Delphi Method in Emerging Technologies

Jhon Wilder Zartha Sossa[a], Jorge Alonso Manrique Henao[b], Juan Manuel Montes Hincapie[c], Juan Carlos Palacio Piedrahita[d], Gina Lia Orozco Mendoza[e], [a]School of Engineering, Faculty of Agroindustrial Engineering. Universidad Pontificia Bolivariana, [b]School of Engineering, Faculty of Textile engineering. Universidad Pontificia Bolivariana, [c]Faculty of Economic and Administrative Sciences. Universidad de Medellín, [d]School of Engineering, Director Faculty of Agroindustrial Engineering. Universidad Pontificia Bolivariana, [e]School of Engineering, Faculty of Agroindustrial Engineering, Universidad Pontificia Bolivariana, Email: Jhon.zartha@upb.edu.co, jorge.manrique@upb.edu.co, jmontes@udem.edu.co, juan.palacio@upb.edu.co, gina.orozco@upb.edu.co

The purpose of this article is to identify new techniques and tools related to the application of the Delphi method, as well as to show which of these techniques and tools have been applied in future studies for emerging technologies, the methodology used was carried out through the in-depth review of 50 articles directly related and obtained from the Scopus database, which had as criteria the focus on emerging technologies, sector of application, time horizon and methods used, an analysis on two axes of discussion was carried out techniques and methods used in future studies compared with the proposals by authors such as Popper and Smith and Saritas, and applications in emerging technologies, at the end 26 new methods and 153 emerging technologies were found prioritized.

Key words: *Delphi, emerging technologies, information technologies, Hype Cycle.*

Introduction

Foresight constitutes preactive and proactive anticipation to illuminate present actions with the light of possible and desirable futures. Preparing oneself for the expected changes does not prevent one from reacting to provoke the desired changes (Godet & Durance, 2007), among the prospective methods of expert consultation is the Delphi method, which was developed to overcome the drawbacks of methods based on expert judgment, At the same time, its advantage of extracting the necessary information and minimizing the possible errors that may occur is highlighted, it is also the method most used by the organizations and even

countries in the last forty years, its ease of use and applicability makes it a method that may be feasible to complement with other quantitative, qualitative or mixed methods used in foresight (Figueroa, Montilla & Melo, 2012)

Since its inception in the studies, the RAND Corporation has conducted Delphi studies focusing on various areas of knowledge, sectors, regions, and countries, Several Delphi studies have been applied in prioritization of technologies, but the emphasis on emerging technologies has been a topic of interest that is only observed since the last two decades.

The importance of this article lies in the in-depth analysis of articles in Scopus with emphasis on the discovery of new methods and techniques in future studies through the Delphi method, which is achieved after the analysis of the cases found and their contrast with the methods proposed by internationally renowned authors such as Popper (2008) and Smith and Saritas (2011), Besides, the identification of emerging technologies focused especially on information technologies which were studied, including their application sector and time horizon, this last aspect was also contrasted with the technologies and information trends mentioned by Gartner reports.

The questions that are addressed in this article are: Are there new methods or techniques in the Delphi studies different from the descriptive statistics? have there been applications of the Delphi method in emerging technologies? and if so, which technologies have been analyzed and prioritized?

The article is divided into several parts. In the first part, the most important background related to the applications of the Delphi method is presented as well as the description of what several authors mention as "prospective schools", In the second part, the methodology used is explained, which emphasizes the in-depth analysis of articles obtained with equation or search strategy in Scopus. In the final part of the article, the results are shown, emphasizing in author, sector and time horizon of each case, this section also includes a discussion on two axes, one of them related to the methods and techniques used and their comparison with the proposals of Popper (2008) and Smith & Saritas (2011), the second axis identifies the applications of the articles studied with a focus on emerging technologies specifically in the area of information technologies, at the end the main conclusions of the research are presented.

Theoretical Framework
Delphi Method

The name Delphi method was proposed by the philosopher Abraham Kaplan, who was part of the American research center The Rand Corporation, where it was developed in the late 1950s and 1960s as an effective means of collecting and synthesizing expert opinions. Since the first RAND study was published in 1964, the technique has been used very frequently in a wide range of subjects (Celiktas & Kocar, 2010a; Banuls & Salmeron, 2008; Yuan, Chih-Hung Hsieh & Wang, 2006; Gordon & Pease, 2006; Builes & Manrique, 2000). It became popular when applied to a large-scale national technology forecast in the 1960s in the   UU. (Helmer, 1983 quoted by Cuhls, 2001). But if we look at the general use of the method to

date, it can be seen that the spread of Delphi throughout the world has been largely concentrated in the area of strategic management of large companies and organizations (Chula, 2001).

The Delphi method to date has remained in a stage of ongoing development, authors like Mackenna found 1000 published research using the method since it was created, as well as Gupta and Clarke, found 463 articles published in a period from 1975 to 1994, which highlighted up to three areas of application such as areas of health, education, and administration" (De Villiers, De Villiers & Atol, 2005 cited by Varela, Diaz & Garcia, 2012). Delphi is a traditional method of future studies that compiles the assessments of a panel of experts on specific theses or arguments related to the future through iterative questionnaire rounds that are repeated at least twice (see, for example, Kuusi, 1999; Mannermaa, 1991 cited by Auvinen, Tuominen & Ahlqvist, 2012).

According to Rowe, Wright and Bolger, (1991) cited by Santos, Araújo & Correia, (2017); Eller & Naveiro, 2016; Karvonen et al 2008, mention that the characteristics of the method are based on four principles: the anonymity of the participants; iterations through several rounds; controlled feedback, where the participants can comment on and criticize the judgments of others so far; and the response of the statistical group, where descriptive statistics of the quantitative judgments are provided to the participants after each round. In this sense, the characteristics of the Delphi method fit with the open prospective paradigm, since the method is "one of the best-known methods for dealing with the creative and open aspects of the problem because it motivates independent thinking" and makes groups gradually form solutions (Gupta & Clarke, 1996 cited by Santos, Araújo & Correia, 2017).
"The Delphi method is used to obtain information on topics marked by uncertainty and for which expert knowledge is accessible" Through iterations, stability is sought in the experts' responses and thus reduce uncertainty in the analyzed topic (Linstone & Turoff, 2002 cited by Pereira, da Silva & Soule 2017).

