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Midiendo la complejidad de un proyecto a través de sus redes
Measuring the complexity of a project through its networks

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Resumen-- **Para poder establecer la complejidad de un proyecto de construcción, es necesario estudiar tanto la complejidad estructural, basada en las redes que pueden formar, como la complejidad dinámica, basada en la coevolución de los componentes de esas redes. En este trabajo, se focaliza dicho estudio sobre la red de intercambio de información entre los stakeholders o interesados en un proyecto.**

Se discute en primer lugar que tipo de red se puede establecer y qué métricas se puede utilizar en ambos tipos de complejidad. En segundo lugar, se disponen las expresiones algebraicas correspondientes. Estos conceptos se aplican a un proyecto de construcción de una Estación Depuradora de Aguas Residuales (EDAR) con una combinación de obra civil e instalaciones.

Palabras clave— Gestión de proyectos; complejidad; adaptabilidad; redes complejas; coevolución.

Abstract— **In order to establish the complexity of a construction project, it is necessary to study both the structural complexity, based on the networks that can form, and the dynamic complexity, based on the co-evolution of the components of these networks. In this paper, this study focuses on the information exchange network between stakeholders in a project.**

Firstly, it is discussed what kind of network can be established and what metrics can be used in both types of complexity. Secondly, the corresponding algebraic expressions are arranged. These concepts are applied to a Waste Water Treatment Plant (WWTP) construction project with a combination of civil works and facilities.

Index Terms— Project Management; Complexity; Adaptability; Complex Networks; Coevolution.

I. INTRODUCTION

MORE often, projects are becoming more complex, and this is intimately related to the performance outcomes of the project. This analysis should not only be carried out in the face of the complexity or uncertainty, which entail, in general, the realization of said project, but more internal aspects of it should be addressed, such as: cost/duration; size of the team; composition and functioning of the project team; flexibility and urgency in the deliverable; complexity in IT, volatility in requirements; Number of interested parties; organization-level, and risks, constraints, and dependencies. (Hass & Lindbergh, 2010)

A new, much more important interrelation with the project stakeholders is therefore necessary, and risk management must be increasingly taken into account, also establishing new tools, life cycles and approaches that allow greater adaptation, both in the management of the project and in the environment where it

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When there are situations of great dynamism, it is necessary not to treat projects in a static way, and it is necessary to reconsider the traditional way of approaching them, using tools used in conventional or predictive projects, since it is very foreseeable that additional costs and planning will arise due to unrealistic initial approaches. (San Cristóbal et al., 2018)

Finally, it is important to establish the degree of complexity of a project to apply the appropriate approach, whether it is predictive, adaptive or hybrid (Alvarez-Espada et al., 2022) . This paper presents a suitable and versatile tool to measure the complexity of a project, which can be used a priori or during the execution of the project.

II. COMPLEXITY. COMPLEX SYSTEMS

A system is a combination of resources (human, material, information, etc.) that are integrated to perform a specific function obtaining a defined need that can be analyzed analytically. (Blanchard, 1995)

A complex system contains more information than the sum of its parts can provide. This is because unexpected interactions can occur that manage to generate new information. This is done dynamically, both internally and externally. The analytical precision with which a conventional system can be treated is not possible, since it does not affect all microscopic components equally, and therefore, an analytical view of the system is no longer possible, from a macroscopic point of view, but it is necessary to apply a probabilistic vision, to link both microscopic and microscopic behaviors, as well as the macroscopic ones of the complex system. Therefore, classical mechanics is replaced by stochastic mechanics. (Arellano et al., 2016).

Complex systems, among many of their properties, are usually controlled systems, but they are out of equilibrium, which makes them difficult to deal with analytically. This will imply that a complex system is a system directed towards out-of-equilibrium areas. The fact that a complex system can be in disequilibrium, and not collapse, is understood by the concept of self-organized criticality, which allows us to explain essential elements of statistical mechanics, such as the presence of power laws. (Marković & Gros, 2014).

A. Complex systems such as multinetworks

An important element in complex systems is that they can be expressed as multilayer interaction networks, which topologically express interactions that occur, with varying degrees of strength, in a series of overlapping interaction networks. This type of network represents much more adequately what happens in nature, in transport interconnections, in projects or in social relations (Boccaletti et al., 2014).

A more formal definition of a complex system is the one adopted by Thurner, Hanel, and Klimek, in and is the basis of this approach to the mechanics, and to the dynamics of complex systems, defining them as (Thurner et al., 2018) Co-evolving multi-layer networks, i.e. states change according to the interaction network and, simultaneously, interactions (networks) change according to states. Fig. 1. Shows two schematic representations of the same multilayer network can be observed.

A complex system is not the same as a complicated system. Complicated systems require more sophisticated tools to divide the whole into its basic parts, and recognizing the interrelationships of these basic parts can be difficult, but in such a system, the maxim that the whole is the sum of its basic parts is still true. In addition, in a complicated system, nodes and interrelationships do not change.

A project is a system that also elaborates a different one, the scope, and has a finitude in time, since, once the result has been achieved, the system is considered finished. It could be understood that from a physical point of view its significance is minimal. Likewise, the relationships between its elements, both in management and in the result, are difficult to establish as considered in (Gomez-Senent et al., 2020) , but it is understood that the hierarchy in management criteria or results does not invalidate the fact that it can be considered a system.

It can be said that a complex project is also a complex system,

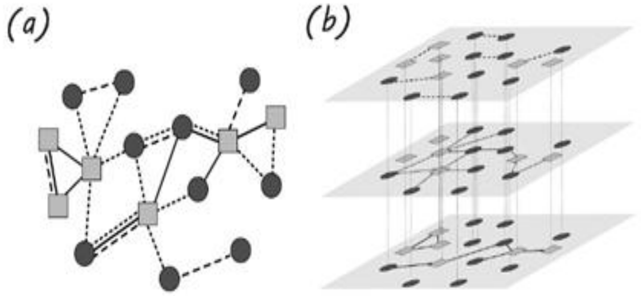


Fig. 1. Complex system as a multilayer network (Source: Thurner et al, 2018).

