

Network Analysis as a tool for ^{historians}¹

Network Analysis as a tool for historians

Montserrat CACHERO VINUESA
Universidad Pablo de Olavide
mcacvin@upo.es
<http://orcid.org/0000-0002-9830-930X>

Natalia MAILLARD ALVAREZ
Pablo de Olavide University
nmaialv@upo.es <http://orcid.org/0000-0001-7084-7563>

Date of receipt: 12/23/2020 Date
of acceptance: 04/11/2021

SUMMARY

In recent decades, references to Network Analysis have gained prominence among historians. We have witnessed a veritable proliferation of articles, monographs and research projects in which the study of interconnections in past societies occupies a central role. Unfortunately, in some of these works conceptualization and quantification have been absent. This paper aims to explore the potential of Network Analysis as a methodological tool applicable to the historical discipline in its various fields of research. We intend to make a clear commitment to the integration of this tool, overcoming the rhetoric of words, but also of the image. To this end, we incorporate an overview of the main contributions to Network Analysis in historiography. In addition, we analyze its fundamental elements and describe its use with examples of recent publications, exploring the challenges for the future.

Keywords: network analysis, methodology, methodology, metrics, visualization

Place names: Latin America, Europe

Period: Neolithic - 20th Century

1 This work has been carried out in part thanks to the projects "Las redes internacionales del comercio de libros en la Monarquía Hispánica. 1501-1648" (HAR2017-82362-P), an R&D&I project funded by the Government of Spain, and *La revolución de los precios y el negocio del crédito en Sevilla ¿Una burbuja del siglo XVI?* (UPO-1261964), funded by the European Union (FEDER Funds) and the Junta de Andalucía.

ABSTRACT

During recent decades, historians have referred with increasing frequency to network analysis. We have witnessed a veritable proliferation of papers, monographs and research projects in which the study of interconnections among individuals from past societies plays a central role. Unfortunately, conceptualization and quantifications have been absent from most of these works. This paper aims to explore the potential of network analysis as a methodological tool applied to history. The objective is to integrate this tool into the historian's work, transcending the rhetoric of words and images. To this end, I first present the main contributions of network analysis to historiography, together with a description of its main elements, using examples from recent academic works. The paper also explores the challenges facing future research.

Keywords: network analysis, Methodology, metrics, visualization

Place names: Latin America, Europe

Period: Neolithic- 20th Century

1. INTRODUCTION

Charles Wetherell warned, already in 1998, that Network Analysis had been adopted very late in the historical discipline, as opposed to the general acceptance it enjoyed in Sociology (Wetherell, 1998). In the first two decades of the present century, however, it seems to have become an increasingly common resource among historians, giving rise to specialized projects and publications (Lemercier and Zalc, 2019: 111-144; Kerschabaumer et al, 2020)². In fact, to anyone outside the discipline it might seem that Network Analysis has flooded the most recent historiography, based on the number of titles that employ the term network, going so far as to speak of a *Network Turn* (Ahnert, Ahnert, Coleman and Weingart, 2020). Undoubtedly, the facilities provided by new technologies (not only in the form of computer programs, but also by the increasing availability of archival and bibliographic information online) have contributed to historians losing their fear of using Network Analysis.

However, it soon becomes clear that we are faced with two positions when using the word network: on the one hand, some pioneering works adapt and apply tools from Social Network Analysis (SNA) to the needs of the study of the past; on the other hand, many publications use networks as a simple metaphor (Cachero, 2013; Lemercier, 2015). This duality responds to a lack of definition of the network concept. Although relational language is common among historians, the use of the word network *per se* does not equate to formal Network Analysis. As Graham, Milligan and Weingart state:

The idea that relationships are essential to understanding the world around us is, of course, ancient. The use of formal network methods for historical research, however, is much more recent, with only a few exceptions dating back beyond 30 years³.

2 Among the communities of experts that have contributed most to the dissemination of this type of studies are *Historical Network Research* (<http://historicalnetworkresearch.org/>, where the four published issues of the *Journal of Historical Network Research* can be found. Consultation: 30-03-2021), *The Connected Past Community* (<https://connectedpast.net/>, Consultation: 30-03-2021) and *Réseaux et Histoire* (<https://reshist.hypotheses.org/>, Consultation: 30-03-2021).

3 Graham, Milligan and Weingart, 2016: 180.

The origin of Network Analysis is to be found in mathematical Graph Theory. From this point of view, a network can be defined as a set of elements (nodes) and the links that connect them (arcs). From this abstraction we can represent the network graphically and measure it. With this in mind, we intend to make a clear commitment to the integration of formal Network Analysis among the tools available to historians, overcoming the rhetoric of words, but also of the image. We believe that networks can be more than just empty terminology, but that, at the same time, they should not be limited to visualization, which has sometimes been given too much weight. Undoubtedly, being able to represent the studied network in a graph is one of the most striking possibilities of Network Analysis, but we do not believe that this is its only contribution, but rather a complement to the calculation of metrics and their ^{historical} interpretation⁴.

On the other hand, Network Analysis as a tool makes special sense within the historiographic paradigm defined by José María Imízcoz as "relational analysis" (Imízcoz, 2011: 21-22), although it should be clear that Network Analysis in a formal sense is not, nor does it pretend to be, the only possible tool within this paradigm, which would consist of:

An inductive type of research that starts from the observation of the actions of social actors located in their contexts (of men and women as actors of their history), to find, from their interactions, their effective social configurations, to follow in time the collective dynamics that they build with their actions and, in the end, to explain the processes of change from the agency of the actors (Imízcoz, 2018: 3).

The purpose of these pages is not to apply a methodology to a specific case, nor to justify its use. Our objective is to offer a clear and useful explanation of the main concepts of Network Analysis and its application to History. To this end, this paper will be divided into three sections: the first will provide a general overview of the use of formal Network Analysis in Hispanic historiography; the second section will be devoted to the definition of Network Analysis and its elements; finally, we will describe in detail issues related to quantification and its potential, using recent international research as examples.

2. PANORAMIC

Since the beginning of the twentieth century, the paradigm shift and the application of mathematical Graph Theory to the study of social realities gave rise to ARS, which was fully consolidated as early as the 1970s, first among sociologists, and somewhat later among economists and anthropologists (Molina, 2001: 22-36; Freeman, 2012).

Despite some early attempts (Smith, 1979), it was not until the nineties of the last century that historians began to approach, even timidly, the formal Network Analysis. In the world of Hispanism, some pioneering works (Castellano and Dedieu, 1998), allowed changing the focus of historical analysis. It is precisely the nascent interest in the individual and his agency in history, as opposed to other more structuralist approaches to the past, which has favored the use of Network Analysis in recent decades (Martínez Romera, 2010; Bertrand and Lemerrier, 2011: 10; Rodríguez

⁴ As Graham, Milligan and Weingart (2016: 201) have pointed out, the visualization of networks using graphs, despite their extraordinary value, can generate confusion and be of little use if they are not accompanied by adequate explanations.

Treviño, 2012: 114; Imízcoz, 2017: 2). The proliferation of studies of this type has been favored by the development of digital tools for handling large amounts of data (*big data*).

Since then, the enormous interest that networks have acquired in Spanish and Latin American historiography has been frequently pointed out, particularly to overcome studies of complex realities based on ethnicities, estates or socioeconomic groups (Ponce and Amadori, 2008). Although this does not always entail a formal use of Network Analysis.

If we focus on the formal application of Network Analysis to historical phenomena, we can begin by citing the article by Pascua Echegaray (1993) on the social network of the Compostela archbishop Diego Gelmírez in the 12th century or the thesis by Sánchez Balmaseda (2002), in which the author, after describing the main network measures, uses them to study the patronage relations of the Spanish Court in the transition from the reign of Charles V to that of Philip II. Since then, the use of Network Analysis among historians has increased significantly, which led Martín Romera (2010) to offer an excellent state of the art, especially focused on medieval and modern times. Only a year later Michel Bertrand and Claire Lemercier (2011) again highlighted the growing use of this approach in history in a monograph, this time in the journal *REDES*. In this monograph, they dealt with very different topics, in all cases going beyond the metaphorical use of networks to delve into their practical application.