Thanks to its anonymity, it allows each expert to contribute freely with his or her judgment. This method involves two rounds with their respective comments. Experts have access to the statistical results of the first round, to continue the process with the questions of the second round; gradually reaching a consensus (National Chengchi University, 2010 cited by Huang & Lee, 2016; Chen & Lv, 2013). It is based on structured surveys, where experts are determined according to the area of knowledge to be investigated, its primary objective is to reach a reliable consensus, as determined by (Okoli & Pawlowski, 2004 and Kulhs,2004 cited by Eller & Naveiro, 2016). Delphi is usually defined as a method that focuses on a consensus with experts on a given topic (Turoff, 1970 cited by Gnatzy et al 2011), the process follows a few steps of communication and anonymity in several stages or survey rounds (Gnatzy et al 2011).

The Delphi es method is perhaps the best-known prospective research method currently in use (Woudenberg, 1991 cited by Celiktas & Kocar, 2010a). Recent studies on the method express that the advance of Delphi-based research proposes criteria such as reliability, validity, and trustworthiness in the evaluation of the trial (Hasson & Keeney, 2011 cited by Nazarko et al, 2015).

What is an Emerging Technology?

Emerging technologies are science-based innovations with the potential to create a new industry or transform an existing one, which includes radical technologies arising from new technologies or incremental technologies arising from the convergence of existing technologies (Day & Schoemaker, 2000), the term commonly refers to technologies that are currently being developed, or are expected to become available within the next five to ten years, and is generally reserved for technologies that are creating, or are expected to create, significant social or economic effects (Winston & Strawn LLP, 2019).

According to (Rotolo, Hicks & Martin, 2015), emerging technology is a technology whose exploitation will produce benefits for a wide range of sectors of the economy and/or society, that shows high potential but has not demonstrated its value nor been established in any type of consensus. The characteristics met by an emerging technology are a radical novelty, relatively rapid growth, coherence, prominent impact, and uncertainty, and ambiguity. However, in the articles analyzed none of them explains or applies the criteria with which they chose these technologies for future studies (Rotolo, Hicks & Martin, 2015 p. 1828).
The characteristics of emerging technologies are uncertainty, network effect, invisible social and ethical concerns, cost, limitation to certain countries and lack of research and investigation (Halaweh, 2013), in turn, for (Small et al. (2014) there is almost universal agreement on two properties associated with emergence: novelty and growth.

According to (Stahl, 2011) defines that..."Emerging technologies are those technologies that have the potential to gain social relevance in the next 10 to 15 years. This means that they are currently at an early stage in their development process. At the same time, they have already moved beyond the purely conceptual stage. Despite this, these emerging technologies are not yet clearly defined. Their exact forms, capabilities, restrictions, and uses are still in the process of change".

The concepts reflected in the definitions of emerging technology can be summarized in four points (1) recent rapid growth; (2) in the process of transition and/or change; (3) market or economic potential not yet fully exploited; (4) increasingly science-based (Cozzens et al, 2010).

METHODOLOGY

The methodology was carried out in 3 phases:

Phase 1.
A review of initial literature on 55 articles in Scopus was carried out using as keywords "Delphi method" and "prospective" on which it was reviewed that were directly related to the search terms, as a result, 50 articles were found in direct relation to the Delphi method, the equation used was TITLE-ABS-KEY ("Delphi Method" and prevision AND NOT scenarios)
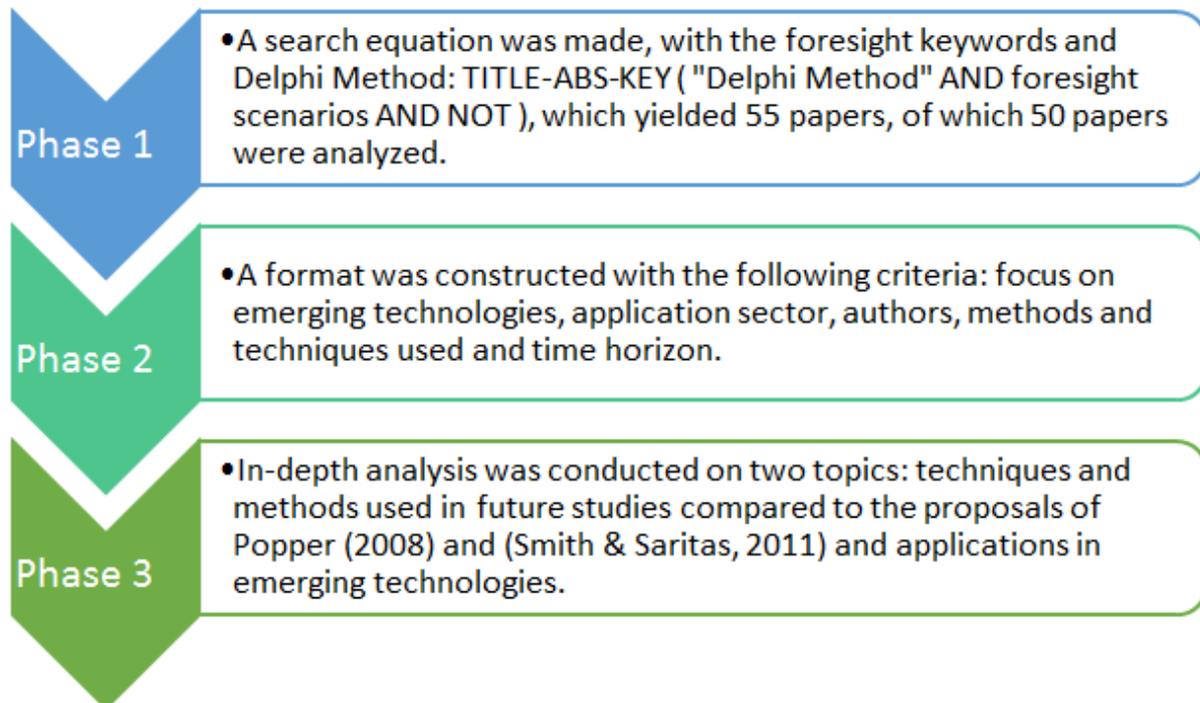
Phase 2.
Once the reading of the 50 articles was done, an in-depth analysis was made on the emerging technologies found in the articles, target of the article, countries, authors, type of Journal, and time horizon, the methods, and techniques used in the articles were also identified.

