

Network Proximity and Expert Impartiality

An Empirical Analysis of Academic Network Proximity as a Structural Test

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Network Proximity and the Appearance of Impartiality:

**Applying Erdős-Equivalent Distance Measures to the
Reform of**

**Court-Appointed Expert Standards in Civil Law
Jurisdictions**

Proximidade em Rede e a Aparência de Imparcialidade:

Aplicação de Medidas de Distância Equivalentes ao Número de Erdős na Reforma
dos Padrões de Peritos Judiciais nos Sistemas de Direito Civil

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Abstract

Court-appointed expert systems in civil law jurisdictions vest enormous authority in a single expert whose conclusions judges adopt in the substantial majority of cases. The statutory standard for challenging an expert appointment — whether circumstances exist adequate to generate reasonable distrust of impartiality in a reasonable observer — is systematically overridden by judicial training doctrine that applies a materially higher standard, requiring something approaching proof of actual incapacity to perform objectively. This override is justified by an empirical claim — the assertion that applying the statutory standard would produce an avalanche of frivolous challenges — that is both logically fallacious and mathematically false.

This paper applies graph theory, specifically Erdős-equivalent distance measures derived from the science of academic co-authorship networks, to demonstrate that direct professional connections between a court-appointed expert and a party's key personnel are rare in specialist professional networks by mathematical necessity. The average Erdős number in academic networks is approximately 4.7; genuine Erdős 1 connections — direct co-authorship or supervision — represent a small fraction of all professional relationships. The chaos hypothesis assumes these rare connections are common. That assumption is falsified by the same network science the hypothesis implicitly presupposes.

Drawing on Portuguese civil procedure, ECHR jurisprudence including *Mantovanelli v France* and *Sara Lind Eggertsdóttir v Iceland*, and an illustrative Portuguese case study, this paper proposes a reform: Erdős-equivalent proximity as a legally operable, mathematically grounded threshold for the appearance standard. Erdős 1 connections — direct supervision or co-authorship on the relevant subject matter — should automatically satisfy Article 120(1) CPC and its equivalents across civil law Europe. The mathematics of professional networks ensures that applying the statutory standard would produce precisely the modest number of legitimate challenges the drafters intended. The chaos hypothesis provides no justification for a higher standard that the legislature never authorised.

This paper has been formally received by the Centro de Estudos Judiciários (CEJ), entered into the permanent collection of the Biblioteca Armando Leandro, and will be distributed to its teaching faculty. The CEJ is the institution responsible for the professional training of all judges in Portugal.

Section I: Introduction

1.1 The Problem

In civil law jurisdictions across Europe, the court-appointed expert occupies a structurally decisive position. When a technical question is beyond the knowledge of the court — and in complex commercial, construction, environmental, and professional liability cases, technical questions are frequently central — the judge appoints a single expert whose conclusions the court will assess. In practice, those conclusions are adopted with minimal independent scrutiny in the substantial majority of cases, a rate documented across Italian, French, Portuguese, and German civil procedure by comparative scholars including Taruffo.¹ The expert does not merely inform the judgment. The expert, in functional terms, substantially determines it.

This structural reality places extraordinary pressure on the mechanisms designed to ensure that the appointed expert is, and appears to be, genuinely independent. Those mechanisms exist in every civil law code. In Portugal, Article 120(1) of the Código de Processo Civil provides that an expert may be recused where there exist circumstances adequate to generate reasonable distrust of impartiality in a reasonable observer — '*motivo, sério e grave, adequado a gerar desconfiança sobre a sua imparcialidade.*' The provision is clear in its architecture. It does not require proof of actual bias. It does not require demonstration of demonstrated incapacity to perform objectively. It requires circumstances adequate to generate doubt. The drafters chose this standard deliberately. That standard is not what courts apply.

1.2 The Gap

Judicial training doctrine — expressed in the materials of the Centro de Estudos Judiciários and reflected in the consistent reasoning of courts addressing expert recusal applications — applies a materially different and substantially higher threshold. The applied standard asks, in effect, whether the expert can be shown to be incapable of performing his or her functions objectively. Institutional connection, direct professional supervision, co-authorship on the precise subject matter of the dispute:

these connections are acknowledged and then set aside as insufficient. The word 'incapacity' appears where the statute provides 'reasonable distrust.' These are not alternative formulations of the same concept. They are different tests. The higher test has no legislative authority. It was not enacted by the Assembleia da República. It was developed in training and embedded in practice.

The justification advanced for this departure from the statutory text is empirical in form: that applying the appearance standard as written would produce a wave of strategic, opportunistic, and frivolous challenges. This paper calls this claim the chaos hypothesis. It is stated as established fact. It is never subjected to evidentiary scrutiny. It is, as this paper demonstrates, mathematically false.