Precisely, one of the advantages of Network Analysis is that it is a multipurpose tool, which can be applied to any period or historical issue, provided that the appropriate sources are available. These are usually written documents, but can also be archaeological records (Brughmans, Collar and Coward, 2016). Thus, for example, Bernabeu, Lozano and Pardo-Gordó (2017), draw a network in which the nodes are archaeological sites linked by the use of similar ceramic decoration techniques, with the aim of explaining the cultural evolution in the east of the Iberian Peninsula during the Neolithic.

Network Analysis is very useful for studying historical phenomena on a global scale (Shepard, 2018). Perhaps for this reason, a particularly fruitful field is that of works dedicated to trade and business from the 15th century onwards, when mercantile relations began to span the five continents. One of the advantages offered by this tool is the possibility of studying the structure of business without forgetting the agency of its protagonists (Crailsheim, 2020: 85). In the transition from the Middle Ages to the Modern Age, David Carvajal de la Vega (2014) uses various graphs to show the process through which mercantile companies acquired an international character; García de León (2007) has analyzed the circuits created by Portuguese merchants in Veracruz during the 17th century, while Cachero (2011) and Crailsheim (2016) have examined the role of Seville in modern Atlantic trade, highlighting the importance of foreign communities and their international links. Heredia López (2019), meanwhile, has applied network analysis to study the links between officials of institutions such as La Casa de la Contratación and Sevillian merchants.

Vieira Ribeiro's (2011) thesis used Network Analysis to study the mechanisms of cooperation in the case of the great 16th century Castilian merchant Simón Ruiz, whose business extended halfway around the world. The study takes as its basis bills of exchange and correspondence - one of the favorite sources, in fact, for historical network analysts (Imízcoz and Arroyo, 2011 and Imízcoz, 2018) - to, among other things, cast doubt on whether ethnic, religious or national differences were decisive when it came to doing business. Picazo (2015) also studies commercial networks, although in.

In this case, it is a comparative analysis, highlighting the similarities between the Atlantic and the Pacific. Many other studies have stressed the usefulness of the network concept when analyzing trade relations (Böttcher, Hausberger and Ibarra, 2011 and Herrero and Kaps, 2017).

Networks, understood not only as structures, but as "processes of change in time and space," serve Mena and Cachero (2019) to offer a different view of the mining activities of the conquistadors in Panama during the first quarter of the 1500s. In this case, they portray a sparsely populated region with an adverse nature, but with a tremendously dynamic business sector and a high degree of social and geographic mobility, which Network Analysis allows to visualize and measure.

Closer to social history, but also attending to political and economic factors, the works of José María Imízcoz emphasize the interactions between individuals that allow linking the rural world of Navarre with the global dimension of the Hispanic Monarchy in the eighteenth century (Imízcoz, 2018). For his part, Gil Martínez (2015) analyzes the government of the Hispanic Monarchy through the connections between the members of the various Councils and Boards in the time of the Count Duke of Olivares. Studies on intellectual history and cultural history, despite certain reluctance towards quantitative methodologies (Iglesias, 2017), have also been able to take advantage of Network Analysis. The Republic of Letters and the circulation of knowledge offer a very interesting field of study that has not remained unexplored, including in the Spanish-speaking world⁵. In recent years, several authors have used Network Analysis to study the literature of the Golden Age. Brown et al. (2016) collected information from paratexts (book covers and legal texts), in order to better understand the functioning of the modern Spanish publishing industry, corroborating its local character. Recently, Martínez and Ulla (2019) have applied this methodology to the study of Golden Age collaborated comedias (i.e., those written by more than one author at a time). Starting from an already known corpus of this type of works, the authors seek to understand the relative importance of the different writers and the logic with which their collaborations are organized.

At the intersection between cultural and economic history we can also situate some studies on the history of the book, where the purely metaphorical use of networks is beginning to be overcome. In the case, for example, of the analysis of the book trade in the 16th century, Network Analysis helps us to visualize a dynamic market that was by no means compartmentalized, and to see how Seville and Mexico were two important poles of attraction for European companies dedicated to the production and marketing of books (Maillard-Álvarez, in press).

In studies on the contemporary world, the use of networks, whether formal or metaphorical, has also known a remarkable momentum in the last decade, both in Spain and in Latin America. Proof of this is the monograph devoted to the subject by the journal *Ayer* in 2017, where we find a detailed study on the possibilities of formal Network Analysis in Contemporary History (Sarno, 2017). The application of Network Analysis has made it possible to offer more complex explanations. For example, Rubio and Garrués (2017) link the economic backwardness of Andalusia, not only to unfavorable preconditions, but also to the absence of weak ties in its business network, which would act as a brake on the modernization of the region. For his part, Daniel Iglesias (2016) is interested in.

5 Within the *Mapping the Republic of Letters* project is Marcelo Aranda's *An Intellectual Map of Science in the Spanish Empire, 1600-1810*, which includes the visualization of several graphs based on a prosopographical study of Spanish scientists of the 16th and 17th centuries. <http://republicofletters.stanford.edu/casestudies/spanishempire.html> (Accessed: 06-06-2020).

Latin American political-intellectual networks to analyze how internationalization allowed Venezuelan politicians to build a democratic alternative for their country in the first half of the twentieth century.

In short, although there is still some work to be done, we believe that the overview we offer here shows that Network Analysis is sufficiently developed in our academic field to deal with the most diverse problems and periods.

3. NETWORK ANALYSIS APPLIED TO HISTORY

Formal Network Analysis is an extremely useful methodological tool for the study of interactions between different elements in past societies. It allows us to emphasize the measurement, visualization and interpretation of these interactions. It is, as we have pointed out above, a developing field, where there are still limitations and obstacles to overcome, both from the point of view of its practical application, as well as the reluctance of many researchers. There are three fundamental pillars on which, in our opinion, the usefulness of Network Analysis for historians is based:

a) **Interaction:** it allows us to study the selected elements (whether people, objects or ideas) in their interrelationship with others and within the structures in which they develop, at the same time as these are measured and represented graphically. Network Analysis makes it possible to study simultaneously interactions of different character and at different levels, allowing us to compare relationships of a social, economic, political, cultural, affective, etc. nature.

b) **Flexibility:** networks go beyond the limits of class, community and border, both geographically and temporally, giving us a more flexible image of past societies and facilitating a more complete vision of them, since it is not based on predetermined categories (Vieira Ribeiro, 2011: 30). It is important to remember that, to achieve this, the network must emerge from the primary information we work with.

c) **Dynamism:** although formal Network Analysis is often blamed for an alleged inability to express phenomena in diachrony (Martín Romera, 2010: 228), something fundamental in the case of historians, the truth is that network measurements can have a dynamic character, allowing to capture the construction processes and the evolution of the relationships between the elements studied.

Thanks to these characteristics, Network Analysis makes it possible to integrate the macro and micro scales of the past in the same study, taking into account both the history of individuals and that of the collectivity of which they were a part (Imízcoz, 1998: 36). The key lies in adapting the instruments of Network Analysis to the study of past societies, although with the necessary precautions and considerations, especially with regard to the use of historical sources. In this sense, Hinks (2017) warns us of the danger of extrapolating conclusions from incomplete data, highlighting the importance of the evidence of the past with which we work being really significant. The passage of time has been responsible for destroying (or selecting) the information available to the researcher. This does not mean, however, that historical sources are not suitable for formal network analysis. In fact, as Lemercier (2015) highlights, some types of sources, such as notarial or judicial records, are easier to access if they are historical documents. It is true that historical information tends to become scarcer and more inconsistent as we go back in time, although the exceptions are too many to consider that we are dealing with a general rule. For example, in Kerschbaumer, Keyserlingk-Rehbein, Stark, and Düring (2020),

we can find the application of Network Analysis to studies ranging from Antiquity to the Cold War.

3.1. Network components: nodes and arcs

3.1.1. Nodes

We call nodes the elements under analysis and arcs the relationships between them. In the network visualization, the nodes are represented by points and the arcs are the lines that connect them. From this perspective, it can be easily inferred that formal Network Analysis places the emphasis on how the elements under study interact, and not so much on their qualities, although they may be included, as we shall see.