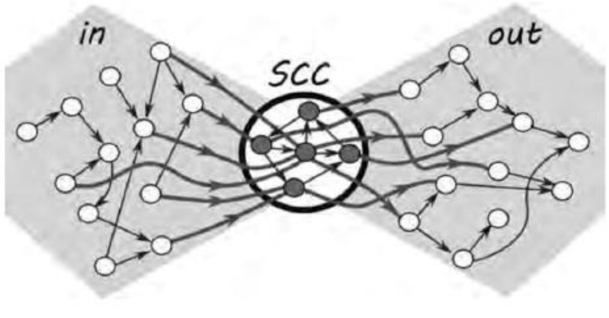


Fig. 2. Directed network composed of SCCs (Source: dobson et al, 2007)

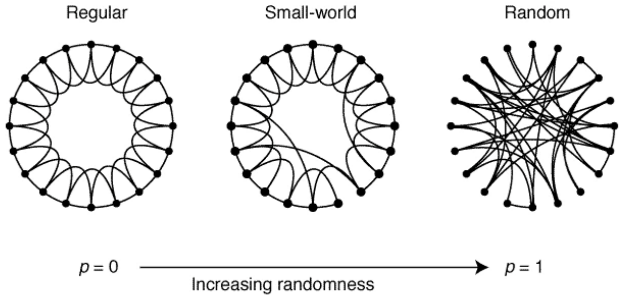


Fig. 3. Random small-world networks. P is the probability of interaction between nodes in a network (Source: Watts-Strogatz)

where a hierarchy is not required for its existence, based on its ability to organize itself. A complex project can be so, because activities can occur that have uncertainty, ambiguity, volatility and complexity, resulting in new processes that are difficult to control, either because the environment where it is developed is also complex or, finally, because its result is complex.

Dobson, Carreras and Newman on (Dobson et al., 2007) , They consider a directed network to be strongly connected, if there is a path in each direction between each pair of nodes. Maximum induced subgrids that are strongly connected are called strongly connected components (SCCs). All nodes that have a connection to at least one node in the SCC is called internal components. All nodes outside the SCC that can be reached by a route starting at the SCC are called output components, as can be seen in Fig. 2.

Of all the random networks, with a certain dynamic, either by diffusion, by modifications of internal states or by multimodal transmission, the ones that are of greatest interest when it comes to their application to complex projects are those studied by Watts and Strogatz (1998) , who formulated a model that combined a high clustering and a low characteristic distance. They called them Small-world networks. They argued that, by introducing an increasing number of random links into the network, distances decrease rapidly, while maintaining a high level of clustering by connecting nodes in a ring and connecting them to their nearest neighboring nodes, as can be seen in Fig. 2.

B. Coevolution in complex systems

Evolutionary processes combine many of the classic characteristics of complex systems: they are algorithmic; states co-evolve with interactions; they show power law statistics; they are self-organizing critical, and they are driven systems that are not in equilibrium.

The evolution of the state of the system by the interaction of the entity can be formally defined by the following equation:

$$\frac{\mathrm{d}}{\mathrm{dt}}\sigma_{\mathrm{i}}(\mathrm{t}) \sim \mathrm{F}\left(\mathrm{M}^{\alpha}_{\mathrm{ijk..}}(\mathrm{t}),\, \sigma_{\mathrm{j}}(\mathrm{t})\right) \qquad \textit{(1)}$$

This is the first equation of coevolutionary dynamics, practically immovable in the last 300 years of science, and indicates that the change, within the next step of time of the state of an entity, will be a function of the states of the rest of the nodes and the interaction matrix M of a single interaction □ on the rest of the nodes of the network that represents the system. The function F can be deterministic or stochastic.

The second equation of coevolutionary dynamics specifies how interactions will evolve over time through a function G which, like F, can be deterministic or stochastic.

$$\frac{\mathrm{d}}{\mathrm{dt}}\mathrm{M}^{\alpha}_{\mathrm{ij}}(\mathrm{t}) \sim \mathrm{G}\left(\mathrm{M}^{\alpha}_{\mathrm{ijk..}}(\mathrm{t}),\, \sigma_{\mathrm{j}}(\mathrm{t})\right) \qquad \textit{(2)}$$

With these two equations it is seen that both states and interactions update each other. It is not possible to analyse these equations analytically and they can only be analysed by algorithms.

III. METRICS ON COMPLEXITY

Pryke believes that social network analysis tools can be focused, and adopted, for the study of project governance, focusing on two of the characteristic properties of social network analysis (SNA), density and centrality, to compare certain aspects of a project such as the role of stakeholders, and the types of contracts that can be established in human activities (Pryke, 2005).

Unlike other types of networks, authors who have developed studies on SNA applications to projects, such as (Borgatti & Halgin, 2011), (Carrington et al., 2005) and consider, like these, that networks established in projects are non-repetitive, temporary and usually have objectives established by stakeholders through requirements. Nowadays, projects are not carried out by a single company, but there is coordination between companies of different kinds, which can be formal (contract), informal (verbal agreements or taking positions), strong (carrying out a specific work in a phase of the project) or weak (an association faced with the passage of a pipe through a street). frequent (carrying out several jobs during the project) or infrequent (carrying out a single job), emotional (carrying out a social challenge through a projected product) or pragmatic (carrying out a work without social interest). Networks are therefore established with elements introduced into relationships, which can generate opportunities or threats(Kenis & Oerlemans, 2008).

According to Borgatti and Haldin (Op. Cit), there are two models of network research to study governance with a structural perspective: the flow model and the coordination model.

The flow model encompasses the interaction of the network structure with a given flow to study individual actors as to their position in the network. Its main structural properties are:

- The centrality of degree, of closeness and of intermediation. They are actor-level properties that reflect the volume of activity of the node studied with respect to other nodes. A node with a high degree is presented with greater visibility and is in contact with other adjacent nodes in the network. Actors with a high degree usually exert dominance over other peripheral actors. The centrality of proximity establishes which nodes have the particularity of receiving, and efficiently sending, information as quickly as possible. The centrality of intermediation indicates which nodes act as a bridge between other nodes to establish the shortest routes(Wasserman & Faust, 1994)(Stock et al., 1998)
- Centralization. It is a network-level property that indicates where in the network the highest flow intensity is concentrated in the exchange. If it is concentrated in a few nodes the network will be hierarchical and if it is widely distributed, it will be a decentralized network. (Kim et al., 2011)
- Density. It is a network-level property that expresses the number of loops established over the maximum number of possible loops. Reflects network connectivity.