Phase 3.
In this phase, according to the information found in the articles, an analysis was carried out on two main lines of discussion: techniques and methods used in future studies compared to Popper's (2008) and (Smith & Saritas, 2011) proposals and applications in emerging technologies, especially their relationship with Gartner's proposals (2019) against cycles of over-expectation or hype cycle in emerging information technologies.

Figure 1. Phases of the methodology used

- **Phase 1**
  - A search equation was made, with the foresight keywords and Delphi Method: TITLE-ABS-KEY ("Delphi Method" AND foresight scenarios AND NOT), which yielded 55 papers, of which 50 papers were analyzed.
- **Phase 2**
  - A format was constructed with the following criteria: focus on emerging technologies, application sector, authors, methods and techniques used and time horizon.
- **Phase 3**
  - In-depth analysis was conducted on two topics: techniques and methods used in future studies compared to the proposals of Popper (2008) and (Smith & Saritas, 2011) and applications in emerging technologies.

Source: Prepared by the authors

Results

For a better understanding of the results in terms of the literature review carried out, the findings are divided into two time periods.

Period 1999-2009

In this period 18 articles were found, among which Kuwahara's research stands out, (1999) determined the basic data for establishing science and technology policies in Japan, Cuhls & Blind (2001) presented the second major German foresight study on the global development of science and technology, Tichy (2001) aimed in his article to investigate market niches with Austrian dominance potential in the next 15 years.

Aichholzer (2001) presented novel results and approaches to foresight in a small country like Austria, (Cuhls, 2001) conducted a prospective study for the fax machine as an example of success, and the earthquake warning as a failure and the question arises as to why, despite this mixed picture, vision with the Delphi method is considered useful in Japan. For (Eto, 2003) evaluating technology foresight and forecasting methods concerning user decision systems for science and technology (S&T).

As for Andersen et al (2003), they carried out a technology foresight study on sensor technology to improve the strategic perspective of sensor technology, (Tichy, 2004) discusses whether foresight exercises should be based on assessments by the best experts or a broader base of less specialized experts and whether self-assessment by experts is an acceptable method. Also (Gordon & Pease, 2006) they propose the development of a new approach to conducting a Delphi study that does not involve the use of sequential rounds called Real-Time Delphi.

Authors such as Yuan, Hsieh & Wang, (2006) explored the possible future business environment, industrial structure, technological transformation, and market for the semiconductor industry in Taiwan in 2015. In turn, Kobayashi et al (2006) focused on the methodology for establishing I+D themes. To strengthen the development power of research in software-related sectors and thus promote I+D strategies more effectively. On the other hand, Kukushkina (2007) describes best practices in the use of Delphi surveys in foresight activities, Bañuls & Salmeron (2008) propose a forecasting model to detect key areas in the information technology (IT) industry.

Kanama, Kondo & Yokoo (2008) examined the integration of the Delphi method with the technology roadmap as a new technology foresight system, Karvonen et al (2008) conducted a study to determine the transformation dynamics of the pulp and paper industry, In turn, Keenan & Popper (2008) propose in their article to explore the nature and degree of variation in the 'style' of prospective in six regions of the world.

Hilbert, Miles & Othmer (2009) aimed to show how international foresight exercises, through online and offline tools, additionally, Gheorghiu et al (2009) present a study that aimed to describe the relationship between the community-oriented web (web 2.0) and the emergence of future-oriented communities.

During this period, specific studies on emerging technologies were provided by Cuhls & Blind, 2001; Cuhls, 2001; Andersen et al., 2003; Yuan, Hsieh & Wang, 2006; Banuls & Salmeron, 2008 and Karvonen et al, 2008, which conducted Delphi rounds on 94 technologies.

Period 2010-2019

In this period 32 articles were found, among which the research of Celiktas & Kocar (2010) stands out. This study aimed to explore how the future of hydrogen technology developments in Turkey, these same authors in 2010 evaluated the future of renewable energy in Turkey to

determine and measure the expectations of the sector's representatives concerning renewable energy prospects Celiktas & Kocar (2010). In turn, Li & Chen (2010) proposed China's first national technology roadmap, developed by the Ministry of Science and Technology in 2007. For (Yoda, 2011) the purpose of the study was to examine how domain experts see themselves, in the practice of foresight in general, and to perceive their overall impact on policy-making in particular, in the context of the Japanese foresight conducted over the last 15 years, Smith & Saritas (2011) aimed to produce a manual that can be easily reproduced in a suitable and portable format for managers to consult at project meetings and in turn work to design foresight processes and select methods. In turn, Gnatzy et al (2011) introduced a new and innovative real-time Delphi technique to address previously identified weaknesses of the conventional Delphi method.

For (Auvinen, Tuominen & Ahlqvist, 2012) they propose the introduction of a process to build long-term visions of the transport system in Finland, Lee & Chuang (2012) aimed to investigate the cognition patterns of officials and stakeholders towards prospective solar energy industry policies in the future of Taiwan, Xue & Guo (2012) built an index system for technology forecasting of the new energy industry, technology fields and tasks of the new energy industry in the next five years, the authors (Chen & Lv, 2013) researched the manufacturing technology of the furniture industry in China in the future of 5 to 20 years. (Hsieh, 2013) presents a hybrid method for assessing the value of patents and determining the strategy in the initial phase of commercialization, Mankoff, Rode & Faste (2013) intended to systematically address future thinking, critically examine multiple future potentials and address both negative and positive future forecasts in the field of interactive computing and technology research in general and discuss their relationship of human interaction with the computer, Wysokińska et al (2013) aimed at identifying the directions of scientific research and development work in the field of preparing a strategy for the Polish Textile Industry Technology Platform, Ito & Kanama (2013) proposed an integrated design of a technology foresight process aimed at creating a social vision of the aging society in Japan, for (Förster et al, 2014) the purpose of their document was to design a strategy for consumer goods and to present a systematic process whose function would be to support decision-makers in the evaluation of important issues for the future and the development of strategies

Ropuszynska & Weglarz (2014) oriented their study to the planning of the energy strategy aimed at a new regulatory process, Keller & Heiko (2014) sought to identify the importance and influence that information and communication technologies (ICT) can have on foresight studies, and what the limitations would be when implementing them. In turn, Lintonen et al (2014) focused on how to predict the changes generated in Finland by drug use by 2020, Nazarko et al (2014) present a study to identify directions, materials development, and technologies for use in road construction in Poland.