It is therefore essential to specify which are the study elements or nodes and why. The correct definition of the nodes will be essential when deciding which metrics are the most appropriate for each study and to be able to interpret the results. Unlike what happens in other disciplines, historical sources are not usually structured a priori to apply Network Analysis. Sometimes, it will be necessary to take a certain distance from the primary data to facilitate the identification of the elements that will constitute the nodes of the network, using the questions that guide our research. Delimiting the set of elements to be included in the network is not always obvious. Sometimes, it is the sources themselves that delimit the object of analysis. For example, in the case of Vieira Ribeiro (2015), the total number of nodes is defined by the people cited in the preserved correspondence of the merchant Simon Ruiz; individuals linked to him who are not mentioned in these sources are not included in the ^{network}⁶.

On the other hand, when faced with particularly rich sources, the historian may find it necessary to restrict the network to a finite number of nodes. This task is facilitated in the case of ego-centered networks or *ego-networks*, i.e. networks that start from a specific individual and whose nodes represent the people who maintained a link with that individual. When Isabelle Rosè (2011) analyzes the networks woven by Odón de Cluny, the nodes selected are those people with whom the religious maintained relationships of various kinds, documented in primary sources. Although these cases facilitate the analysis because of their clarity, they sometimes prevent us from observing global phenomena or make it difficult to compare trajectories and behaviors.

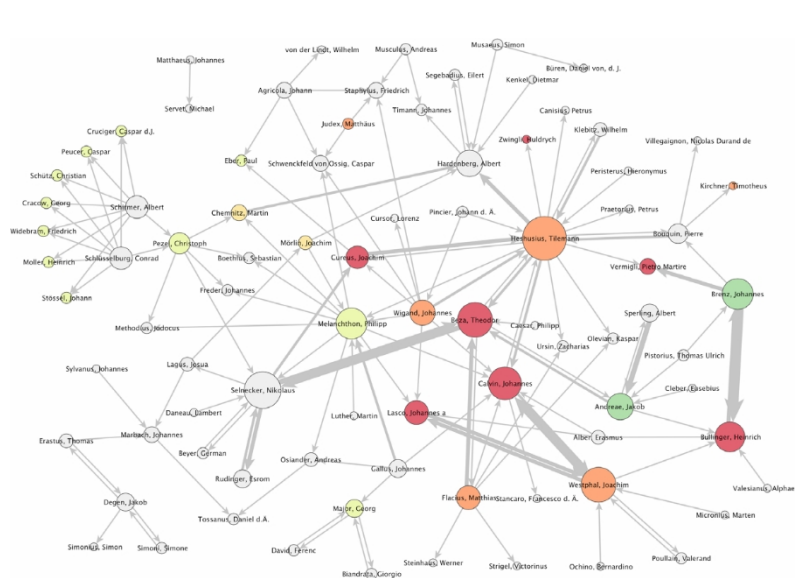
The concept of *ego-network* can be expanded and, instead of an individual, a family or a specific group of people can be studied. This strategy is quite common in the study of commercial networks, when analyzing the commercial trajectory of a given firm or studying the networks woven by the members of institutions such as consulates, chambers of commerce or economic societies (Antonio Ibarra, 2000). In these cases it is necessary to reflect on the level of subjectivity that the researcher introduces into the analysis. If a merchant saga is studied, for example, we would have to start from definitions that clarify fundamental points such as what we understand by family, who we consider to be members and which persons will be excluded? This is an exercise in honesty that is not without its difficulties, but when working with a tool that requires quantification, it is necessary to be very precise in the criteria for selecting the nodes.

6 Similarly, in the aforementioned study on the book market in Seville (Maillard-Alvarez, in press), a sample of notarial documents of a mercantile nature was selected in which printers, booksellers and book merchants were involved, which constitute the nodes of the network. It is possible that there are agents who, despite participating in this market, were not included because they did not appear in the selected contracts.

If, on the other hand, we want to use a more general network because our interest transcends the idea of the individual, we will most likely have to carry out tastings and work with samples. The selection of sources in these cases is often the subject of criticism or debate⁷. Decisions in this regard must be duly justified in the light of historical data or a thorough knowledge of the documentation. Likewise, we must not forget that, when using numerical indicators with samples that are not sufficiently representative, the results will be spurious.

As previously stated, nodes can have their own qualities or characteristics, called attributes, which will allow us to distinguish one from another. Examples of attributes are gender, marital status or religion. To visualize them within the network, attributes are usually represented by combining the shape and color of the nodes. In the following graph, Deicke (2017) distinguishes the agents forming his network according to their religious denomination, represented by colors.

Figure 1. Network with attributes



Source: Deicke, 2017: 99

The definition of attributes must be clear, derive from historical information or from strictly academic criteria, and be sufficiently justified to avoid any arbitrariness. Likewise, the researcher must reflect on the limitations, since the categories are not absolute. In fact, by incorporating a time horizon in the analysis, they may change. Marital status is a clear example: maidens become married and sometimes widowed. This nuanced difference is fundamental if we are studying contracts, since their capacity to contract may be affected by changes in marital status (Dermineur, 2019). To avoid biased conclusions, it is suggested to establish a categorization that, as far as possible, does not change during the study period and that is always correctly defined and delimited.

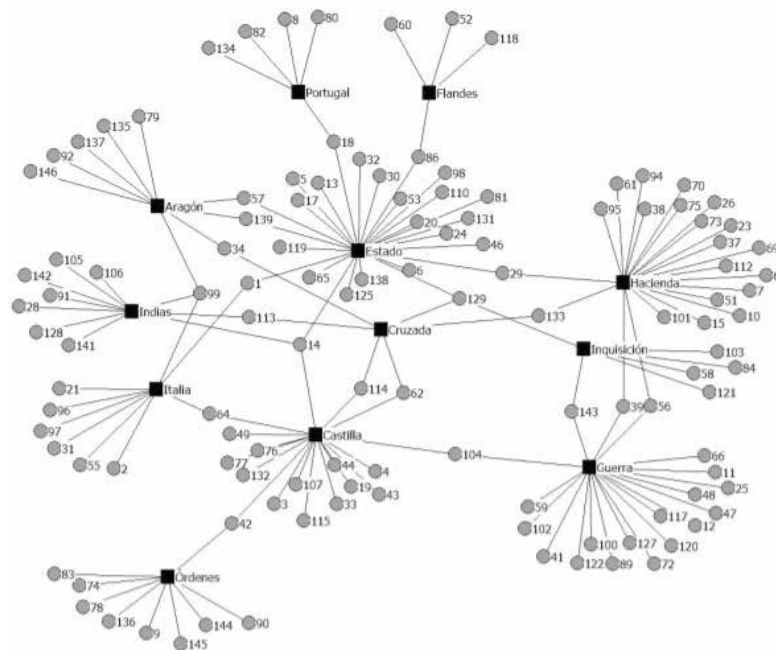
Finally, the use and abuse of attributes should be emphasized. Although defining categories can be useful for establishing comparisons or answering certain questions, their excessive use can make the network analysis inoperative when it comes to drawing conclusions. To avoid complex graphs, the following is recommended

⁷ See for example discussions around Crailsheim (2016) in the review of Lamikiz (2020).

not define more than two attributes (e.g., profession and nationality), with a maximum of four values for each of them.

On the other hand, networks can also be unimodal (a single type of nodes) as shown in the previous image, or bimodal (when the nodes are of different nature), the former being the most frequent in History. The following graph, extracted from Gil Martínez (2015), shows a bimodal network with two types of nodes: councilors and councils to which they belonged.

Figure 2. Bimodal network



Source: Gil Martínez, 2015: 70

Both the graphical representation and the associated calculations and their interpretation are more complex in bimodal networks. We must be careful with this type of networks, which can be more confusing than enlightening when interpreting information from the past. Van Vugt (2017), for example, studies a network of intellectuals, using the readings they shared. Two types of nodes coexist in the network, people and letters. In this case, the bimodal option allows only temporal information to be entered.

