe articles (scientific domains, type of documents...) and also some trend words in the keywords of the article. Another perspective would be to automatically generate keywords based on the content of the article in order to use complementary approaches such as cognitive and semantic analysis.

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**Linda ACOSTA SALGADO** is a Ph.D. Student in Industrial Systems Engineering at Université de Lorraine. Bachelor degree in Industrial Design (Universidad Nacional de Colombia, 2015), Master of Design global (Université de Lorraine, 2017).

**Laure MOREL** Professor of Industrial Engineering at the University of Lorraine – École Nationale Supérieure en Génie des Systèmes et de l'Innovation (ENSGSI). Her research focuses on the study and evaluation of the upstream phases of innovation processes.

**Isabelle VÉRILHAC** Head of Business and Innovation department at the Cité du design. She is in charge of the development and the management of projects for economic, territorial and societal projects. She has worked in design, in medical research and development activities.





# Appendix B. Evolution diagram