Complexity in a project is related to centralization and density. Authors such as Provan and Milward consider that networks with many actors, with high interdependence between them, require a high level of coordination and therefore complexity. Kim, Yan and Dooley (Op. Cit.) consider that greater complexity is associated with a large network size, a large centrality and a high network density. Finally, other authors, such as Choi and Hong (2002) and Provan & Milward (1995) , consider that a high centralization in the information network indicates weak interactions between centre and periphery, and therefore, a possible formation of consortia between actors in external areas, which tends to slow down operations and decision-making, thus increasing costs and failures. and therefore complexity.

The coordination model studies how the nodes of a network are united. If a node is attached to many weak nodes (nodes with a small degree) it is considered a powerful node. If a node is attached to many powerful nodes (nodes with high grade) it is considered weak. Unlike the flow model, the coordination model has a single important metric, the Beta centrality or Bonacich centrality. (Bonacich, 1987)

Adami and Verschoose propose a framework of reference, applying flow and coordination models, for the structural analysis of a project using networks formed by a three-level multi-network:(Adami & Verschoore, 2018)

- Supply network. This network controls the coordination and control of the supply of goods and services. In addition, it studies the distribution of power and authority among actors. According to the authors, high values of degree centralization imply a greater centralization of authority, and consequently, there will be high levels of control in project networks and therefore will be subject to a high operational workload by their suppliers. Actor-level centrality allows the identification of real buyers and suppliers in project networks. Companies with a high degree of centrality will assume the role of integrating companies, by organizing their goods and resources in the result of the project.
- Contractual network. This network controls from the formal involvement of the companies in the project and from the formal power associated with the contracts. It is also in charge of the formal instruments used in new relationships, and when there are changes of suppliers. High values of centralization in the contract network indicate weak interactions between central and peripheral firms, and disconnected relationships between firms at different levels of supply. The degree of centrality in a contractual network indicates the extent of a firm's influence on operational decisions, and the behaviour of other firms in a project. A contractual network with a high volume of connections between companies is related to high complexity.
- Information network. This network controls the informal power of information, contributing to the effective governance of relationships. It represents the actual operation of the network. The centralization property is usually associated with a company's control of project communications. With high centralization, there will be restrictions on the exchange of information between the most concentrated nodes and the most peripheral ones. This slow and limited communication can lead to delays in solving local problems and the formation of "resilient" nodes that can lead to failures in project operations.

A first approach to the realization of metrics on complex networks is the graphical and analytical analysis of structural networks using software tools, among which the UCINET network management software in its version 6 described in (Borgatti et al., 2018) .

UCINET is a computer program that offers a comprehensive analysis of social networks. It was created in 2002, and its authors were Borgatti, Everett and Freeman. From a functional point of view, data entry is carried out using adjacency tables, which can represent unidirectional, bidirectional, unweighted or weighted networks in their own format or using external tools, such as Excel. It can analyse a multitude of parameters associated with social networks, including centrality, subgroup identification, network role analysis, elementary graph theory, and permutation-based statistical analysis.

Therefore, the complexity of the structure, in the form of a network, that forms a project will be analysed and then the dynamic level, through co-evolution, of said project will be analysed. By establishing these two parameters, it will be possible to obtain the level of complexity of a project, in this case, construction.

A. Metrics to measure the structure of a complex system

It is necessary to point out the manifest difficulty of trying to know when a system is complex given its nature of continuous change, however, it would be convenient to know some metrics that may be interesting to consider, to measure its complex structure (Sancho Caparrini, 2020).

The first thing to establish is what type of network is going to represent the complex projects that are being studied, since it is important to know the elements that must define it. Random networks are networks that can "self-generate" by completely changing their structure and interrelationships. Within random networks, there is a very interesting type of network, small-world networks. These networks, as described, have both small values of average characteristic length between nodes, like random networks, and have high clustering values like simple or regular networks. These networks are characteristic of social networks, electric power networks, collaboration networks, technical projects, operation of industries, terrorist groups, neighborhood associations or business networks in general(Fellman et al., 2014) . (Frenken, 2000)

Another characteristic that must be considered are mutually beneficial relationships, that is, networks can be established randomly, as we have seen, but there will always be an imbalance in their formation, and this imbalance is called "mutual benefit" or mutualist, and they occur in small-world networks with well-established relationships of dependence. forming bipartite networks. In other words, if a given technical innovation project enters a network where other technical projects can establish mutual benefits, its level of survival is higher than others that cannot establish this relationship. It also happens in nature with the interactions between plants and

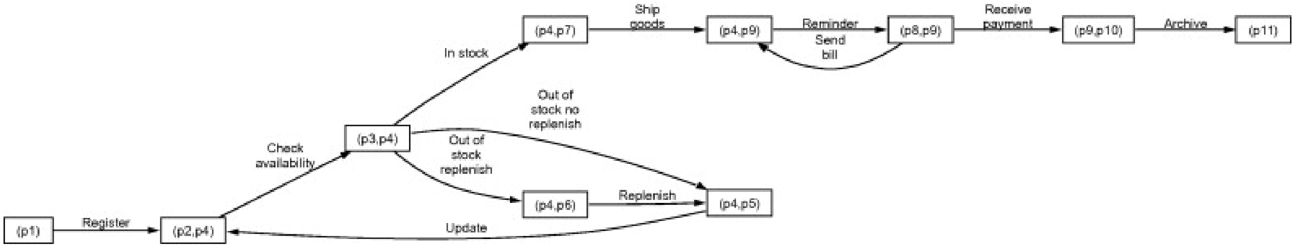


Fig. 4. Petri net of a supply process (Source: (Lassen & van Der Aalst, 2009)

animals that pollinate them (Bascompte & Jordanian, 2007).