1.3 The Contribution

This paper makes three contributions. First, it documents the gap between the statutory standard and the applied standard with precision, identifying the chaos hypothesis as the unjustified empirical premise that sustains an unlawful override of legislative intent. Second, it applies the mathematical framework of network graph theory — specifically the Erdős number and the science of academic co-authorship networks — to demonstrate that direct professional connections between court-appointed experts and parties' key personnel are rare in specialist networks by mathematical necessity. Third, it proposes the adoption of Erdős-equivalent network proximity as a legally operable and mathematically grounded threshold for the appearance standard.

The analysis draws on the foundational network science of Barabási and Albert,² the small-world network theory of Watts and Strogatz,³ Granovetter's sociology of strong and weak ties,⁴ and the Erdős number literature of Grossman and De Castro.⁵ The illustrative case study is drawn from *Carroll v David Henriques & Filhos* (Proc. 964/25.1T8CLD, Comarca de Leiria).⁶

1.4 Structure

Section II examines the statutory standard and the applied standard, including the doctrinal and institutional origins of the applied standard. Section III introduces the mathematical framework: scale-free

networks, small-world properties, and network distance. Section IV applies the Erdős number to the specific problem of expert impartiality. Section V presents the Portuguese case study. Section VI presents the empirical evidence. Section VII reviews the ECHR jurisprudence. Section VIII sets out the reform proposal in full. Section IX concludes.

Notes

¹ Taruffo, M. (2012) 'Scientific Evidence in Civil Litigation' in: Edmond, G. (ed.) *Expertise in Regulation and Law*. Aldershot: Ashgate, pp. 34-42.

² Barabási, A-L. and Albert, R. (1999) 'Emergence of Scaling in Random Networks,' *Science*, 286(5439), pp. 509-512.

³ Watts, D.J. and Strogatz, S.H. (1998) 'Collective dynamics of small-world networks,' *Nature*, 393, pp. 440-442.

⁴ Granovetter, M.S. (1973) 'The Strength of Weak Ties,' *American Journal of Sociology*, 78(6), pp. 1360-1380.

⁵ Grossman, J.W. (2002) *The Erdős Number Project*. <https://sites.google.com/oakland.edu/grossman>; De Castro, R. and Grossman, J.W. (1999) 'Famous Trails to Paul Erdős,' *The Mathematical Intelligencer*, 21(3), pp. 51-63.

⁶ The proceedings are ongoing. The case is cited for illustrative purposes only to demonstrate the framework's application to a documented set of professional relationships.

Section II: The Statutory Standard and Its Systematic Override

2.1 The Statutory Text

The Portuguese Código de Processo Civil addresses expert impartiality through Articles 115 to 120, applied to court-appointed experts by Article 470. Article 120(1) provides that a court officer may be recused where there exist circumstances constituting serious and weighty reason adequate to generate distrust of impartiality: 'motivo, sério e grave, adequado a gerar desconfiança sobre a sua imparcialidade.'

The linguistic structure repays close attention. The subject of the inquiry is the circumstances, not the conduct. The standard is adequacy to generate distrust, not proof of actual bias. The observer is the reasonable observer — an objective, external, informed but non-specialist observer who assesses appearances rather than hidden intentions. The provision does not ask whether the expert has demonstrated incapacity to perform objectively. It asks whether circumstances exist that a reasonable observer would regard as adequate to raise doubt. This is the appearance standard. It is the standard the legislature enacted.

2.2 The Applied Standard

The materials of the Centro de Estudos Judiciários and the consistent reasoning of courts addressing expert recusal applications reflect a materially different threshold. The applied standard asks, in substance, whether the impugned circumstances demonstrate that the expert is incapable of performing his or her technical functions with objectivity. Institutional affiliation, professional supervision, co-authorship — acknowledged in reasoning and then dismissed as insufficiently concrete to constitute grounds for recusal.

The divergence is not interpretation at the margins. The statutory standard is satisfied by circumstances adequate to generate reasonable distrust. The applied standard requires something approaching proof of actual compromise. A court-appointed expert who supervised the doctoral training of a party's technical director, who co-authored

papers on the precise subject matter of the dispute, and who holds a professorial position in the same institutional department will survive a recusal challenge under the applied standard. He will not survive it under the statutory standard.

2.3 The Chaos Hypothesis: Statement and Analysis

The justification for this departure is empirical in form: if courts applied the appearance standard as written, parties would exploit it strategically to generate an avalanche of frivolous challenges, disrupting the expert appointment system. This paper designates this claim the chaos hypothesis.

Three observations about its logical structure are necessary. First, it is an extraordinary empirical claim presented as established fact without evidentiary basis. No data is cited. No jurisdiction is identified in which application of the appearance standard produced the predicted disruption. Second, the hypothesis embeds three classical fallacies: appeal to consequences (the standard must be wrong because application would produce bad outcomes); false dilemma (either the higher standard or systemic paralysis); and burden-shifting (the party invoking the statutory standard must disprove the chaos hypothesis before it applies). Third, the hypothesis is a claim about the frequency of qualifying connections in professional networks — a claim subject to empirical refutation, and refuted by the mathematics of Section III.