Gomez, Camarero & Gonzalez (2015) carried out a prospective study to determine the factors related to supply and demand and external factors in the growth of container ships over the next 20 years, Prokesch et al (2015) present an electronic combination of a forecasting market and the Delphi methodology, in turn, Eller & Naveiro (2016) showed a Delphi study in the textile sector in Brazil, Huang & Lee (2016) conducted a prospective study in Taiwan, using the Delphi method, intending to identify the most urgent problems related to soil and

water conservation and sustainable development of water resources. Yesbolova et al, (2016) suggest institutional measures that would improve the development and competitiveness of the poultry industry in Kazakhstan.

For, Ibiyemi, Adnan & Daud (2016) the aim of the study was to accumulate knowledge for the collateral exploration of the classical Delphi survey method to assess the correction factor related to industrial sustainability, using a real field study in Nigeria, Sheydaee, Talebpour & Rezaeian (2017) talk about the application of the Delphi method, to identify the state of Iran in the knowledge life cycle and the impact of the technology in the area of IT applications, Santos, Araújo & Correia (2017) propose a technology foresight methodology based on the development of a complementary approach to the Delphi method that allows the identification of strategic technological competencies, Pereira, Da Silva & Soule (2018) present a prospective study on business model innovation, technological adaptation, and redesigned electricity market policy alternatives, these same authors in 2017 addressed in their research, the uncertainty observed through a prospective study in which 57 policy alternatives were evaluated in terms of business model innovation, technological adaptation, and market design problems (Pereira, Da Silva & Soule, 2017). Finally, Mateos & Peiró (2019) who focused on art galleries, which are the most influential intermediaries in the contemporary art market in Spain.

During this period, specific studies on emerging technologies were provided by Liz & Chen, 2010; Kanama, 2013; Keller & Heiko, 2014; Wysokińska et al, 2013; Eller & Naveiro, 2016; Santos, Araújo & Correia, 2017 and Pereira, Pereira Da Silva & Soule, 2018 which conducted Delphi rounds on 59 technologies.

Table 1: Emerging technologies identified in the period 1999-2019.

Emerging technologies	Author	Sector	Time horizon
Intelligent networks	Pereira, Pereira Da Silva & Soule, 2018	Electric	2050
Machine design	Santos, Araújo & Correia, 2017	Metallurgical	2036
Sensing			
Robotics			
Mechatronics			
Process automation and integration			
ICT			
Materials			
Optics and photonics			
Industrial electronics			
Smart textiles	Eller & Naveiro, 2016	Textile - Nanotechnology	Next 15 years
Technological textiles or functional textiles (within a framework that incorporates monitoring, information processing devices that make it possible for the textiles to react to environmental conditions or stimuli)			
Nanotechnology and its use in natural fiber enrichment processes to give them multifunctional properties, vast fiber modification technology with plasma	Wysokińska et al, 2013		2020

Access to experts			
Financial Access			
Prospective access			
Access to information			
Enabling collaboration			
Social networking			
Online interaction			
Wisdom of the Crowds			
Process Automation			
Cost efficiency	Keller & Heiko, 2014		2020
Real-Time Effects			
Process optimization			
Data Cross-Reference			
Managing complexity			
Global Perspectives			
New IC technologies			
Data mining			
Semantic analysis			
Detecting weak signals			
Technology that allows objects to recognize natural presence, nature, and condition so that they can automatically avoid dangerous situations and work in a coordinated manner		TIC/ NANO	
Micro-communication chip or sensor that can execute semi-permanent or disappearing objects, organize the definition and information of each assigned ID, and automatically delete obsolete data.			
A medical chip that can be embedded in the human body and function semi-permanently with bioenergy sources such as body heat or blood flows			
Nanochips and microsensors that have external control and communication capabilities and can be integrated into the human body or move through blood vessels.	Kanama, 2013		2030
Small single-function (small-scale function) robots that cooperate and share tasks to achieve more complex functionality			
Solar Celis			
Hydrogen storage			
Environmental catalysts			
Fuel cell anode / cathode			
Targeted drug administration			
Bone growth promoters			
Sunscreens			
Bio-labelling and detection			
Chemical sensors			
Structural/physical improvement of			

polymers/compounds			
Optoelectronic devices			
Electronic circuits			
Improved efficiency in H2 generation			
Manufacturing technology and process, nano microelectronic integrated systems test equipment	Liz & Chen, 2010		to 6 years
Human-computer interaction technology			
Network Operating System			
High-performance computer technology			
Security chip			
Wireless security technology			
The national information security system			
The technical information network system of the next generation national unit			
New generation mobile communication technology			
Pulp and paper about ICTs	Karvonen et al, 2008		x
IT infrastructure (data storage, server scalability, nanotechnology, ASP servers, microcomputer technologies, BackOffice technologies, operating systems, I/O peripherals, NetPC)	Bañuls & Salmeron, 2008	Information Technology	to 2 years
Strategic and tactical (Data mining, data warehouse/data marts, EIS / DSS, global information systems, GIS, expert system, GDSS, OLAP / MOLAP / ROLAP)			
Operational (ERP industry solutions, collaborative ERP, ERP downsizing, office intelligence, database technologies, office automation, artificial intelligence, speech recognition, data compression, CAD/CAM)			
Internet and networks (Extranets, Internet communications, tools, VPN, search engines, WAN technologies, teleworking, groupware, web technologies, LAN technologies, data communications protocols, browser suites, switching)			
Business: (security and EPS, B2B applications, CRM, data transmission standards, e-Marketplace, e - Benchmarking technologies, e-Procurement & SCM, m-Commerce, Advertising and Marketing in e-Business, B2C, C2C, C2C), G2C applications)			