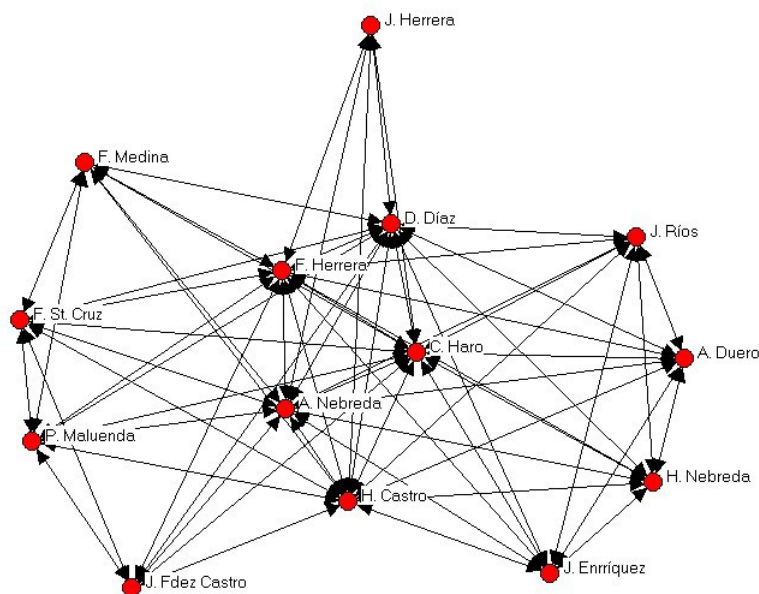
3.1.2. Arcos

Although the nodes represent the object of study, Network Analysis really emphasizes the relationships. The idea is not so much to identify the nodes as to define and measure the interactions between them, and for this purpose the arcs will constitute the structure of the network. Finding such a structure often involves some difficulty since, again, the historical sources reflect complex relationships that overlap, creating a tangle that is difficult to untangle. These complex relationships give rise to what the Anglo-Saxons call *multi-level networks*, that is, networks in which the nodes are related at different levels.

Many of the detractors of network analysis consider that the quantification of relationships in history is very difficult. In a way, this assertion could be valid if the researcher's aim were to measure relationships in the same way as they are measured in other disciplines, where rankings or pre-determined values are often used in a survey. In historical terms, it is possible to infer the existence or not of a link between two agents that are part of a network if objective information from primary sources is available. For example, if two individuals appear jointly signing a contract (Crailsheim, 2016), sharing a privilege granted by the Crown (Cachero and Rodríguez, in press) or participating in a financial transaction (Carvajal de la Vega, 2017). In these cases, we only know the existence or not of a link and, to measure it, binary variables are usually used, i.e., those that only take two values 0 and 1 (1 being success and 0 being failure). In other words, the relationship between two nodes will take the value 1 if there is documentary evidence of it and 0 if not.

Sometimes, however, it may also be of interest to evaluate the strength of a connection between two nodes. In these cases, it is necessary to resort to a numerical indicator to estimate the robustness of the various links. This indicator should come from historical sources instead of resorting to mathematical artifices, as is done in other disciplines. For example, the strength of links has been measured in terms of the frequency in the exchange of information (Ribeiro, 2015) or the number of transactions between two agents (Dermineur, 2019). There are exceptional cases where historical evidence provides a direct measure of link strength. In Cachero (2011) we found a network between merchants where the strength of the relationships between each pair of nodes is measured in terms of the number of years since both agents established contact. This valuable information was found among the interrogatories of the lawsuit followed by the members of the merchant company.

Figure 3. Nebreda's Company Network

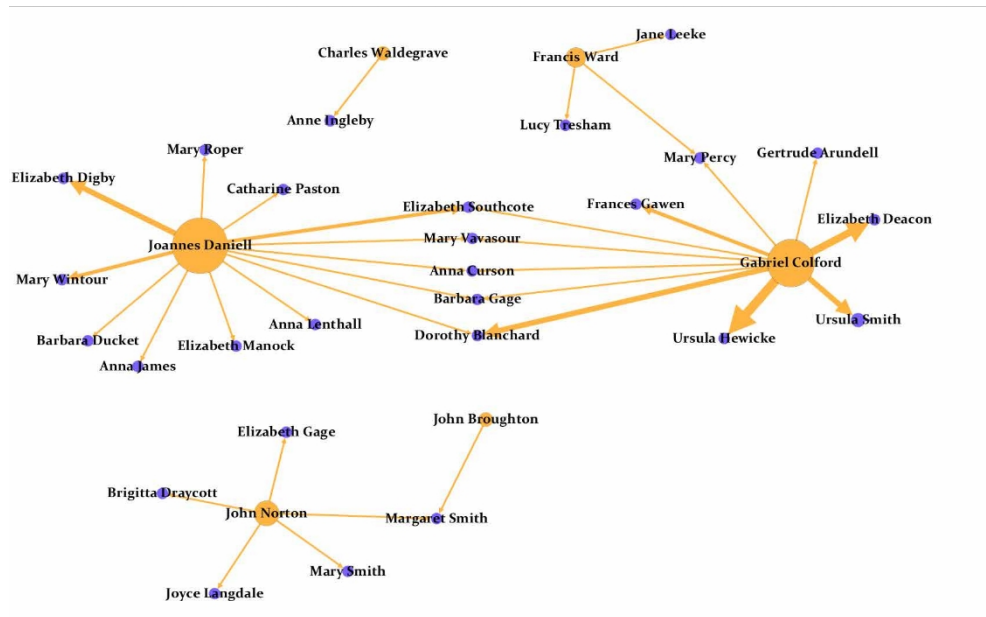


Source: Cachero, 2011: 36

Finally, in the representation of the arcs it is necessary to take into consideration directionality in relationships. Sometimes, the link that is established between two

The flow from one node to another, either of information, goods, ideas or even of an economic nature. If this directionality exists in the relationships, it is represented graphically by arrows. Networks built from epistolary information are a good example. Mc Shane (2018) reconstructs the relationships between English Benedictine sisters in Brussels during the 17th century. In this case, each node represents a sender, a receiver, or both. Capturing directionality in this type of analysis is crucial because we can reconstruct and measure the circulation of information through the network.

Figure 4. Directionality in the network



Source: Mc Shane, 2018: 16

4. APPLYING NETWORK ANALYSIS: METRICS FOR HISTORIANS

What differentiates a solid network analysis from a simple approximation is the calculation of the appropriate metrics and the interpretation of its results in the light of the primary sources. Only in this way can we build robust conclusions, thereby contributing to the advancement of our knowledge of the historical past.

As Molina (2001: 15) points out, calculations associated with Network Analysis traditionally "required knowledge of statistics and at least some knowledge of matrix algebra and graph operations"; however, the same author recognizes that currently available software packages facilitate a wide range of calculations. Nevertheless, the selection of the appropriate metrics for each analysis is not an automatic task and requires some thought. Calculating all the available algorithms and grouping them in a table does not necessarily make the study robust and, in fact, can detract from it, generating confusion. We need to think about which metrics answer the questions posed in each specific investigation. Obviously, this task is impossible if the researcher does not know the meaning of each of these measures. In the following section we will review the main algorithms that can be calculated by the available Network Analysis software, in order to understand their usefulness and interpret them in the corresponding historical context.

There is a whole range of network metrics, but for the sake of simplicity, we could group them into two categories: general, referring to the entire network, and specific to each node. While the

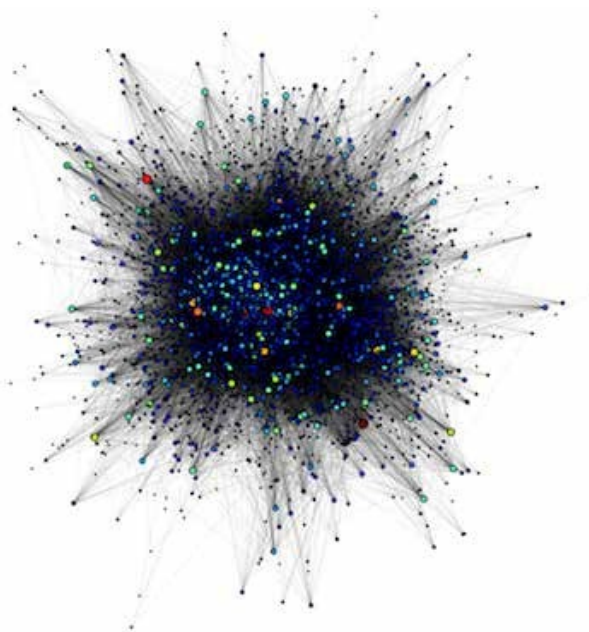
While most of the measures are static, there are dynamic indicators that capture the flows that circulate through the network. These dynamic measures are of great interest to historians and for this reason we dedicate a specific section to them.