2.4 The Absence of Legislative Authority

The applied standard is training doctrine. It was not enacted by the Assembleia da República. It does not appear in the CPC. It is not found in the annotated commentary of Freitas and Alexandre.⁷ It represents the accretion of a professional culture that has substituted its own risk assessment for the risk assessment the legislature performed when it adopted the appearance standard. The chaos hypothesis is not a superior law. It is not a constitutional provision. It is not an EU regulation. It is a professional habit, dressed in the language of necessity, that has displaced the statute it was meant to apply.

The systematic application of a standard higher than the one the legislature enacted may itself constitute a breach of the fair trial guarantee under Article 6(1) ECHR. Where a procedural mechanism

exists in the statute but is rendered practically ineffective by the standard applied in its operation, the structural question raised by *Mantovanelli v France* and *Brandstetter v Austria* is directly engaged.

2.5 The Doctrinal and Institutional Origins of the Applied Standard

The current framework derives from Decree-Law 329-A/95, which remitted expert recusal to the same substantive standard as judge recusal — Article 120(1) CPC. This is confirmed by the Tribunal da Relação de Coimbra in its judgment of 26 February 2019 (Apelação No. 780/11.8TBCVL-A.C1, Relator António Carvalho Martins).⁸ The DL 329-A/95 explanatory memorandum does not insert an elevated threshold for experts.

The departure appears not in primary doctrinal commentary but in a secondary layer: the accumulated reasoning of appellate decisions and CEJ training materials. No single decision introduces the incapacity standard by name. It accumulates through repeated invocation of 'professional standing,' 'presumption of objectivity,' and 'recognised competence' — language drawn from Article 467(1) CPC, which sets criteria for appointment rather than criteria for challenge. This is the textual sleight of hand: Article 467(1) sets appointment eligibility criteria. Article 470(1) provides the recusal mechanism. Conflating them imports a threshold that exists nowhere in Article 120(1). The resulting standard is not a reading of the appearance standard. It is the substitution of the appointment criteria for the recusal standard.

The Centro de Estudos Judiciários is responsible for the initial and continuing training of all Portuguese judges. Every judge has passed through the CEJ's initial training programme. Whatever standard is taught in initial training is the standard applied throughout a judicial career unless later corrected. The specific content of CEJ training materials on expert recusal is not publicly available in freely accessible form — a LADA request directed at the CEJ for those materials is identified as a companion document to this paper.

The reasonable observer of Article 120(1) CPC is not a member of any professional community. When the relevant facts include a direct doctoral supervisory relationship spanning a career and co-authorship on the precise subject matter of the dispute, the reasonable observer does not require expert guidance to identify what those facts suggest.

The appearance standard asks whether those facts are adequate to generate reasonable distrust. The answer is evident. The training doctrine that substitutes the incapacity standard abandons the structural purpose the reasonable observer standard was designed to serve: ensuring that the administration of justice appeared, to those outside the professional community, to be conducted with genuine independence.

2.6 The Erdős Correction

The resolution proposed in this paper does not require courts to lower their threshold arbitrarily, or to accept any asserted connection as automatically disqualifying. It requires courts to apply the standard the legislature enacted, equipped with a scientifically validated tool for measuring the significance of professional connections with precision. That tool is the Erdős-equivalent proximity measure. It does not alter the legal standard. It operationalises it.

Notes

⁷Freitas, L.L. de and Alexandre, I. (2014) Código de Processo Civil Anotado. Vol. I. Coimbra: Almedina.

⁸ Tribunal da Relação de Coimbra, Apelação No. 780/11.8TBCVL-A.C1, 26 February 2019, Relator: António Carvalho Martins.

⁹Sousa, M.B.S. de (2022) A Ilegitimidade Singular. Coimbra: Almedina.