Interconnected copper process	Yuan, Hsieh & Wang, 2006		2015
PROCESO NANO < 0.1 micras			
"High -k" (High kappa) materials of high dielectric constant k			
CMOS (metal oxide semiconductor)			
Physical Sensors Electromagnetic: (Gamma radiation, Optical. Microwave, radio waves, current) Mechanical: Sound (infra- to ultra). MEMS. Fluid. Electrical: Electrostatic Chemicals: Affinity (molecular recognition), Catalytic reactions, Electrochemistry Biochemistry. Nuclear: Nuclear magnetic resonance. Systemic issues: Materials technology Fluid physics. Information processing (signal and data) Packing. Production technology (production of sensors). Interfaces (e.g. between sensors and objects) Integration. Value chain.	Andersen et al, 2003		2015
Satellite technologies	Cuhls, 2001		2016
Electronic currency as a payment method in multimedia networks.			
Satellite supported traffic control			

Source: Prepared by the authors

Discussion

New methods and techniques used in Delphi studies

Comparing the traditional methods of Popper (2008) and (Smith & Saritas, 2011), new methods for prospective studies were found which are shown in the following table:

Table 2: Methods used in future studies

Methods used in future studies			
	Popper, 2008	Smith & Saritas, 2011	Other authors
Common methods	Literature Review	Literature Review	Literature Review (Pereira, Da silva & Soule, 2018)
	Panel of experts	Panel of experts	Panel of experts (Santos, Araujo & Correia, 2017; Nazarko et al.,2014; Kobayashi et al., 2006; Gordon & Pease, 2006; Andersen et al., 2003)
	Interviews	Interviews	Interviews Lee & Chuang (2012)
	Roadmapping	Roadmapping	Roadmapping (Huang & Lee, 2016; Kanama, 2013; Li & Chen, 2010; Kanama, Kondo, Yokoo, 2008)
	Scenario Workshop	Scenario Planning	Scenarios (Bañuls & Salmeron, 2008; Yuan, Hsieh & Wang, 2006)

SWOT	SWOT analysis	SWOT analysis Yuan, Hsieh & Wang, (2006)
Conference / Workshop	Panel Workshops	Panel Workshops, Stimulating Workshops, Future Workshops (Ropuszynska & Weglarz, 2014; Wysokinska et al., 2013; Mankoff, Rode & Faste, 2013; Andersen et al., 2003; Cuhls & Blind, 2001)
questionnaire	questionnaire	Delphi survey/questionnaire (Santos et al., 2017; Sheydaee et al., 2017; Ibiyemi et al., 2016; Eller & Naveiro, 2016; Gomez et al., 2015; Nazarko et al., 2014; Forster et al., 2014; Ito & Kanama, 2013; Wysokinska et al., 2013; Kanama, 2013; Xue & Guo, 2012; Yoda, 2011; Celiktas & Kocar, 2010; Karvonen et al., 2008; Gordon & Pease, 2006; Andersen et al., 2003)
Indicators / TSA	Trend indicators	Forecast indicators Xue & Guo (2012)
Relevance Tree / Logical Chart	Tree of relevance	Relevance Index Eto (2003)
Multi-criteria analysis	Multi-criteria analysis	Multi-criteria analysis Bañuls & Salmeron (2008)
Scanning	Scanning	Scanning the environment Andersen et al (2003)
Modeling	Agent-based modeling	Modeling and simulation Tichy (2001)
Bibliometrics, Simulation Games, WILD CARDS.	Bibliometrics / Crowd Sourcing, Games, Jokers / Weak signals	Bibliometrics (Gnatzy et al., 2011; Celiktas & Kocar, 2010)
Backcasting	Backcasting	Essays Mankoff et al (2013)
Testing/Strategic Planning	Strategic Planning	Multi-factor analysis Yesbolova et al (2016)
Key Technologies / Critical	Risk analysis	Key technologies (Chen & Lv, 2013; Li & Chen, 2010)
Patent analysis	Logical letters	Trend Extrapolation Eto (2003)
Extrapolation	Emergency lane technology	Technology Roadmapping Liz & Chen, 2010
Stakeholder analysis	System mapping	Stakeholder analysis Pereira, Da silva & Soule (2018)
creative meeting	Dynamic simulation of variables	Creative meeting Nazarko et al., 2014
Others	Others: Science Fiction, Genius Forecasting, Role Playing / Acting, Citizens Panel, Morphological Analysis, Voting / Polling, Quantitative / Scenario / Smic, Cross Impact / Structural Analysis, Benchmarking, PESTE	Others: Network Analysis	Others: PEST analysis Auvinen, Tuominen & Ahlqvist (2012)
Other authors - NEW METHODS		

Delphi	Policy	-	Policy Delphi
(Hilbert, Miles &Othmer, 2009; Wysokińska et al, 2013; Ropuszynska & Weglarz, 2014; Pereira, Da silva & Soule, 2018)			
Online			survey
(Hilbert, Miles &Othmer, 2009; Celiktas & Kocar, 2010)			
QFD	matrix		modified
Santos, Araujo & Correia (2017)			
Cross-relationship			analysis
Santos, Araujo & Correia (2017)			
Forecast	of	technological	achievement
Sheydaee, Talebpour & Rezaeian (2017)			
Degree	of	expertise/importance and	time
Sheydaee, Talebpour & Rezaeian (2017)			
Ranking	of	technology-related	events
Santos, Araujo & Correia (2017)			
Analysis	of technological	and strategic	competencies
Santos, Araujo & Correia (2017)			
Fuzzy			
Hsieh, 2013			
Technology	Portfolio	Planning	(TPP)
Hsieh, 2013			
Focus			groups
Mankoff, Rode & Faste (2013)			
Factorial			design
Lee & Chuang (2012)			
Q-Method			
Lee & Chuang (2012)			
Delphi	Platform		2.0
Gheorghiu et al (2009)			
Group	communication		techniques
Bañuls & Salmeron (2008)			
Hierarchy	analysis	analytical	(AHP)
Bañuls & Salmeron (2008)			
Delphi			Decision
Tichy (2001)			
Real-time			Delphi
(Gary, 2012; Gnazy et al., 2011; Celiktas & Kocar, 2010; Gordo & Pease, 2006)			
Futures			table
Auvinen, Tuominen & Ahlqvist (2012)			
Managing	the		transition
Auvinen, Tuominen & Ahlqvist (2012)			
Regression			analysis
Gnazy et al (2011)			
Feedback	effect		analysis
Gnazy et al (2011)			
Mann-Whitney			Test
Gnazy et al (2011)			
Delphi	Argument		(AD)
Karvonen et al (2008)			
Real-time	Web	tool for	Delphi
Gordon & Pease (2006)			
Technology			maps
Andersen et al (2003)			