4.1. General measures

The general measurements are those that allow observing the network as a whole. They represent a first approximation and are the result of an external study, allowing to observe the network architecture. The most common metrics in this group are the following: Density measures the ratio between the number of actual and potential interactions of each pair of nodes. The more actual interactions, the higher the density. In the software, the density calculation will yield a value between 0 and 1: if it is close to 1 we will have a very dense network and, on the contrary, if the coefficient is close to 0 the network will be simpler. A priori, one might think that the more information we add to the network, the more complete the analysis will be, but studying a network with a high number of nodes and density close to 1 can be very complex. At the graphical level, we would be faced with a tangle of intricate relationships that are difficult to interpret, known as *Spaghetti Monster*.

and is reflected in the following network.

Figure 5. *Spaghetti Monster*

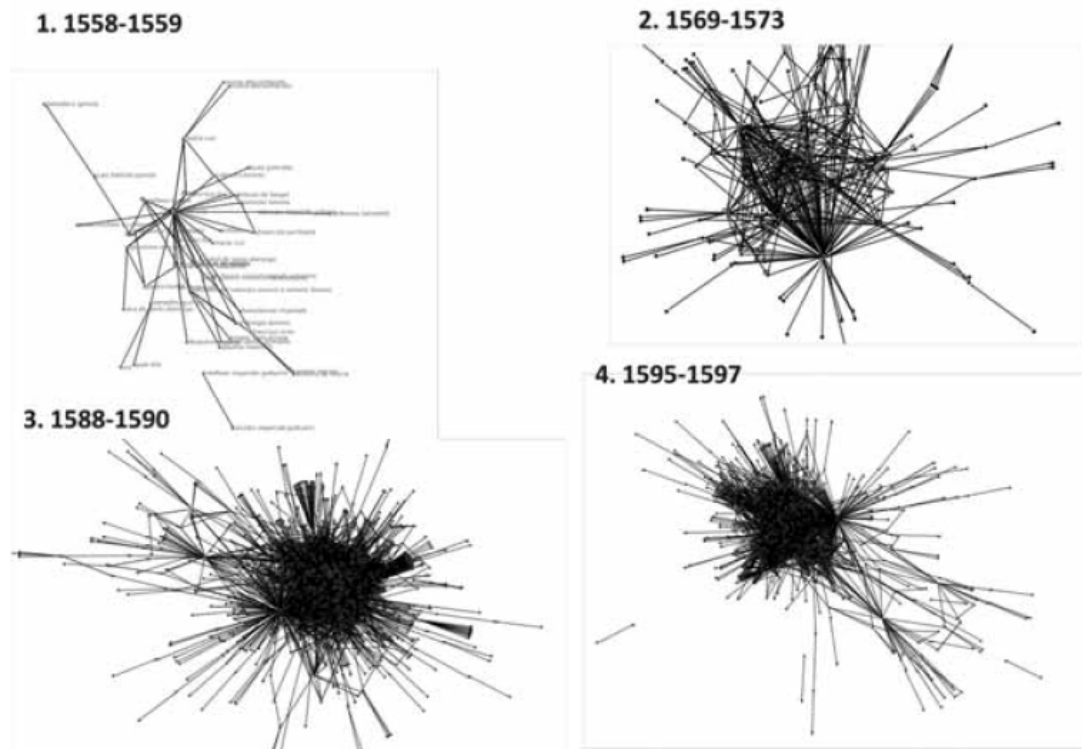


Source: Graph with Facebook and Twitter data prepared by ^{SandLab}8.

Poland, Pinto and Ribeiro (2014), in reconstructing the network of contacts of Simón Ruiz, noted how the density increased throughout the years of active life of the famous merchant. In this case, network density estimates the proportion of commercial links maintained by the subject of study over a period of time. This becomes especially relevant from 1574 onwards, when he begins to act as a banker and the average number of connections in his network increases from 2,132 to 17,000.

281. In other words, in the case of Simón Ruiz the condition of public banker accelerated its contracting capacity, increasing the density of the network almost eightfold.

8 <http://sandlab.cs.uchicago.edu/> (Consultation: 05-07-2020)

Figure 6. Simón Ruiz network

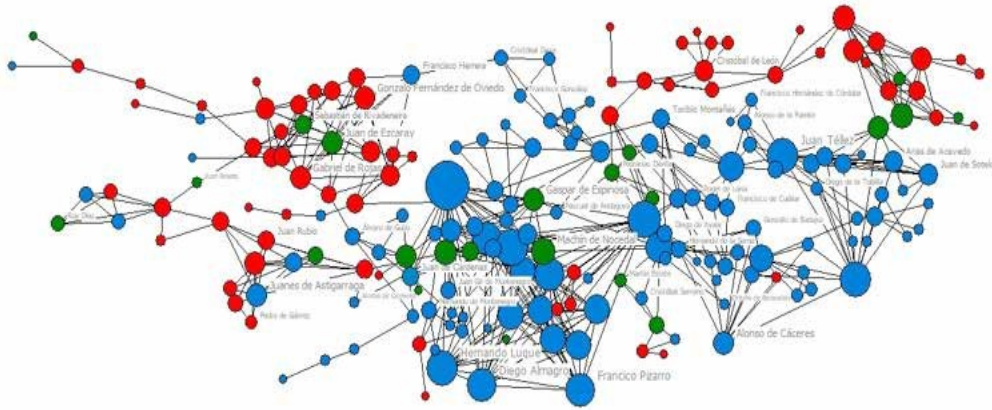
Source: Poland, Pinto and Ribeiro, 2014: 149.

The second of the general measures is the average distance, which refers to the size of the network, and indicates the average path we have to travel to get from one node to another. The concept of distance is related to the number of intermediate nodes and will be an indicator of the efficiency of information transmission. What the software calculates is the average of all the distances between each pair of elements. In this case, the value of the coefficient is not bounded, as was the case with density. The greater the average distance, the more distant the nodes will be from each other, and the more difficult it will be to communicate between them. This is an indicator frequently used in the study of business networks to compare the average size of each of them. In Rubio and Garrués-Irurzun (2017), the concept of distance is applied to the Andalusian business fabric to study its evolution from the period 1886-1913 to 1936-1959. The article analyzed the connections between board members of the main Andalusian companies between the end of the nineteenth century and the mid-twentieth century. The concept of distance in this network refers to the number of intermediate nodes to get from one agent to another in the network. In the words of the authors "The closer they are structurally - that is, the fewer intermediary actors separate them - the higher the quality of information transfer" (Rubio and Garrués-Irurzun, 2017: 800).

The last of the general measures we are interested in is the *clustering* coefficient. Sometimes within a network some nodes tend to form subgroups known as *clusters*. The elements in a *cluster* are better connected to each other than to the rest of the network. This concept is very useful if in the analysis we are interested in studying power groups or *lobbies*. To measure this coefficient, the software calculates an average considering the degree of interrelation between each node and its nearest neighbors. Sometimes, we can intuit a certain *cluster* structure.

simply by looking at the network and the probability of splitting it into different groups. In the The following network is a structure that can be easily divided into clusters.