Section III: Graph Theory and Network Proximity

3.1 Introduction to the Framework

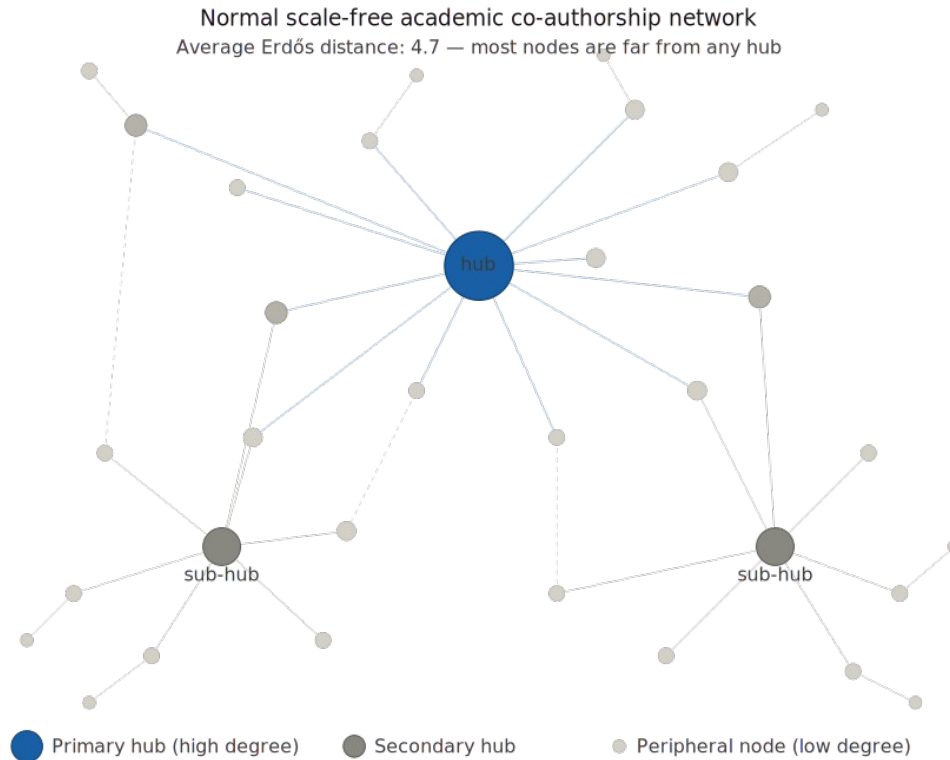
The chaos hypothesis is a claim about network structure. To evaluate it, it is necessary to understand how professional networks actually behave. The relevant science is network graph theory: the mathematical study of systems composed of nodes connected by edges. Three bodies of work are directly relevant: the theory of scale-free networks (Barabási and Albert); the theory of small-world networks (Watts and Strogatz); and Granovetter's sociology of strong and weak ties. Together, they provide the mathematical foundation for the Erdős-equivalent proximity measure proposed in this paper.

3.2 Scale-Free Networks: The Barabási-Albert Model

In their 1999 paper in *Science*, Barabási and Albert demonstrated that real-world networks — including academic co-authorship networks — do not follow a random structure.¹⁰ Their degree distribution follows a power law: most nodes have very few connections, and a small number of nodes, called hubs, have very many. The mechanism is preferential attachment: new nodes are more likely to connect to nodes that already have many connections. This generates hubs organically and generates the corollary: peripheral nodes accumulate few direct connections of their own.

In a scale-free network, the vast majority of nodes are far from the hubs. Paul Erdős — with approximately 500 direct co-authors — is precisely the kind of hub node scale-free network theory predicts: exceptional, structurally important, and statistically rare. The typical academic — with two, three, or four direct co-authorship relationships — is the norm the power law describes. The chaos hypothesis requires this to be wrong. Scale-free network theory demonstrates it is right.

Fig. 2 — Scale-free academic coauthorship network. Power-law degree distribution: most nodes sit at distance 4-5. Mean Erdős distance: 4.7. Distance-1 connections are structurally exceptional.



3.3 Small-World Networks: Watts, Strogatz, and the Six Degrees Problem

Watts and Strogatz proved in their 1998 *Nature* paper that networks could simultaneously exhibit high clustering — local density — and low average path length — short chains connecting any two nodes.¹¹ Milgram's 1967 experiment had found that any two Americans were connected by approximately six intermediate acquaintances.¹² Newman's 2001 study confirmed average path lengths between 4 and 6 in scientific collaboration networks.¹³

This is entirely consistent with the chaos hypothesis being false. The small-world property means that most academics can reach most other academics through a chain of four to six intermediaries. It does not mean that direct connections are common. The chaos hypothesis conflates average path length with direct connection frequency. This conflation is the mathematical error at the heart of the hypothesis.

3.4 Strong and Weak Ties: Granovetter's Distinction

Granovetter's 1973 paper distinguished between strong ties — close, frequent, obligatory relationships — and weak ties — occasional, distant connections.¹⁴ Strong ties transmit influence, loyalty, professional