(left vertical label: New methods)

Source: Prepared by the authors

According to table 2, 14 common methods were found, while within the 26 new methods not described by (Smith & Saritas, 2011), and (Popper, 2008) are highlighted:

Policy Delphi, is part of the Delphi technique group, in which expert knowledge on a topic of interest is systematically collected through iterative surveys combined with processes to provide structured feedback to participants, the knowledge collected being used to discern assessments based on the forecast, which increases the accuracy of forecasts on complex issues, was developed specifically to assess policy issues, which are defined as issues where different resolutions are advocated, or for which guidance is sought (Hilbert, Miles &Othmer, 2009; Wysokińska et al, 2013; Ropuszynska & Weglarz, 2014; Pereira, Da silva & Soule, 2018), the Q method, is a research method used in psychology and social sciences to study the subjectivity of people or their point of view, has been used in nursing, veterinary medicine, public health, transport, education, mobile communication among other sectors (Lee & Chuang, 2012), on the other hand, we find the futures table which is (a tool to organize the elements of the future and to create images of the future through their grouping) used as an intermediate step to the description of visions and the analysis PESTE (Auvinen, Tuominen & Ahlqvist, 2012), the Delphi 2.0 platform is a new methodology called Delphi 2.0 includes the logic elements of classical Delphi and new categories and estimators, new statements, Arguments (pros or cons) for the realism of the statements and estimators of the relevance of the arguments (Gheorghiu et al, 2009), the technological maps that are a categorization and classification of the technological panorama to make a general vision of the object under analysis and to identify the limits (Andersen et al, 2003), the Delphi Decision is a bottom-up approach, which is based on the participation of the people involved in the development of the relevant technologies (Tichy, 2001).

Delphi in Emerging Technologies and the Hypecycle

One of the points s of view for the analysis of emerging technologies is that of the Hype cycle or cycle of over-expectation which is understood as a tool that allows to know in one or a group of technologies their current and future state, allowing to know the most promising ones at world level, in addition to those that are not known now but that present expectations to continue growing, which provides a graphic representation of the maturity and adoption of technologies and applications, and how they are potentially relevant to solving real business problems and seizing new opportunities (Gartner, 2019), several recent studies have been conducted on this topic especially with applications in Biotech or artificial tissue culture, and flying autonomous vehicles, smart dust, general artificial intelligence, knowledge graphs, neuromorphic hardware, conversational platform, self-healing system technology, volume screen, artificial intelligence in servers, silicon anode batteries, connected housing, 5G, 4D printing, blockchain for data security, exoskeletons, artificial edge intelligence, autonomous level 5 conduction, quantum computing, deep neural networks, intelligent robots, autonomous mobile robots, brain-computer interface, intelligent workspace, biochips, digital twins, deep neural networks (deep learning), carbon nanotubes, IoT platform, virtual assistants, blockchain, autonomous driving level 4 and mixed reality (34 in total according to Gartner 2018 report), according to Gartner and IT trends for 2018 and 2019 are technologies like Autonomous things, augmented analysis, AI-driven development, digital twins, enhanced advantage, immersive technologies, Blockchain, smart spaces, digital ethics and privacy, and

quantum computing (10 in total), however, of the technologies or trends proposed by Gartner were only found in common in the article analyzed in Scopus: artificial intelligence and intelligent robots which were developed by (Bañuls & Salmeron, 2008; Kanama, 2013) in the information technology sector and were only analyzed at 2010 and 2030.

The above shows a great lack of future studies through the Delphi method and its emphasis on emerging technologies. In Gartner's hype cycle proposal, 34 technologies and 10 trends related to information technologies are presented, especially because of the need not only to know the hype cycle with indicators from web tools proposed by Gartner but also to know through consultation with experts - Delphi the absorption hype cycle in specific contexts, regions, and sectors as well as their impacts or effects on employability, technology transfer, absorption capacities in organizations and sectors and public policies.

Conclusions

There are not enough future studies on emerging technologies related to Nano-Bio-Info-Cogno, only 2 of the studies found are related to nanotechnology and 12 of them are related to information technologies, moreover, the studies analyzed did not care to show that the chosen technologies met emergency criteria, In addition to the existence of future studies for time horizons between 2 and 45 years (projected between 2008 and 2050), there were also very few future studies beyond 2050, since only one related to transport had a time horizon of 2100.

New methods and techniques were found in the future studies through the Delphi method, some are more strongly related to indicators or mathematical techniques such as Modified QFD Matrix, Cross Relationship Analysis, Degree of experience/importance and time, Fuzzy, Factorial Design, Analytical Hierarchy Analysis (AHP), Regression Analysis and Mann-Whitney Test, while others are related to Web tools and qualitative methods, among them are Delphi in Policy or Delphi Policy, Technology Performance Forecasting, Technology Event Ranking, Technology, and Strategic Skills Analysis, Focus Groups, Online Surveys, Delphi 2.0 Platform, Real-Time Delphi, Futures Table, Transition Management, Feedback Effect Analysis, Argument Delphi (AD), Web Tool for Real-Time Delphi and Technology Maps.

Within the topics and technologies that were analyzed in the 50 Delphi studies analyzed there are 146 related to information and communication technologies and 7 related to nanotechnology, there were not found future studies on other topics and technologies or the trends considered as emerging by Gartner in its last reports, it would be convenient to have new future studies on the generation of innovations in these trends, the time predicted of absorption and adoption strategies in specific companies and sectors, that allows them to anticipate the decision making.

The technology is in continuous transformation, where proposals are constantly emerging, some innovative, disruptive and others difficult to conceive, where only those that reach maturity are preserved, the Hype Cycle or cycles of over-expectation provides a graphic representation of maturity and adoption of technologies and applications, which have the relevant potential to solve institutional problems and allow glimpses of the exploitation of

new opportunities, this methodology offers a vision of how a technology or application will evolve (CIAT, 2017).

It is suggested in new future studies on emerging technologies to make a previous analysis on the fulfillment of criteria on emergency, besides, not only to prioritize technologies with Likert scale but to include other aspects in the Delphi rounds such as the probability of occurrence, employability, degree of absorption, the desirability of occurrence,

REFERENCES

Aichholzer, G. (2001). The Austrian foresight program: organization and expert profile. International Journal of Technology Management, 21(7-8), 739-755.