In the structural design of networks that represent complex systems/projects, some interesting metrics can be established. For example, establishing that, within the possible networks that can be formed, information is the main element of complexity within a project. (Poveda-Bautista et al., 2018)

These metrics, despite being intuitive, involve quite specific calculations and it is necessary to explicitly know the system and its representation in a network.

In (Summers & Shah, 2010) , Summers and Shah establish a series of tools based on three dimensions arranged in multi-network: size, coupling and "solubility" (understood as objectives achieved through all the given requirements).

For the size dimension, three parameters are analyzed: size of the objectives, size of the problems and size of the processes to be established between objectives and problems. For the coupling dimension, it defines an algorithm to find the level of interrelation that exists in the complex network. For the solubility dimension, the degree of similarity between the different variables that are part of the problem, the process and the objective is studied. The more similarity there is, the greater the ability of the system to achieve the objective from a given problem.

These metrics are a good way to go since they can analyse the structure of the system from a holistic point of view. However, it is necessary to have a good knowledge of the networks proposed. There are many more metrics that attempt to establish the degree of complexity of a system, using numerous techniques and methodologies, a set of which can be seen in (Polančič & Blinding, 2017) . However, their use in early stages of analysis makes them difficult to manage. It is necessary to find a metric that is quick to realize that does not require a deep analysis of the network or multi-network created.

A metric that, if easily usable, is proposed by Lassen and Aalst in (Lassen & van Der Aalst, 2009) . In this study they intuit that structural complexity is made up of three parameters like those proposed by Summers and Shah, which they now call: size, connections and solvency, based on McCabe's (1976) cyclomatic complexity but considering only the number of strongly connected components, calling this extended cyclomatic complexity:

$$ECyM(PN) = |E| - |N| + p \qquad (3)$$

Where PN (P,T,F) is a Petri grating with three fundamental parameters: P is the number of nodes; T is the number of states or transitions, and F is the number of interrelationships in the network. E is the number of links, N is the number of nodes, and p is the number of strongly connected components (SCCs). The following example is proposed, see the (Petri, 2005), taken from where the cyclomatic complexity of a supply network can be established.(Lassen & van Der Aalst, 2009)

Applying the cyclomatic complexity formula, its value is obtained:

$$ECyM(PN) = 12 - 10 + 6 = 8 \qquad (4)$$

According to McCabe, this value is considered to respond to a simple system.

If this formula were applied to a system with more links, for example, 30 links, in a network of the same number of nodes and the same number of connected components, the cyclomatic complexity defined in the equation *(4)* would be:

$$ECyM(PN) = 30 - 10 + 6 = 26 \qquad (5)$$

According to McCabe, this value is considered to respond to a complex system.

Although cyclomatic complexity measures complexity well in small-world networks, it does so consider that state transitions, basic in a network to know the movement in it, have many starting constraints (elimination of mutually beneficial links due to the lack of adequate conditions), being extremely complex if any of the constraints are eliminated. In addition, the measurement of structural complexity suffers from a serious problem, it does not measure the change in interactions caused by coevolution. Therefore, structural metrics must be complemented.

B. Metrics to measure dynamics in complex systems

There are, therefore, two metrics, easy to use, with the due reservations established by their authors, which allow establishing the level of complexity of a system/project:

- Structurally using extended cyclomatic complexity.
- Dynamically, by the coevolution parameter g, to establish the complexity with the number of nodes that are in the network under study.

If we divide the type of project according to the definitions provided by Stacey, we will have to:(Stacey, 1996)

- Project without complexity. Reference value, 1.
- Moderately complex project. Reference value, 5.
- Complex project. Reference value, 10.

The total complexity will be given by the SUM of the two complexities studied:

- Structural complexity (SC) by measuring extended cyclomatic complexity. This complexity is always present, since it depends on the structure of the network that represents the project. Thus, the following reference values (MacCabe, Op. Cit) and their assignments to the complexity level will be considered:
    - Cyclomatic complexity □ 10. Simple project. The structural complexity will have a value of 0.

- Cyclomatic complexity > 10 and 20. Complicated project. The structural complexity will have a value of 3.
- Cyclomatic complexity > 20. Complex project. The structural complexity will have a value of 5.

- Dynamic complexity (CD) by applying the coevolution parameter g, which will depend on the number of nodes. Thus, the following reference values (Iñiguez and Barrio, Op. Cit.) and assignments to the level of complexity will be considered:
  - Number of nodes 25. High coevolution. The dynamic complexity will have a value of 4.
  - Number of nodes > 25 and 100. Medium coevolution. The dynamic complexity will have a value of 2.
  - Number of nodes > 100. Low coevolution. The dynamic complexity will have a value of 0.

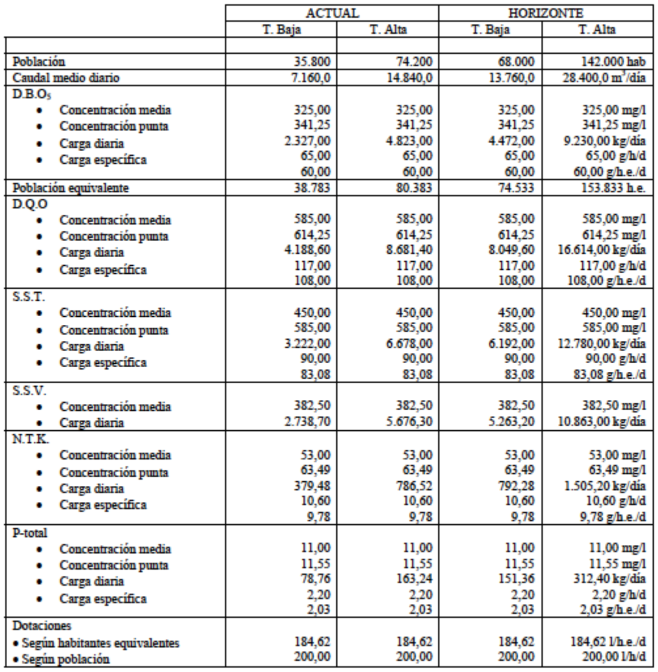
Being, therefore, the total complexity:

$$CT = CE + CD \qquad (6)$$

IV. MARSHES OF ODIEL WASTEWATER TREATMENT PLANT

The Marismas del Odiel Wastewater Treatment Plant (WWTP) is in the municipality of Punta Umbría (Huelva, Spain) and in the vicinity of the Marismas del Odiel Natural Park.