Figure 7. Network with several clusters

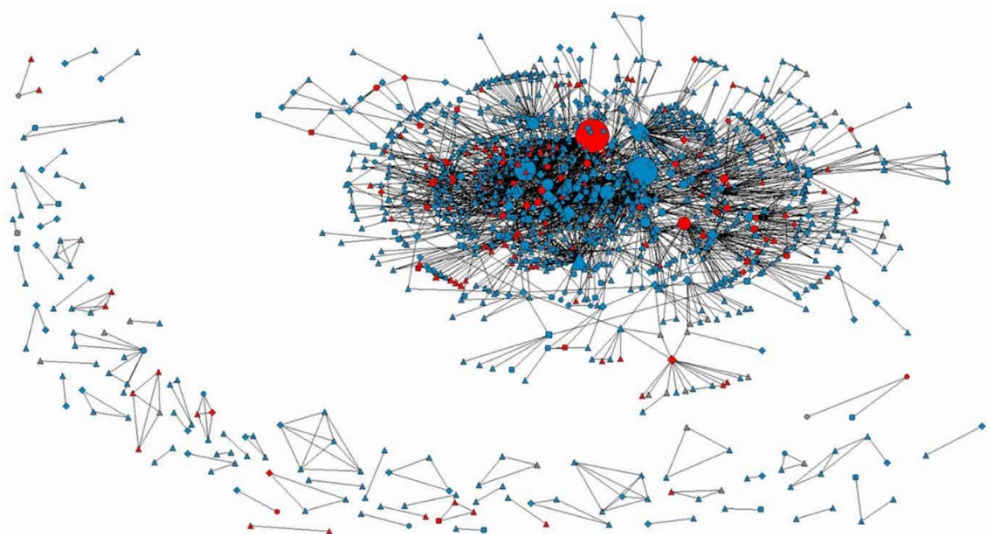


Source: Mena and Cachero, 2019: 14.

The nodes represent agents involved in the mining sector in Panama in the first half of the 16th century. The nodes connecting the different *clusters* turned out to be professional miners who served in various companies. These intermediaries had been ignored by traditional historiography, but this new approach allows us to prove that they were an indispensable part of mining in Castilla del Oro.

On the contrary, in this other graph the clustering coefficient is very low. The nodes represent agents of the book trade in Seville in the 16th century, it is a heterogeneous market where there is no exclusivity and almost all contract with each other. This is a dynamic market in which attributes such as nationality or profession did not condition the selection of partners.

Figure 8. Network with low clustering coefficient



Source: Maillard-Álvarez and Cachero, in press.

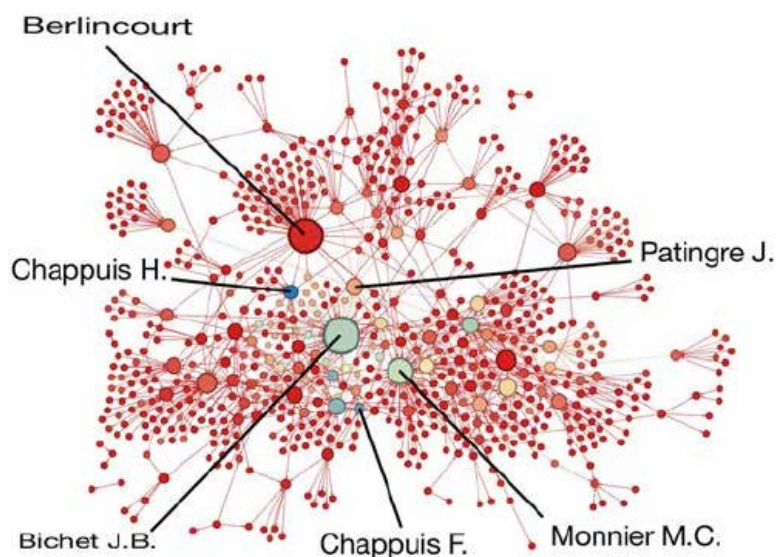
4.2. Specific measures

The specific measurements emanate from the direct observation of each node, providing values about them. Generally, they are related to the relative position of the nodes. Of these, the best known are the so-called centrality measures. Centrality calculates the relative popularity of each node within the network. But popularity is a concept that can be approached from different perspectives. We say that an agent is more popular within the given group if:

- Has more contacts and is therefore better connected (*degree* or *degree*)
- It occupies a central place in the network of relationships (*closeness*).
- Acts as a link between two or more agents (*intermediation* or *betweenness*).
- It is directly linked to the most relevant stakeholders (*relevance* or *eigenvector*)

The first of the measures, the degree, is generally used as a standard to represent graphically which nodes are the most important within the network. In fact, in most graphs the size of the nodes is resized according to their degree. It is important to understand in each case what this measure means. Normally, a higher degree implies more direct connections and, therefore, more popularity. The following graph represents the notarized agreements of the inhabitants of the Florimont manor. The size of each node reflects its degree, measured by the number of contracts signed.

Figure 9. Resized nodes as a function of grade

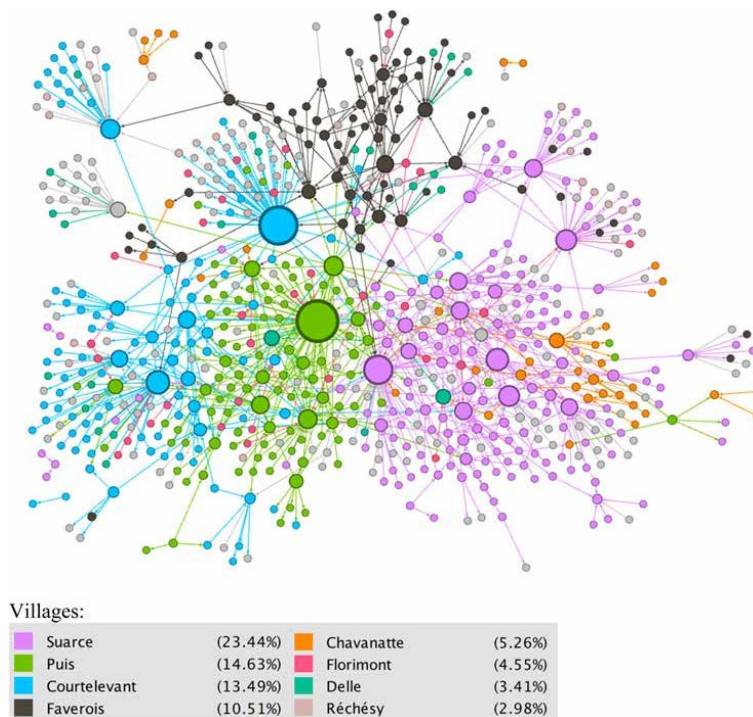


Source: Dermineur, 2019: 20

Despite its importance, closeness is the least used measure within this group. The concept of closeness in Network Analysis is related to distances within the network. The most central nodes in this sense will be those whose average distance to the rest of the nodes in the network is smaller. This is a fundamental concept when studying

the news circulating in the network, since the nodes with the highest closeness value will have better control of the information.

Figure 10. Credit network



Source: Dermineur, 2019: 16

The image above shows the credit network in various French villages. The nodes are agents in the financial market, the color represents the locality where they operate and the size shows the degree (measured by the number of credit contracts signed). The most active agents work in the locations of Courtelevant (blue), Puis (green) and Suarce (purple). In contrast, agents working in Chavanatte (orange) sign fewer contracts and are also further away from the center of the network, since they do not have direct contacts with the most popular individuals and therefore have a lower centrality value.

The concept of intermediation is extremely useful in networks whose nodes are individuals. In Garrués and Rubio (2011 and 2012), for example, intermediation is used to illustrate a characteristic concept of business organization: *interlocking directorates* (advisors common to several companies). These agents will simultaneously maintain links with two or more business groups and thus act as bridges or connectors between them. In this case, rather than calculating the value of intermediation for each of the nodes in the overall network, what interests the authors is to compare different business groups. Thus, for each business group, the software allows the degree of dependence of the network on one of the advisors to be calculated.

Relevance is likewise a crucial concept in historical studies, especially in those networks where we analyze power, whether at the political, economic, social or financial level. When analyzing the capacity of agents to receive grants or influence decisions, what is of interest is not their total number of connections, but that they are directly connected to those individuals who hold the power.

power. Despite its usefulness, the algorithm used for its measurement is not very popular in historical network analysis. There are, however, exceptions. Cachero and Rodríguez (in press), in analyzing the negotiation of privileges for the colonization of the New World, show that what was most interesting was not to count the number of people to whom one was connected, but to have direct access to the monarchs.