Andersen, P., Jørgensen, B., Lading, L., & Rasmussen, B. (2004). Sensor foresight—technology and market. Technovation, 24(4), 311-320.

Auvinen, H., Tuominen, A., & Ahlqvist, T. (2012). Towards long-term foresight for transport: Envisioning the Finnish transport system in 2100. Foresight, 14(3), 191-206.

Banuls, V. A., & Salmeron, J. L. (2008). Foresighting key areas in the information technology industry. Technovation, 28(3), 103-111.

Builes, C., Manrique, J. (2000). Research priorities in mechanical engineering: a prospective study in Antioquia - Medellín, 2000. Master's degree work. Medellín: Pontifical Bolivarian University. School of Engineering. Faculty of Mechanical Engineering, 2000, p 56

Celiktas, M. S., & Kocar, G. (2010a). Hydrogen is not a utopia for Turkey. international journal of hydrogen energy, 35(1), 9-18.

Celiktas, M. S., & Kocar, G. (2010b). From potential forecast to the foresight of Turkey's renewable energy with Delphi approach. Energy, 35(5), 1973-1980.

Chen, M., & Lv, J. H. (2013). Research on Advanced Manufacturing Technology Foresight of the Chinese Furniture Industry. In InformaTIC and Management Science I (pp. 243-249). Springer, London.

Cozzens, S., Gatchair, S., Kang, J., Kim, K. S., Lee, H. J., Ordóñez, G., & Porter, A. (2010). Emerging technologies: quantitative identification and measurement. Technology Analysis & Strategic Management, 22(3), 361-376.

Cuhls, K. (2001). Foresight with Delphi surveys in Japan. Technology Analysis & Strategic Management, 13(4), 555-569.

Cuhls, K., & Blind, K. (2001). Foresight in Germany: the example of the Delphi'98 or: how can the future be shaped? International Journal of Technology Management, 21(7-8), 767-780.

Day, George S., & Schoemaker, Paul J. H. (2000). Wharton on managing emerging technologies. New York, NY: John Wiley and Sons, Inc

Eller C; Naveiro R.M. (2016). Technological trends in the functional textiles sector. International Association for Management of Technology.

Eto, H. (2003). The suitability of technology forecasting/foresight methods for decision systems and strategy: A Japanese view. Technological Forecasting and Social Change, 70(3), 231-249.

Figueroa, G. A., Montilla, M. A. C., & Melo, R. M. (2012). DELPHI method: applications and possibilities in the prospective management of research and development Venezuelan Magazine of Situation Analysis, 18(1), 41-52.

Förster, B., Keller, J., A. von der Gracht, H., & Darkow, I. L. (2014). Delphi-based strategic issue management: crafting consumer goods supply chain strategy. International Journal of Physical Distribution & LogisTIC Management, 44(5), 373-391.

Gartner, Inc. (2019). Gartner Top 10 Strategic Technology Trends for 2019. Recovered from https://www.gartner.com/smarterwithgartner/gartner-top-10-strategic-technology-trends-for-2019/

Gary, J. E. (2012). Outlook 2020: Results from a Real-Time Delphi Survey of Global Pentecostal Leaders. Pneuma, 34(3), 383-414.

Gheorghiu, R., Curaj, A., Paunica, M., & Holeab, C. (2009). Web 2.0 and the emergence of future-oriented communities. Economic Computation and Economic CyberneTIC Studies and Research, 43(2), 117-127.

Gnatzy, T., Warth, J., von der Gracht, H., & Darkow, I. L. (2011). Validating an innovative real-time Delphi approach-A methodological comparison between real-time and conventional Delphi studies. Technological Forecasting and Social Change, 78(9), 1681-1694.

Godet, M., & Durance, P. (2007). Strategic Foresight: problems and methods. LIPSOR Notebooks, 104.

Gomez Paz, M. A., Camarero Orive, A., & González Cancelas, N. (2015). Use of the Delphi method to determine the constraints that affect the future size of large container ships. Maritime Policy & Management, 42(3), 263-277.

Gordon, T., & Pease, A. (2006). RT Delphi: An efficient, "round-less" almost real-time Delphi method. Technological Forecasting and Social Change, 73(4), 321-333.

Halaweh, M. (2013). Emerging Technology: What is it? Journal of technology management & innovation, 8(3):19–20.

Hilbert, M., Miles, I., & Othmer, J. (2009). Foresight tools for participative policy-making in inter-governmental processes in developing countries: Lessons learned from the ELAC Policy Priorities Delphi. Technological Forecasting and Social Change, 76(7), 880-896.

Hsieh, C. H. (2013). Patent value assessment and commercialization strategy. Technological Forecasting and Social Change, 80(2), 307-319.

Huang, W. C., & Lee, Y. Y. (2016). Strategic Planning for Land Use under Extreme Climate Changes: A Case Study in Taiwan. Sustainability, 8(1), 53.

Ibiyemi, A. O., Adnan, Y. M., & Daud, M. N. (2016). The validity of the classical Delphi applications for assessing the industrial sustainability-correction factor: an example study. foresight, 18(6), 603-624.

Ito, Y., & Kanama, D. (2013). Development of an integrated foresight process oriented toward social vision creation on an aging society in Japan. International Journal of Foresight and Innovation Policy, 9(2-3-4), 235-252.

Kanama, D. (2013). Development of technology foresight: integration of technology road mapping and the Delphi method. In Technology Road-mapping for Strategy and Innovation (pp. 151-171). Springer, Berlin, Heidelberg.

Kanama, D., Kondo, A., & Yokoo, Y. (2008). Development of technology foresight: integration of technology road mapping and the Delphi method. International Journal of Technology Intelligence and Planning, 4(2), 184-200.

Karvonen, M., Kytola, O., Kassi, T., & Mustonen, T. (2008). New perspectives on industry transformation through the expansion of the technology base and creative cooperation. In Engineering Management Conference, 2008. IEMC Europe 2008. IEEE International (pp. 1-5). IEEE.

Keenan, M., & Popper, R. (2008). Comparing foresight "style" in six world regions. foresight, 10(6), 16-38.