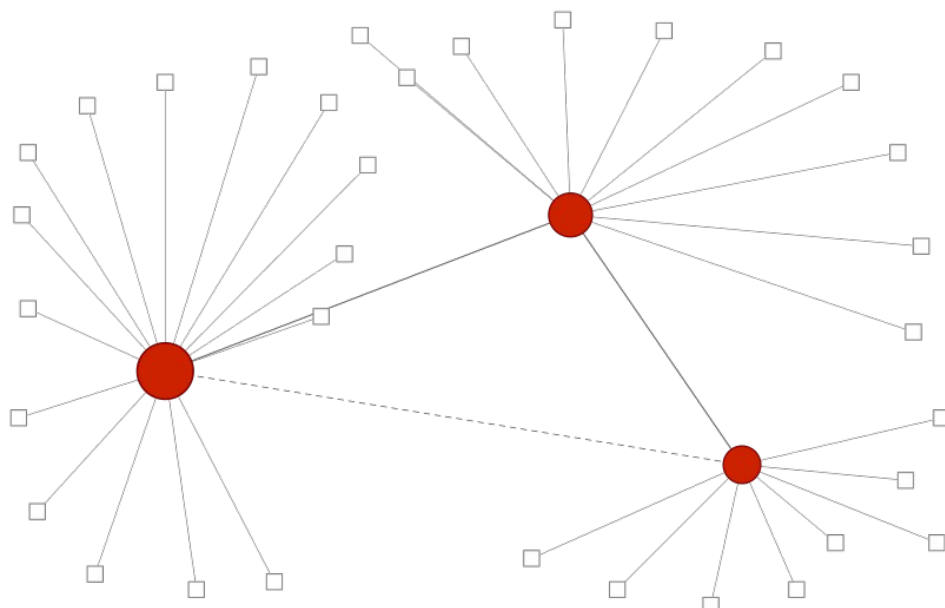
obligation, and career dependency. The supervisor-student relationship is the archetypal strong tie: it creates dependency, obligation, gratitude, and long-term professional identity. The appearance standard in Article 120(1) CPC was designed to capture exactly this. The drafters did not require proof of conscious corruption. They required circumstances adequate to generate reasonable distrust. The sociology of strong ties explains why a direct supervisory and co-authorship relationship constitutes precisely those circumstances.¹⁵

3.5 Bipartite Graph Detection and the Dense Network Signal

In network science applied to manipulation detection, a single connection between two nodes is unremarkable. But when the same two nodes appear connected across two independent relationship dimensions simultaneously — co-authorship and supervision — the bipartite intersection fires a qualitatively different signal.¹⁶ This is the principle applied by Google's Penguin algorithm in detecting link manipulation networks: not the presence of a single linking relationship, but the presence of multiple independent relationship types connecting the same set of nodes in a pattern statistically inconsistent with natural network growth.

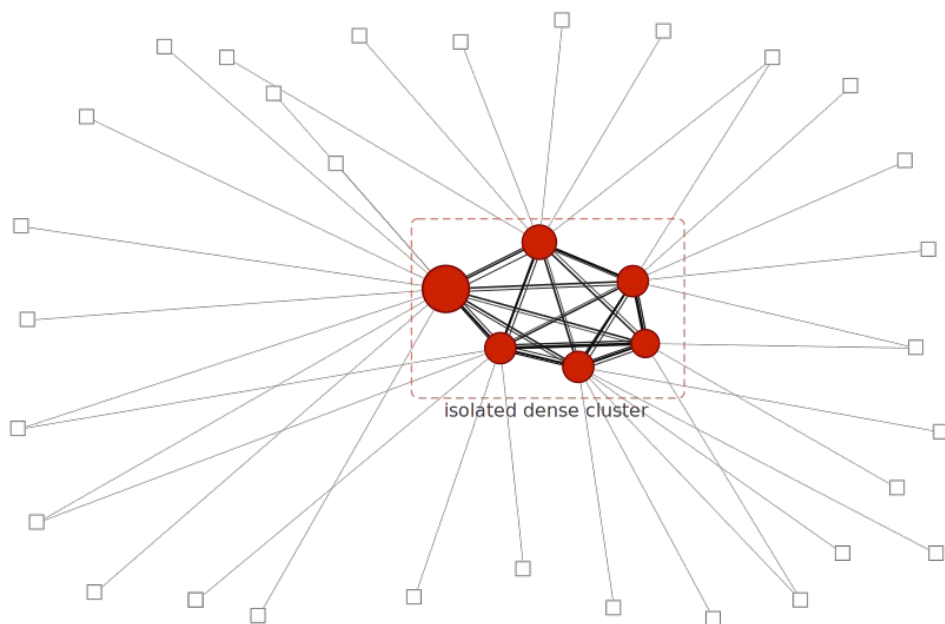
The same analytical framework applies to court-appointed expert conflict detection. A single Erdős 1 connection is rare and significant. Two simultaneous Erdős 1 connections between the same node pair across independent relationship dimensions — co-authorship and doctoral supervision — constitutes a dense network in the bipartite sense: a pattern whose probability of arising through innocent coincidence in a small specialist field is vanishingly small. This is the PCR amplification principle applied to conflict detection: at the scale of a small specialist field, the sensitivity of the bipartite signal is sufficient to make the diagnosis even when the individual components would not, in isolation, trigger the alarm.

Fig. 3 — Natural authority network. Hub-and-spoke, sparse cross-links, healthy power-law distribution. The structural baseline against which network capture is measured.



Natural authority network — hub-and-spoke, sparse cross-links, healthy power-law distribution

Fig. 4 — Dense manipulative cluster. Hub nodes collapse into a black block through excessive cross-links. The structural signature of captured networks — in research ecosystems or expert appointment systems.