Whichever centrality measure is selected, the software will return a value for each node in the network. In historical terms, the interpretation of the numerical value of the various measures for each node can be complex. However, using the results of these metrics it is always possible to construct classifications or rankings that will make it possible to state whether within a given network one individual is more or less relevant than another, whether one agent has more or fewer contacts than another, or whether one node is more or less central in a network of relationships than another.

4.3. Dynamic analysis

One of the great obstacles in the application of Network Analysis as a tool for the historical discipline lies in the difficulty of carrying out diachronic studies. Network measures applied in Sociology generally capture a snapshot of interactions between various agents at a given time instant. In history, however, changes over time are essential for analysis. In this case, the most common technique so far has been to make time slices in the analyzed sample (Sánchez Balmaseda, 2002: 29-30), proceeding, for example, to visualize the same network at different times, but avoiding the study of the process of change *per se*.

However, we should not forget that network analysis comes from mathematics and some algorithms can be applied by introducing time as a fundamental variable in the ^{equation9}. In this way, the overall network measures can be calculated at all time instants over the period under study and capture the evolution process dynamically. The most commonly used ARS software, such as Gephi or Stata, allow the calculation of dynamic measures by adding a start and end date to each of the arcs or interactions between the agents studied. Similarly, it is also possible to enter information on the start and end date of each node in the network. Thus it is possible, for example, to measure the evolution of the complexity of the total interactions in the network over time. Also, we can observe how the average number of links of the nodes changes. Or we may be interested in studying whether individuals tend to group together over time and whether these alliances are stable or, on the contrary, are changing. For the latter, it would be sufficient to analyze the average clustering coefficient over the entire period. It is precisely in this direction that Network Analysis in History should evolve, however, it is a field that is still little explored, even in the field of mathematical Graph Theory (Michele Starnini, 2012).

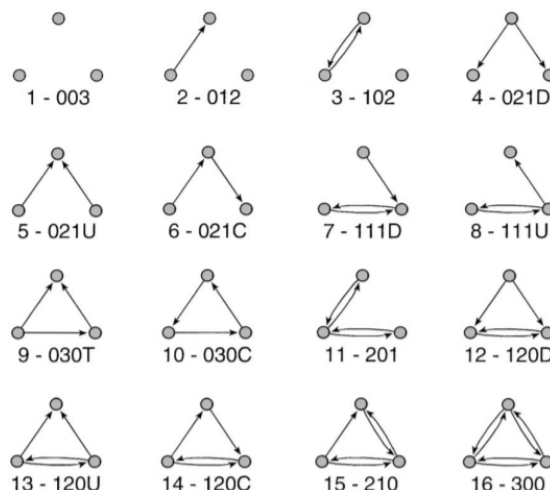
4.3.1. Flow study

Within the dynamic analysis of networks, flows are of particular interest, as they allow the study of the information flowing through a given network. In the available software, flow analysis generally focuses on two aspects: triad study and trajectory analysis. Triads are simply groups of three nodes, which may or may not be

9 As pointed out by Lemercier, (2015): "Network methods, as they are based on graph theory, tend to be intrinsically static, although it is now possible to visualize network evolutions as films; but this in turn opens the complicated question of dating ties".

be related to each other. Network analysis software has mathematical algorithms that compare theoretical interaction patterns (such as those shown in the following image) with the real connections between the nodes under study.

Figure 11. Possible triads



Source: Batagelj and Andrej, 2001: 238.

The relevance of triads is related to the concept of structural holes. A structural hole is basically an empty space within the network and, to detect it, it is necessary to divide the nodes into triads and study their connections. It was Ronald Burt (1995) who first defined and developed this concept, which represents failures in the connections within the network. Although it has not had much trajectory among network historians to date, we believe that it could play a key role in the future, since these holes constitute a comparative advantage for those individuals who develop strategies aimed at solving them, generating connections where there was previously a gap, thus obtaining extraordinary benefits (Garrués and Rubio, 2012). This concept is applied to the analysis of flows, studying the mechanisms of information transmission and measuring the efficiency of a network in terms of the capacity of agents to minimize structural holes.

The second of the metrics related to flow analysis is the study of trajectories. In this case, we analyze the speed with which information travels from one position to another in the network. As indicated above, flow analysis is usually represented in most cases by arrows distinguishing between source and destination nodes.

5. CONCLUSIONS

As we have shown throughout this paper, formal Network Analysis is a tool that offers great possibilities in the study of past societies, as long as it is applied with scientific rigor and taking into consideration the particularities of our discipline. We have seen that numerous studies already integrate Network Analysis into the historical narrative, providing a more complete vision and contributing to the advancement of knowledge and historiographic debate. This tool opens the door to new questions and hypotheses about the past, allows us to capture tendencies

and group dynamics, models of individual leadership that would otherwise be left to the faded.

There are many possibilities opening up for historians in the near future with Network Analysis, but it is necessary for each researcher to reflect on the applicability of this methodology to his or her specific study. The technical requirements, although increasingly accessible, do not cease to exist and pretending to use this tool when the sample is not sufficiently significant or the objective we are pursuing is not adequate may result in a significant loss of resources and opportunities. For this reason, the historian who wishes to start out in this methodological field should, first of all, make a critical exercise and decide, depending on the information derived from his sources and the questions guiding the research, whether it is worthwhile. It is advisable to review the objectives and measure the computer skills and the capacity to analyze the results to assess the cost-benefit of applying Network Analysis, so as not to underuse a methodological tool that has great potential for History.

BIBLIOGRAPHY .

- Ahnert, R., Ahnert, S., Coleman, C. N. and Weingart, S. B. (2020), *The Network Turn. Changing Perspectives in the Humanities*, Cambridge, University Press.
- Batagelj, V. & Mrvar, A. (2001), "A subquadratic triad census algorithm for large sparse networks with small maximum degree", *Social Networks*, 23, pp. 237-243.
- Bernabeu Aubán, J., Lozano, S and Pardo-Gordó, S. (2017), "Iberian Neolithic Networks: The Rise and Fall of the Cardial World", *Frontiers in Digital Humanities* (4).
- Bertrand, M., Guzzi-Heeb, S. and Lemercier, C. (2011), "Introduction: where does network analysis stand in History?", *REDES. Hispanic journal for social network analysis*, 21, pp. 1-12.
- Böttcher, N., Hausberger, B. and Ibarra, A. (2011), *Redes y negocios globales en el mundo ibérico, siglos XVI-XVIII*, Mexico City, Iberoamericana.
- Brughmans, T., Collar, A. and Coward, F. (2016), *The Connected Past. Challenge to Network Studies in Archaeology and History*, Oxford, University Press.
- Brown, D. M., Soto-Corominas, A. and Suárez, J. L., (2017), "The preliminaries project: Geography, networks, and publication in the Spanish Golden Age", *Digital Scholarship in the Humanities*, 32-4, pp. 709-732.
- Burt, R. (1995), *Structural holes: The social structure of competition*, Boston, Harvard University Press.
- Cachero, M. (2011), "Mercantile networks in the beginnings of Atlantic trade. Sevilla entre Europa y América, 1520-1525", in N. Böttcher, B. Hausberger and A. Ibarra (eds.), *Redes y Negocios Globales en el Mundo Ibérico, siglos XVI-XVIII*, Mexico City, Colegio de México, pp. 25-52.
- Carvajal de la Vega, D. (2014), "Merchant Networks in the Cities of the Crown of Castile", in A. Caracausi and C. Jeggle (eds.), *Commercial Networks and European Cities, 1400- 1800*, London, Pickering & Chatto, pp. 137-152.
- Castellano, J. L. and Dedieu, J. P. (1998), *Réseaux, familles et pouvoirs dans le monde ibérique à la fin de l'Ancien Régime*, Paris, CNRS.
- Crailsheim, E. (2016), *The Spanish Connection. French and Flemish Merchant Networks in Seville. 1570-1650*, Vienna, Bohlaus Verlag.
- (2020), "Flemish merchant networks in early modern Seville. Approaches, comparisons, and methodical considerations", in F. Kerschbaumere et al., *The Power of Networks. Prospects of Historical Network Research*, London, Routledge, pp. 84-109.