It was designed to treat the wastewater of 142,000 equivalent inhabitants in the horizon year of 2036, belonging to the towns of Punta Umbría, Aljaraque and El Rompido, population centers that are within a maximum radius of 12 km from the location of the WWTP. Its construction was carried out between 2008 and 2012 and the technology used was quite novel at the time, since it reduced both carbon pollution and nutrients (nitrogen and phosphorus) below the limits required by the administration through biological treatment (A2O, Anaerobic, Anoxic, Oxic technology).



	ACTUAL		HORIZONTE	
	T. Baja	T. Alta	T. Baja	T. Alta
Población	35.800	74.200	68.000	142.000 hab
Caudal medio diario	7.160,0	14.840,0	13.760,0	28.400,0 m^3/día
D.B.O$_5$				
• Concentración media	325,00	325,00	325,00	325,00 mg/l
• Concentración punta	341,25	341,25	341,25	341,25 mg/l
• Carga diaria	2.327,00	4.823,00	4.472,00	9.230,00 kg/día
• Carga específica	65,00 60,00	65,00 60,00	65,00 60,00	65,00 g/h/d 60,00 g/h.e./d
Población equivalente	38.783	80.383	74.533	153.833 h.e.
D.Q.O				
• Concentración media	585,00	585,00	585,00	585,00 mg/l
• Concentración punta	614,25	614,25	614,25	614,25 mg/l
• Carga diaria	4.188,60	8.681,40	8.049,60	16.614,00 kg/día
• Carga específica	117,00 108,00	117,00 108,00	117,00 108,00	117,00 g/h/d 108,00 g/h.e./d
S.S.T.				
• Concentración media	450,00	450,00	450,00	450,00 mg/l
• Concentración punta	585,00	585,00	585,00	585,00 mg/l
• Carga diaria	3.222,00	6.678,00	6.192,00	12.780,00 kg/día
• Carga específica	90,00 83,08	90,00 83,08	90,00 83,08	90,00 g/h/d 83,08 g/h.e./d
S.S.V.				
• Concentración media	382,50	382,50	382,50	382,50 mg/l
• Carga diaria	2.738,70	5.676,30	5.263,20	10.863,00 kg/día
N.T.K.				
• Concentración media	53,00	53,00	53,00	53,00 mg/l
• Concentración punta	63,49	63,49	63,49	63,49 mg/l
• Carga diaria	379,48	786,52	792,28	1.505,20 kg/día
• Carga específica	10,60 9,78	10,60 9,78	10,60 9,78	10,60 g/h/d 9,78 g/h.e./d
P-total				
• Concentración media	11,00	11,00	11,00	11,00 mg/l
• Concentración punta	11,55	11,55	11,55	11,55 mg/l
• Carga diaria	78,76	163,24	151,36	312,40 kg/día
• Carga específica	2,20 2,03	2,20 2,03	2,20 2,03	2,20 g/h/d 2,03 g/h.e./d
Dotaciones				
• Según habitantes equivalentes	184,62	184,62	184,62	184,62 l/h.e./d
• Según población	200,00	200,00	200,00	200,00 l/h/d

Fig. 6. Starting data of the Marismas del Odiel WWTP (Source: author)

A. *Starting data and design requirements*

The main starting data of the WWTP are reflected in the Fig. 6., where it is highlighted that the daily flow is 28,400 m^3/day and the maximum hourly inflow is 5,425 m^3/h. biological contamination, which is reflected in the starting data, can be considered as a strong concentration, not being altered by industrial activities located in the basin area. The data on suspended solids are slightly higher than usual, as two of the three towns (Punta Umbría and El Rompido) are in the beach area.

Finally, it should be noted that the characteristics of the effluent at the exit of the secondary treatment had to comply with the current regulations established below:

- COD < 125 mg/l
- BOD5 < 25 mg/l
- SS < 35 mg/l
- Ntotal < 10 mg/l
- Total < 1 mg/l

As for the design and subsequent construction requirements, they were as follows:

- Part of the discharge of outlet water used as reused water, rest to natural park.
- High seasonality winter / summer. Modularity to select the necessary treatment lines and cope with seasonal fluctuations in flow and contamination.
- Layout in plan, considering the logical sequence of the process, the topographical characteristics, constrained between the access road to Punta Umbría and the natural park.
- Elimination of nutrients, required to avoid possible eutrophication effects in the marshes of the natural park.
- Backup and homogeneity elements for exchange between debug elements.

B. *Description of the main elements of the treatment plant*

The treatment is composed of two lines: water line, and mud line. The water line comprises the following stages:

- Arrival of raw water through 5 collectors to the pumping well, with isolation gate.
- Pretreatment composed of 3 main roughing lines with 30 mm thick coulter and 3 mm fine sieve with a passage light. There is a by-pass line of 30 mm of passage light. The pre-treatment ends with a de-degreasing in 3 lines by means of aerated 14 m long and 3.5 m wide sand traps-degreasers with a central bridge and sand extraction for classification and extraction of grease for concentration.
- Biological reactor with a volume of 36,888 m3, divided into three lines of 12,296 m3. The reactor is 103 m long and 78 m wide. Each line is 25.9 m wide. Each line is divided into three zones: anaerobic zone (15%); anoxic zone (30%) and oxic zone (55%). Aeration in the oxic zones is carried out by 5 blowers (4+1R) of 6,235 Nm3/h/ud. In the anoxic and anaerobic zones, two submerged horizontal agitation systems have been installed to prevent the sedimentation of organic matter. The stability of the system is ensured by two recirculations, an external recirculation from the decanters

to the anaerobic zone of each reactor line and an internal recirculation from the oxic zone to the anoxic zone of each reactor line.