Keller, J., & Heiko, A. (2014). The influence of information and communication technology (ICT) on future foresight processes—Results from a Delphi survey. Technological Forecasting and Social Change, 85, 81-92.

Kobayashi, S. I., Kumeno, F., Shirai, Y., Sano, S. Y., Nishiyama, S., Asai, N., ... & Inujima, H. (2006, January). A methodology for planning R&D topics in the IT field. In Proceedings of the 39th Annual Hawaii International Conference on System Sciences (HICSS'06) (Vol. 2, pp. 45c-45c). IEEE.

Kukushkina S. (2007). Delphi method in foresight exercises. Foresight.

Kuwahara, T. (1999). Technology forecasting activities in Japan. Technological Forecasting and Social Change, 60(1), 5-14.

Lee, T. L., & Chuang, M. C. (2012, July). Foresight for public policy of the solar energy industry in Taiwan: An application of Delphi method and Q methodology. In Technology Management for Emerging Technologies (PICMET), 2012 Proceedings of PICMET'12: (pp. 60-67). IEEE.

Li, Z., & Chen, J. (2010). National technology road mapping of China: practices and implications. Journal of Science and Technology Policy in China, 1(1), 50-63.

Lintonen, T., Konu, A., Rönkä, S., & Kotovirta, E. (2014). Drugs foresight 2020: a Delphi expert panel study. Substance abuse treatment, prevention, and policy, 9(1),18.

Mankoff, J., Rode, J. A., & Faste, H. (2013, April). Looking past yesterday's tomorrow: using futures studies methods to extend the research horizon. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (pp. 1629-1638). ACM.

Mateos, R. A., & Peiró, T. N. (2019). Sustainable Management of Contemporary Art Galleries: A Delphi Survey for the Spanish Art Market. Sustainability, 11(2), 541.

Nazarko, J., Radziszewski, P., Dębkowska, K., Ejdys, J., Gudanowska, A., Halicka, K., & Nazarko, Ł. (2015). Foresight study of road pavement technologies. Procedia Engineering, 122, 129-136.

Pereira, G. I., da Silva, P. P., & Soule, D. (2017). Policies for an EU smarter grid environment: A Delphi study on DSOs. In the European Energy Market (EEM), 2017 14th International Conference on the (pp. 1-6). IEEE.

Pereira, G. I., Da Silva, P. P., & Soule, D. (2018). Policy-adaptation for a smarter and more sustainable EU electricity distribution industry: a foresight analysis. Environment, Development, and Sustainability, 20(1), 231-267.

Popper, R. (2008). How are foresight methods selected? Foresight, 10(6), pp. 62– 89.

Prokesch, T., Heiko, A., & Wohlenberg, H. (2015). Integrating the prediction market and Delphi methodology into a foresight support system—Insights from an online game. Technological Forecasting and Social Change, 97, 47-64.

Ropuszynska-Surma, E., & Weglarz, M. (2014). Regional energy strategy as a guideline for the novel regulation process. Competition and Regulation in Network Industries, 15(3), 258-283.

Rotolo, D., Hicks, D., Martin, B. (2015). What is an emerging technology? Research Policy. Available in   https://ac.els-cdn.com/S0048733315001031/1-s2.0-S0048733315001031-main.pdf?_tid=97a7149d-a0bd-4007-bb50-566adc5a8894&acdnat=1552400378_dbce57ffdfb46462ab2f5f0621b1ce81

Santos, C., Araújo, M., & Correia, N. (2017). A methodology for the identification of strategic technological competences: An application in the sheet metal equipment industry. Futures, 90, 31-45.

Sheydaee M; Talebpour A, & Rezaeian A. (2017). Information technology research & development foresight in Iran. Iranian Journal of Information Processing Management, 1-23. ISSN 2251-8223.

Small, H., Boyack, K. W., and Klavans, R. (2014). Identifying emerging topics in science and technology. Research Policy, 48(8):1450–1467.

Smith, J. E., & Saritas, O. (2011). Science and technology foresight baker's dozen: a pocket primer of comparative and combined foresight methods. Foresight, 13(2), 79-96.

Stahl, B. C. (2011). What does the future hold? A critical view of emerging information and communication technologies and their social consequences. In Chiasson, M., Henfridsson, O., Karsten, H., and DeGross, J. I., editors, Researching the Future in Information Systems: IFIP WG 8.2 Working Conference, Future IS 2011, Turku, Finland, June 6-8, 2011, Proceedings, pages 59–76. Springer, Heidelberg.

Tichy, G. (2001). The decision Delphi as a tool of technology policy-the Austrian experience. International Journal of Technology Management, 21(7-8), 756-766.

Tichy, G. (2004). The over-optimism among experts in assessment and foresight. Technological Forecasting and Social Change, 71(4), 341-363.

Varela, R. M., Díaz, B. L., & García, D. R. (2012). Description and uses of the Delphi method in health research Medical Education Research, 1(2), 90-95.

Winston & Strawn LLP. (2019). What is the Definition of Emerging Technology? Recovered from de https://www.winston.com/en/legal-glossary/emerging-technology.html

Wysokińska, Z., Koszewska, M., Czajkowski, T., & Malinowska-Olszowy, M. (2013). Future of the Polish Textile Industrial Sector. An Overall Analysis of the Empirical Research Performed with the Delphi Method within the Project Foresight 'Modern Technologies for the Textile Industry. A Chance for Polan. Fibres & Textiles in Eastern Europe.

Xue, W. X., & Guo, R. (2012). An Empirical Study of Energy Industry with Energy Materials and an Indexing System. In Advanced Materials Research (Vol. 578, pp. 12-16). Trans Tech Publications.

Yesbolova, A. Y., Mergenbaeva, A. T., Abdikerimova, G. I., Kydyrova, Z. S., Kunafina, G. T., & Maciejczak, M. (2016). Issues and Prospects of Poultry Industry Development in Kazakhstan. Journal of Advanced Research in Law and Economics, 7(3 (17)), 685-697.

Yoda, T. (2011). Perceptions of domain experts on the impact of foresight on policy-making: The case of Japan. Technological Forecasting and Social Change, 78(3), 431-447.

Yuan, B. J., Chih-Hung Hsieh, J., & Wang, C. (2006). Foresight for the semiconductor industry in Taiwan. Foresight, 8(5),