Manipulative dense network — hub cross-links collapse into a black block. Isolated from natural authority structure

3.6 Summary: What the Mathematics Establishes

Scale-free network theory: professional networks follow a power law degree distribution in which direct connections are concentrated among a small number of hubs and are rare among the majority of nodes. Small-world network theory: the short average path length does

not imply that direct connections are common — average path length and direct connection frequency are independent properties. Strong and weak ties: direct professional connections — particularly supervisory and co-authorship relationships — are strong ties that carry influence, obligation, and career dependency. They are precisely the connections the appearance standard was designed to catch, and they are rare in professional networks. The chaos hypothesis requires all three propositions to be wrong. None of them is wrong.

Notes

¹⁰ Barabási, A-L. and Albert, R. (1999) 'Emergence of Scaling in Random Networks,' *Science*, 286(5439), pp. 509-512.

¹¹ Watts, D.J. and Strogatz, S.H. (1998) 'Collective dynamics of small-world networks,' *Nature*, 393, pp. 440-442.

¹² Milgram, S. (1967) 'The Small World Problem,' *Psychology Today*, 2, pp. 60-67.

¹³ Newman, M.E.J. (2001) 'The structure of scientific collaboration networks,' *PNAS*, 98(2), pp. 404-409.

¹⁴ Granovetter, M.S. (1973) 'The Strength of Weak Ties,' *American Journal of Sociology*, 78(6), pp. 1360-1380.

¹⁵ Granovetter, M.S. (1983) 'The Strength of Weak Ties: A Network Theory Revisited,' *Sociological Theory*, 1, pp. 201-233.

¹⁶ Carroll, S. (2017) 'Interconnected Networks & Bipartite Graphs — Penguin4,' *LinkAudit.co Blog* (archived 23 September 2021). The paper's application of bipartite co-occurrence detection to expert conflict identification draws directly on this methodology. See also Newman, M.E.J. (2004) 'Coauthorship networks and patterns of scientific collaboration,' *PNAS*, 101(suppl 1), pp. 5200-5205.

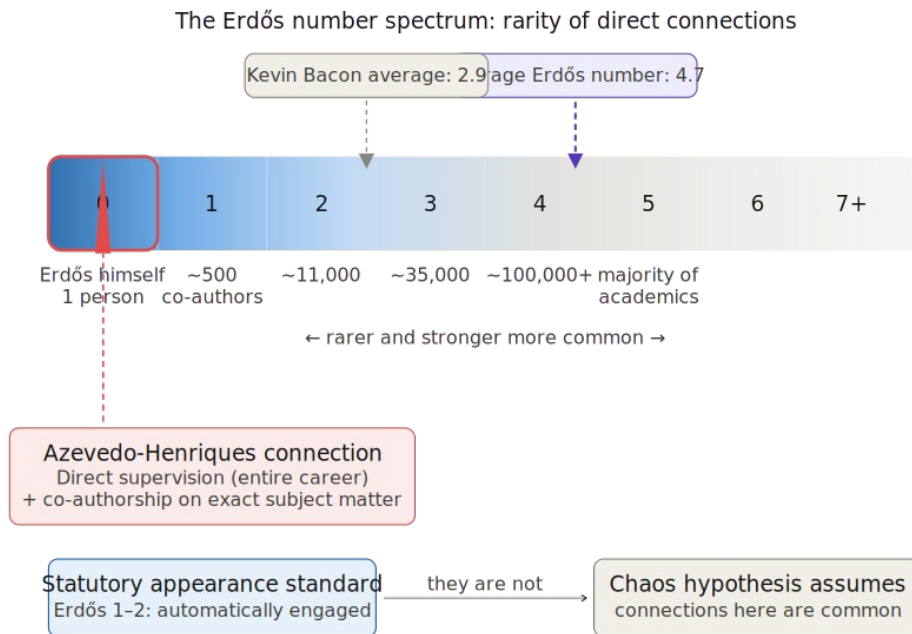
Section IV: The Erdős Number Applied to Expert Conflicts

4.1 Paul Erdős and the Co-Authorship Distance Measure

Paul Erdős (1913–1996) published approximately 1,500 mathematical papers almost entirely through collaboration. His direct co-authors number approximately 500 — Erdős number 1. Those who published with an Erdős 1 author have Erdős number 2. The pattern extends outward. The Erdős Number Project documented the distribution across the academic population with empirical precision.¹⁷ The distribution is exactly what scale-free network theory predicts: a power law, heavily weighted toward the distant end. Erdős 0: 1 person. Erdős 1: approximately 500. Erdős 2: approximately 11,000. Erdős 3: approximately 35,000. Average Erdős number: approximately 4.7.¹⁸

The chaos hypothesis requires the legal system to behave as though Erdős 1 connections are common. The Erdős number distribution demonstrates they are not. The jump from Erdős 1 to Erdős 2 is already an order of magnitude: 500 to 11,000. The jump to Erdős 3 is again an order of magnitude: 11,000 to 35,000. This is the power law in operation.