Fig. 7. Odiel Marshes WWTP in 2012 (Source: author).

- The decantation of the organic matter is carried out by means of three mobile bridge decanters and articulated scrapers of 32 m in diameter and a 3.4 m vertical draft of the landfill.
- Tertiary treatment consisting of two microfiltration channels with fabric discs and UV disinfection system of 592 m3/h/channel.

The sludge line comprises the following stages:

- Thickening of excess sludge by means of 2 gravity thickeners of 18 m diameter and 4.5 m draft in the vertical of the landfill.
- Sludge dewatering by means of two centrifuges with a capacity of 34 m3/h/unit, with amalgamation polyelectrolyte dosing.
- Storage of dewatered sludge in hopper to ensure a storage capacity of more than 72 hours.

C. *Nutrient removal.*

Conventional biological treatment of urban wastewater is generally aimed at the biodegradation of organic matter. Increasingly, however, the concentration of nitrogen components (mostly ammonia, ammonium, and organic nitrogen) in the receiving channel is required to be low to protect natural life that is sensitive to these compounds, especially at somewhat alkaline pH (Larrea, 2007) .

To achieve, above all, the elimination of ammonia nitrogen, the generation in the biological process of a special process based on microorganisms that oxidize these elements to convert them into nitrates. This is what is called NITRIFICATION. These elements are also harmful to the receiving channel since they can cause eutrophication. To avoid this, another process completely different from nitrification is needed, DENITRIFICATION, which consists of the reduction of nitrates, in an anoxic environment, to nitrogen gas.

The nitrification process takes place through two sequential stages through two different types of microorganisms: Nitrosomes and Nitrobacters, of an autotrophic type and with different reaction speeds. This process affects the design phase of WWTPs because their reactions consume oxygen and alkalinity, which are also necessary for the biodegradation of organic matter, so it may happen that these consumptions are not considered in this phase and may lead to faulty operation(Rodriguez et al., 2000).

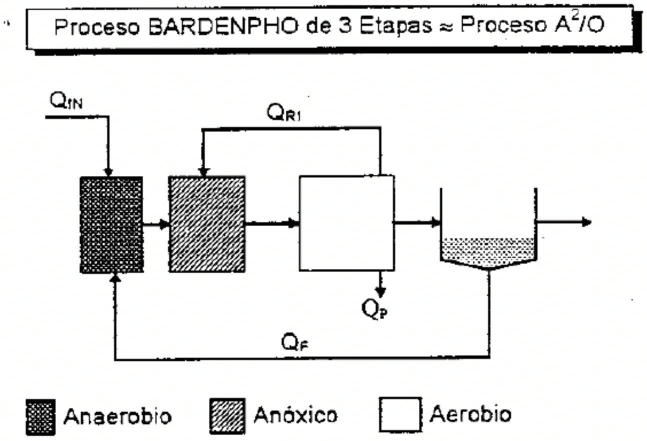


Fig. 8. Bardenpho or A2O process used in Marismas WWTP (Source: Larrea)

In addition to nitrogen, the existence of phosphorus in wastewater from household cleaners, fertilizers, and human and animal excretions can contribute, along with nitrates, to the eutrophication of watercourses. Barnard's studies describe a process of phosphorus elimination, by biological means (there is another process of phosphorus elimination by chemical means by dosing of ferric chloride), through heterotrophic phosphorus accumulating bacteria (PAO), through two phases: a first phase, under anaerobic conditions, which produces soluble phosphorus, and a second phase, under aerobic or oxic conditions. where these bacteria accumulate phosphorus, being evacuated by decantation (Barnard, 1976) .

The secondary system of choice for nutrient removal and biodegradation of carbon organic matter was the modified BARDENPHO or A2O system patented by Spector in 1976. This system can be seen in Fig. 8. (Esfahani et al., 2018). Prior to its completion on site, its dimensioning and characterization were studied in various research centers of the University of Navarra, Valladolid and Seville.

D. *Main stakeholders in the project*

In addition to the difficulty of implementing advanced water purification technology, another added difficulty was the fact of building the treatment plant in a narrow space, as indicated above, and right next to a natural park. In addition, another important conditioning factor was the execution time, which led to the duplication of construction, installation and control companies through compression or "crashing" processes of the execution units.

Therefore, an essential element in the management of this project was the general identification of stakeholders, the analysis of their expectations and their impact on the project, to be able to develop appropriate management strategies to achieve their effective participation in decision-making and in the execution of the project. The figure (make a cross-reference) has listed the most important stakeholders for this project, in the execution phase.

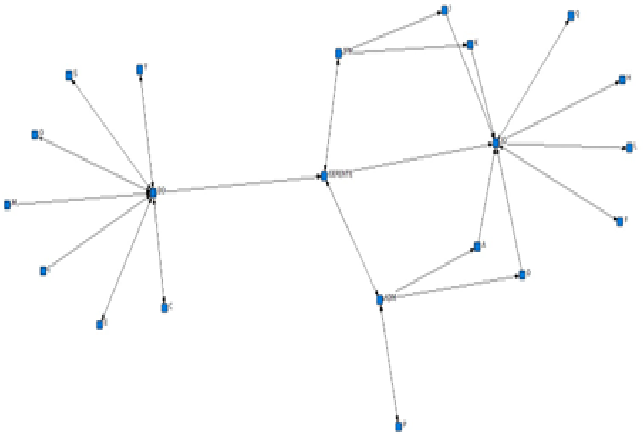


Fig. 9. Marismas del Odiel WWTP contractual network (Source: author)

V. APPLICATION OF THE COMPLEXITY TOOL TO THE MARISMAS WWTP

The Adami and Verschoose methodology is applied through the structural analysis of the three levels, contractual, supplies and resources and information among the interested parties or stakeholders. This example has been based on the review of the documentation on the project available to the author and has been carried out on the main components.