- Deicke, A. J. E. (2017), "Networks of Conflict: Analyzing the 'Culture of Controversy' in Polemical Pamphlets of Intra-Protestant Disputes (1548-1580)," *Journal of Historical Network Research*, 1, pp. 71-105.
- Dermineur, Elise (2019), "Peer-to-peer lending in pre-industrial France", *Financial History Review*, 3, pp. 359-388.
- Freeman, L. (2012), *The development of social network analysis. A study in the sociology of science*, Bloomington, Palibrio.
- Garrués-Irurzun, J. and Rubio, J. A. (2012), "La formación del espacio empresarial andaluz: 1857-1959", *Scripta Nova. Revista electrónica de Geografía y Ciencias Sociales*, 16, <http://www.ub.edu/geocrit/sn/sn-404.htm> (Accessed: 04-07-2020).
- Graham, S., Milligan, I. and Weingart, S. (2016), *Exploring big historical data: the historian's microscope*, London, The Imperial College Press.
- Gil Martínez, F. (2015), "Las hechuras del Conde Duque de Olivares. The high administration of the monarchy from network analysis", *Cuadernos de Historia Moderna*, 40, pp. 63-88.
- Heredia López, A. J. (2019), "Los comerciantes a Indias y la Casa de la Contratación: vínculos y redes (1618-1644)", *Colonial Latin American Review*, 28:4, pp. 514-537.
- Herrero Sánchez, M. and Kaps, K. (2017), *Merchants and Trade Networks in the Atlantic and the Mediterranean, 1550-1800*, London, Routledge.
- Hinks, J. and Feely, C. (2017), *Historical networks in the Book Trade*, New York, Routledge.
- Ibarra, A. (2000), "The consulate of commerce of Guadalajara, 1795-1821. Institutional change, Corporate Management and Transaction Costs in the Novo-Hispanic Economy", in B. Hausberger and N. Böttcher (ed.), *Money and Business in Latin American History*. Hausberger and N. Böttcher (ed.), *Dinero y negocios en la historia de América Latina*, Frankfurt, Vervuert, pp. 231-264.
- Iglesias, D. (2016), "Las redes político-intelectuales y los orígenes del Plan Barranquilla, 1929-1931", in A. Pita González, *Redes intelectuales transnacionales en América Latina durante la entreguerra*, Mexico City, Universidad de Colima, pp. 25-50.
- (2017), "The contribution of social network analysis to intellectual history," *History and Space*, 49, pp. 17-37.
- Imízcoz Beunza, J. M. (1998), "Communauté, réseau social, élites. L'armature sociale de l'Ancien Régime", in J. L. Castellano and J. P. Dedieu, *Réseaux, familles et pouvoirs dans le monde ibérique à la fin de l'Ancien Régime*, Paris, CNRS, pp. 31-66.
- (2011), "Actors and social networks in History", in D. Carvajal de la Vega et al. (eds.), *Redes sociales y económicas en el mundo bajomedieval*, Valladolid, Castilla ediciones, pp. 21-33.
- (2018), "For a global history. Aportaciones del análisis relacional a la 'global history'", in A. Ibarra, A. Alcántara and F. Jumar (eds.), *Actores sociales, redes de negocios y corporaciones en Hispanoamérica, siglos XVII-XIX*, Mexico City, UNAM- Bonilla Artigas Editores, pp. 27-57.
- Imízcoz Beunza, J. M. and Arroyo Ruiz, L. (2011), "Redes sociales y correspondencia epistolar. From the qualitative analysis of personal relationships to the reconstruction of egocentric networks", *REDES, Journal for the analysis of social networks*, 21, pp. 99-138.
- Kerschbaumer, F., Keyserlingk-Rehbein, L., Stark, M. and Düring, M. (2020), *The Power of Networks. Prospects of Historical Network Research*, London, Routledge.
- Lamikiz, X. (2020), Review of *The Spanish Connection. French and Flemish Merchant Networks in Seville. 1570-1650*, *Research in Economic History*, 16-1, pp. 60- 61.

- Lemercier, C. (2015), "Formal network methods in history: why and how?", *Social Networks, Political, Institutions, and Rural Societies*, Leiden, Brepols, 281-310.
- Lemercier, C. and Zalc, C. (2019), *Quantitative methods in the Humanities. An Introduction*, Charlottesville, University of Virginia Press.
- Mac Shane, B. A. (2018), "Visualising the Reception and Circulation of Early Modern Nuns' Letters," *Journal of Historical Network Research*, 2, pp. 1-25.
- Maillard Álvarez, N. (in press), "Las grandes compañías europeas en el mercado hispano del libro durante siglo XVI: el caso de Sevilla y Ciudad de México", in P. Bravo (ed.), *Livres écrits, lus, transmis, échangés, collectionnés: circulation des livres et des hommes au Siècle d'Or*, Paris, Presses de la Sorbonne Nouvelle.
- Martín Romera, M. Á. (2010), "New perspectives for the study of medieval societies: the analysis of social networks", *Studia Historia. Historia Medieval*, 28, pp. 217-239.
- Martínez Carro, E. and Ulla Lorenzo, A. (2019), "Redes de colaboración entre dramaturgos en el teatro español del Siglo de Oro: nuevas perspectivas digitales", *RILCE: Revista de Filología Hispánica*, 35-3, pp.896-917.
- Molina, J. L. (2001), *El análisis de redes sociales. An introduction*, Barcelona, Edicions Bellaterra.
- Pascua Echegaray, E. (1993), "Redes personales y conflicto social. Santiago de Compostela in the time of Diego Gelmirez", *Hispania*, 53-185, pp. 1069-1089.
- Picazo Muntaner, A (2015), "Comparative systems and the functioning of networks: the Caribbean and Indo-Pacific models of trade. XVII and XVIII centuries", *Culture & History Digital Journal*, 4 (1): e0009.
- Poland, A., Pinto, S. and Ribeiro, A. S. (2014), "Trade Networks in the First Global Age. The case study of Simon Ruiz Company: Visualization Methods and Spatial Projections", in A. Crespo Solana, *Spatio-Temporal Narratives: Historical GIS and the Study of Global Trading Networks (1500-1800)*, Cambridge, Cambridge Scholars Publishing, pp. 140-177.
- Ponce Leiva, P. and Amadori, A. (2008), "Redes sociales y ejercicio del poder en la América Hispana: consideraciones teóricas y propuestas de análisis", *Revista Complutense de Historia de América*, 34, pp. 15-42.
- Rodríguez Treviño, Julio César (2013), "Cómo utilizar las Redes Sociales para temas de historia". *Signos Históricos*, 29, pp. 102-141.
- Rubio, J. A. and Garrués-Irurzun, J. (2017), "Scarcity of weak ties: the economic backwardness of contemporary Andalusia from the perspective of business networks", *Hispania*, 257, pp. 793-826.
- Sánchez Balmaseda, M. I. (2002), *Análisis de redes sociales e historia, una metodología para el estudio de redes clientelares*, Madrid, Universidad Complutense.
- Sarno, E. (2017), "Social network analysis and contemporary history", *Ayer*, 105, pp. 23-50.
- Shepard, J. (2018), "Networks", *Past & Present*, 238, supplement 13, pp. 116-157.
- Smith, R. M. (1979), "Kin and Neighbors in a Thirteenth-Century Suffolk Community," *Journal of Family History*, 4, pp. 27-62.
- Starnini, M. (2012), "Random walks on temporal networks", *Physical Review*, 85, no. 5.
- Vieira Ribeiro, A. S. (2011), *Mechanisms and Criteria of Cooperation in Trading Networks of the First Global Age. The case study of Simon Ruiz network. 1557-1597* (Doctoral dissertation defended at the University of Porto), <http://www.cervantesvirtual.com/>

work/mechanisms-and-criteria-of-cooperation-in-trading-networks-of-the-first-global-age-the-case-study-of-simon-ruiz-network-1557-1597/ (Accessed: 23-12-2020)

Vieira Ribeiro, A. S. (2015), *Early Modern Trading Networks in Europe. Cooperation and the case of Simon Ruiz*, Abingdon, Routledge.

Wetherell, C. (1998), "Historical Social Network Analysis", *International Review of Social History*, 43, pp. 125-144.