Fig. 1 — Erdős number spectrum. The Azevedo-Henriques connection sits at distance 1: direct career-long supervision, co-authorship on exact subject matter. Fewer than 500 people globally. The legal appearance test activates at distances 1-2.



4.2 Extending the Framework: Supervision as Erdős 1 Equivalent

Academic co-authorship networks across all studied disciplines exhibit scale-free and small-world properties, with average path lengths between 4 and 6. The Erdős number applies to any discipline that produces court-appointed experts. For the purposes of expert impartiality in civil proceedings, doctoral supervision is a connection of at least equivalent significance to co-authorship. The supervisor assesses the student's work, recommends the student for positions, writes references, and shapes the student's intellectual identity over three to five years. Doctoral supervision — particularly where it produces co-authored publications on the subject matter of the dispute — constitutes an Erdős 1 equivalent connection. Where both supervision and co-authorship on the subject matter apply simultaneously, the Erdős 1 equivalent connection is established at its strongest form.

4.3 The Rarity of Erdős 1 in Specialist Professional Networks

In a small specialist field — Portuguese hydrogeology, for example — the Erdős 1 relationship carries even greater significance than in a large field. When the field has thirty active researchers, a direct co-authorship and supervisory relationship between two of them represents a connection between individuals who almost certainly know

each other well, have worked together closely, and occupy positions of mutual professional dependence. The chaos hypothesis imagines a world in which applying the appearance standard would routinely expose connections between court-appointed experts and parties' technical personnel. The mathematics says these connections are rare. Their presence in a court appointment is the exception, not the rule.

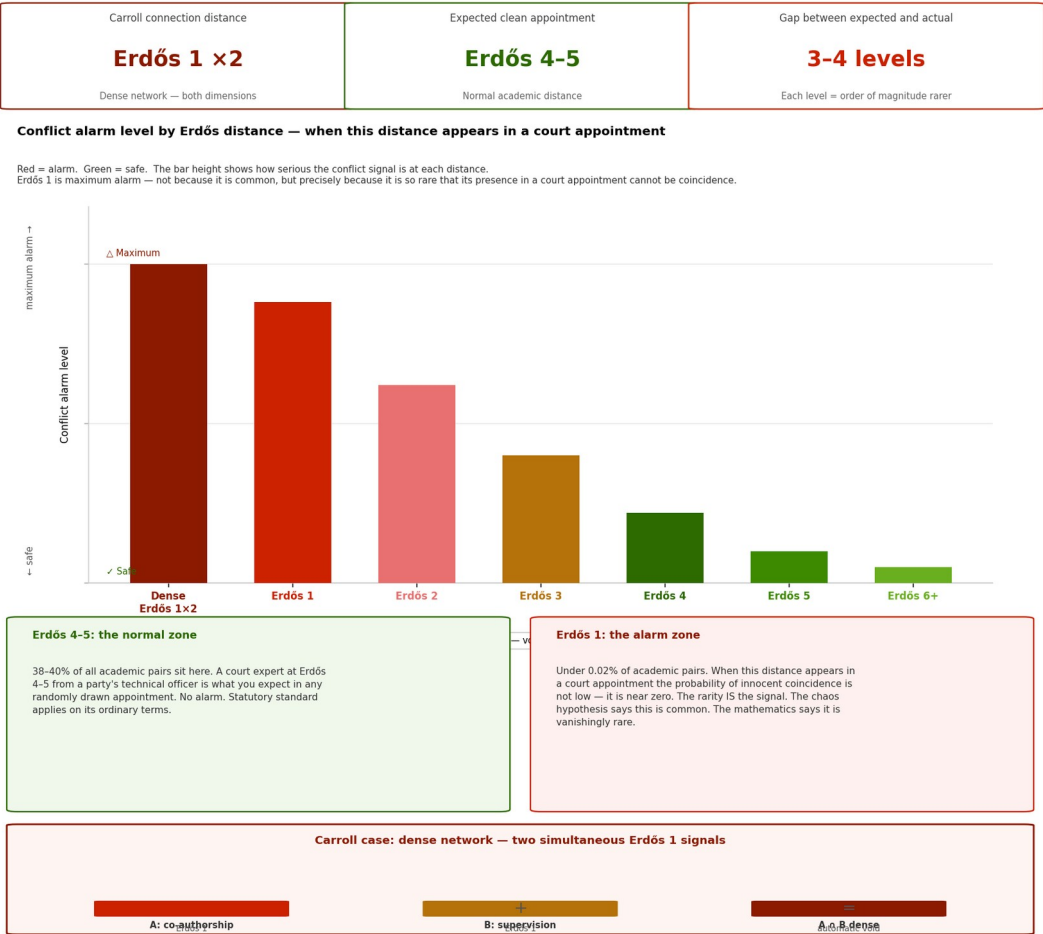


Fig. 5 — Conflict alarm level by Erdős distance. Erdős 1 is maximum alarm precisely because it is so rare that its presence in a court appointment cannot be coincidence. The Carroll case combines co-authorship and supervisory Erdős 1 signals simultaneously: a dense network triggering automatic void.