In this network, represented in Fig. 9, the manager of the joint venture has a contractual relationship with the administration through the figure of the DO (construction manager) who hires his work team to control the development of the project. The project manager (MANAGER), in turn, has a contractual relationship with the person in charge of administration (ADM), with the site manager (JO) and with the head of mechanical and start-up equipment (JPM), and in turn, each manager below the manager will hire his work team. However, the JO must supervise (not direct) some contracted elements since, although they do not report hierarchically to the site manager, they will be collaborating with him during the work. The network is not managed, except in the cases of supervision mentioned, since the contract binds the two actors in the fulfillment of it. Hiring is not carried out by managers, but normally, proposals for hiring or transfer of personnel are made according to the criteria of these managers.

TABLE I
NETWORK OF STAKEHOLDERS OF THE MARISMAS WWTP PROJECT (SOURCE: AUTHOR).

Name	Agent
I1	Ayuntamiento
I2	Construction Company 1
I3	Installation Company 1
I4	Management Company 1
MANAGER	MANAGER
I5	Management Company 2
JO	JO
I6	Environment administration
DO	DO
I7	Construction Company 2

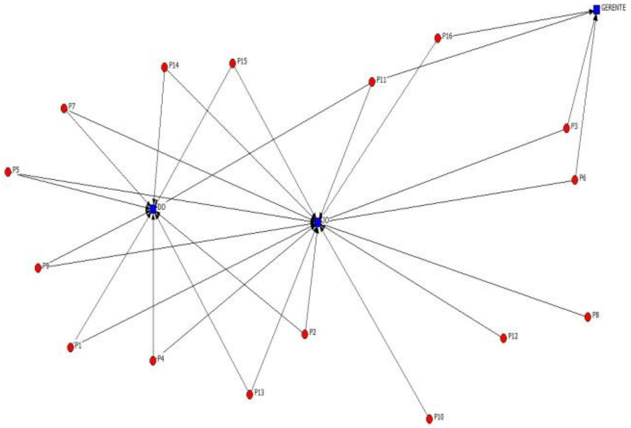


Fig. 10. Marismas del Odiel WWTP supply network (Source: author)

- Network Supplies and Resources:

In this network, represented in Fig. 10.**Error! Reference source not found.**, the supplies of the main resources and goods purchased during the implementation of the project have been presented. This network has been created, unlike the previous one, as a directed network, since it is the suppliers who send the necessary equipment or services to the project. It has been considered that the JO is the maximum responsible for the contracts, except for four of the contracts, (piling work, blowers, electrical system and control system) in which the MANAGER participates since these contracts were of vital importance for the work, and he should be included. Later they will be referred to the different subordinates responsible. The figure of the DO is included because the resources must be approved by him or by whoever depends on him for approval. Suppliers have been marked in red and project members in blue.

It was said earlier, when studying the metrics to measure the structure of a complex system, that information is the main element of complexity in a construction project. This study focuses on stakeholder networking and information.

Given that this work is subject to confidentiality in the main contractor and subcontractor companies, it has not been possible to record the name of these. Not all stakeholders have had the same role throughout the project life cycle. Therefore, only a snapshot of the main stakeholders at the peak of the project implementation has been included in the table.

The table of interested parties that were detected during the implementation of the project is first established, materialized in Table 1.

The information network of interested parties is now briefly studied. It is interesting, previously, to analyze some parameters of network centrality, which were previously exposed, when these were addressed theoretically. To this end, the UCINET programme will be used, as previously done in previous sections.

One of the most interesting parameters of centrality is the identification of the "most important actors in the network", and this can be addressed under three concepts:

- Centrality of degree. It is based on locating those nodes that have more links. In other words, they are more interconnected. As can be seen in Fig. 11, the site manager

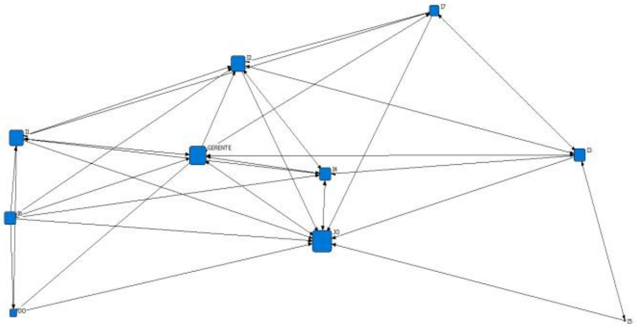


Fig. 11. Stakeholder information network. Centrality of degree (Source: Author)

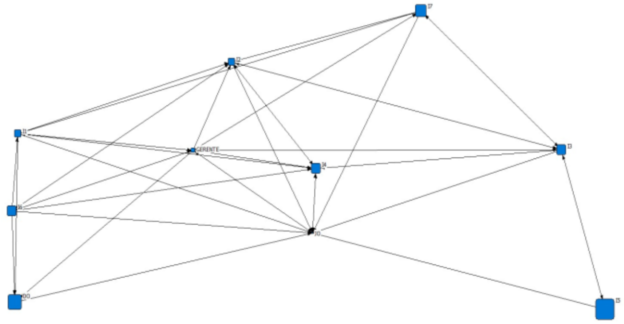
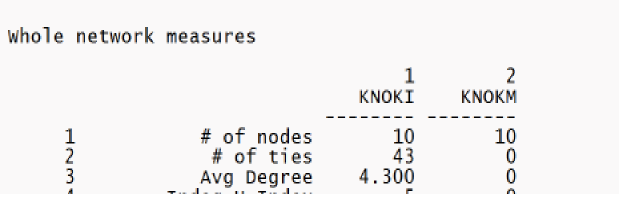


Fig. 12. Stakeholder information network. Centrality of proximity (Source: author)

(JO) is the actor who is most interconnected with the rest of the stakeholders, outside and inside the work. This representation that is made fits the scenario, since this actor is one of the most important in a construction project. Below him, is the MANAGER, as the legal representative of the contractor in the work. External to the contract, there is an interested party named as I1 who is one of the most active and who in this case corresponded to the representative of the town council of the town where the WWTP was placed and who raised numerous demands during the project.

- Centrality of proximity. It indicates which node goes faster and more efficiently from one node to another. As can be seen in Fig. 12, node I5, which corresponds to control company 2 that carried out the control link with the water company in the area, has a greater preponderance over the network than the rest. It is only related to node I3, which corresponds to the installation company 1 and to the JO. This fact corresponds to the continuous changes in the prescriptions to be made in the control and SCADA and their impact on the needs of the installation of the equipment to be controlled. Apparently, you could believe that I4, Control Company 1, company that installed the control equipment of the plant or the JO could be the most important nodes, but here the speed of change is measured and that is achieved when you are weakly connected.



```
Whole network measures

                                  1        2
                              KNOKI    KNOKM
                           -------- --------
     1            # of nodes       10       10
     2            # of ties        43        0
     3           Avg Degree     4.300        0
```

Fig. 14. Parameters obtained from the network through the UCINET program (Source: author)

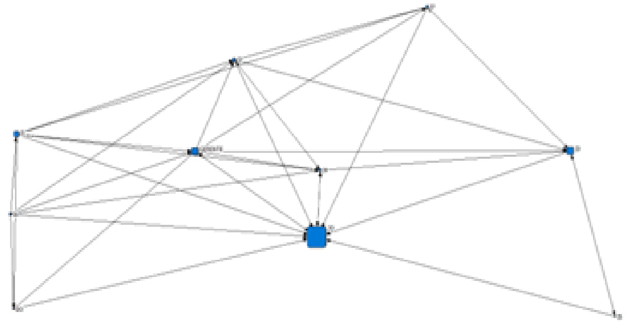


Fig. 13. Stakeholder information network. Centrality of intermediation (Source: author)

- - Centrality of intermediation. In this case, the frequency at which a node acts as a bridge on the shortest path between two nodes, whatever it may be, is quantified. In this case, the intermediary node is the one that can control or regulate the flows of information. In the Fig. 13 it can be seen how the intermediation node is the JO. And this is what happens. All the information passes through the site manager, and oversees transmitting it to the rest of the network:

Although it can be achieved by traditional counting methods, the UCINET program can acquire the three parameters needed to obtain structural complexity. In the case of the information network of interested parties of the Marismas WWTP that is being analysed, the following data are obtained:

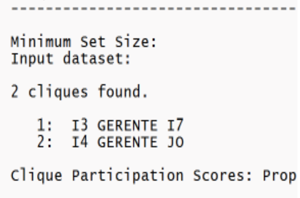
In this network there are, therefore, 10 nodes and 43 links. In this case, the network of interested parties is represented as a directed network, so the number of links is the one that appears in Fig. 14. It may happen that the network of interested parties is represented as a non-directed network, in which case, the actual number of links will be half of those obtained with the UCINET programme.

The average grade of each node is 4.3. In addition, the number of strongly connected components (SCC) can be obtained, which is the third variable in the calculation of structural complexity. This parameter indicates those actors that are closest and that are more connected to each other than the rest. This parameter is essential in small-world networks, which are the ones that are being dealt with in greater depth.

In the case analysed, there will be 2 strongly connected components, called in English by the word clique (a formal translation of this term in English would be strong connection). In Fig. 15 two SCCs are observed, the first is formed by the relationship between nodes I3, MANAGER and node I7, and the second, by the relationship between nodes I4, MANAGER and JO.

Total complexity will be the sum of structural complexity and dynamic complexity:

a) Structural complexity. By analysing the information



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Minimum Set Size:
Input dataset:

2 cliques found.

   1:  I3 GERENTE I7
   2:  I4 GERENTE JO

Clique Participation Scores: Prop
```

Fig. 15. Number and description of SCCs in the network concerned (Source: author)

network with the interested parties, the following parameters are obtained:

- Number of links (E): 43
- Number of nodes (N): 10
- SCC: 2

$$ECyM(PN) = 43 - 10 + 2 = 35 \qquad (7)$$

A cyclomatic complexity of 35 is obtained, therefore, as it is a value greater than 20, the Marismas del Odiel WWTP project has a structural complexity value equal to 5.

b) Dynamic complexity. In this case, it is observed that the number of nodes in the network is 10, therefore, as indicated in section 3.3, the Marismas del Odiel WWTP project has a dynamic complexity value equal to 4.

Therefore, the total complexity is:

$$CT = (5 + 4) = 9 \qquad (8)$$

As the value of the total complexity is equal to 9, therefore the Marismas del Odiel WWTP project corresponds to a complex project.

VI. CONCLUSIONS

The common thread in this work has been the search for a metric that could quantitatively establish how complex a project is, so that the appropriate approach can be carried out in its management beforehand.

Complexity has been divided into two dimensions, structural complexity, i.e. the structure of representation of the project through networks, and dynamic complexity, referring to the coevolution between states and interactions, of this multinetwork. Both have limited themselves to analysing a component of the multi-network of a project, the information network between stakeholders, since this exchange of information can be important when developing and executing a project.

The metric selected for the study of structural complexity has been the extended cyclomatic complexity of McCabe on networks with strongly connected components, such as those established in technical projects since such networks are considered small world.

The metric selected for the study of dynamic complexity has been based on the work of Iñiguez and Barrio, who propose the measurement of coevolution as a function of the average degree of the network, the number of nodes and its average clustering.

These metrics have been applied to a construction project, in this case the Marismas del Odiel WWTP in Huelva, studying, firstly, the structural complexity through the network of stakeholders, analysing some of its main components and establishing that this structural complexity had a very high value. Secondly, the dynamic complexity of this network has been studied, finding that its value was also high, due to the low level of nodes in the network.

It has been determined, from the data obtained on structural and dynamic complexity, that the construction project of the Marismas del Odiel WWTP had a high total complexity. As it happened.

Therefore, the use of these metrics can help us to measure complexity, and establish tools beforehand, to determine what type of approach is the most appropriate to manage a project, both at the beginning and during its execution.

Finally, it should be noted that in this work only the network of stakeholders has been studied, but its expansion would be necessary, with the study of the contractual networks and the networks of resources that are used in the execution of the project and this with the aim of having a more complete vision of the complexity in a technical project.

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