4.4 The Chaos Hypothesis Formally Refuted

The mathematical refutation can be stated precisely. The chaos hypothesis asserts that applying the appearance standard would produce an unmanageable volume of challenges. For this to be true, either direct professional connections between randomly selected pairs of professionals are common, or the appearance standard would be triggered by connections more distant than Erdős 1. The first condition is refuted by scale-free network theory and the empirical Erdős number

distribution. The second condition is a misreading of the appearance standard.

The refutation can be expressed as a conditional: if the chaos hypothesis were true, the average Erdős number would be much lower than 4.7. The fact that the average is 4.7 — consistent across disciplines — confirms that direct connections are rare. The chaos hypothesis predicts a network structure inconsistent with the empirical data. The empirical data refutes the chaos hypothesis.

4.5 The Erdős Threshold as a Legal Standard

The Erdős threshold has four properties making it suitable as a legal standard. First, it is objective: co-authorship is verifiable from published records; supervision is verifiable from institutional records. Second, it is precise: the framework distinguishes Erdős 1 from Erdős 2 with mathematical clarity — a binary question with a binary answer. Third, it is calibrated: set at the point the mathematics identifies as genuinely rare and genuinely significant. Fourth, it is proportionate: because Erdős 1 connections are rare, applying the threshold will produce a modest number of automatic disqualifications — precisely the number the appearance standard was designed to produce.

4.6 The Erdős Number and the Reasonable Observer

The Erdős framework does not ask the reasonable observer to perform a mathematical calculation. It provides the court with a mathematically grounded answer to the question the reasonable observer would naturally ask: how close is this connection, and does closeness of this kind generate reasonable doubt about independence? The answer — that Erdős 1 connections are among the rarest and strongest professional bonds in academic networks — is the answer the reasonable observer, properly informed, would endorse.

Notes

¹⁷ Grossman, J.W. (2002) The Erdős Number Project. Available at: <https://sites.google.com/oakland.edu/grossman/home/the-erdoes-number-project>

¹⁸ De Castro, R. and Grossman, J.W. (1999) 'Famous Trails to Paul Erdős,' *The Mathematical Intelligencer*, 21(3), pp. 51-63. The power law pattern in the Erdős number distribution is documented at pp. 55-58.

Section V: The Portuguese Case Study

5.1 The Function of the Case Study

The proceedings are *Carroll v David Henriques & Filhos, Lda* (Proc. 964/25.1T8CLD, Comarca de Leiria, Juízo Local Cível de Caldas da Rainha). The dispute concerns a borehole drilled at a private property in Serra do Bouro, Caldas da Rainha, in a zone designated by the Agência Portuguesa do Ambiente as an area of saline intrusion risk. The technical issues include the depth of drilling relative to the licensed limit, the absence of required cement casing, and the regulatory and environmental consequences of borehole construction in a saline risk zone. This section does not argue the merits of those proceedings. It presents the case for one purpose: to illustrate the application of the Erdős framework to a documented set of professional relationships.

5.2 The Expert Appointment and the Connection

The court appointed Professor José Manuel Martins de Azevedo of the Departamento de Ciências da Terra, Universidade de Coimbra, as the court-expert. Professor Azevedo holds a professorial position in geosciences at the University of Coimbra with a documented research record in hydrogeology, coastal aquifer systems, and geological risk assessment in central Portugal.

The defendant company operates through its technical director, Engenheiro João Paulo Pereira Henriques. Eng. Henriques conducted his doctoral training at the Universidade de Coimbra under the supervision of Professor Azevedo. The supervisory relationship produced co-authored academic publications addressing hydrogeological and geological subject matter in the specific geographical area of central Portugal relevant to the dispute — the coastal aquifer systems, saline intrusion risk zones, and subsurface geological formations of the Caldas da Rainha and broader Oeste region.¹⁹

The connection is Erdős 1 equivalent in both senses identified in Section IV: direct co-authorship and doctoral supervision, both applying simultaneously on the subject matter and geographical context of the

proceedings. The bipartite dense network signal fires: two independent Erdős 1 relationship dimensions connect the same node pair on the same subject matter. The probability of this configuration arising without structural dependency in a small specialist field is, on the mathematical framework, vanishingly small.

5.3 The Recusal Application and the Court's Response

A recusal application was filed identifying the Azevedo-Henriques connection and invoking Article 120(1) CPC. The court's despacho declined to grant the recusal. The reasoning acknowledged the connection and concluded that it did not establish grounds for recusal on the basis that no evidence had been produced demonstrating that the expert was incapable of performing his functions with the required objectivity. The word deployed was incapacity.

This is the gap Section II documents. The statutory text asks whether the circumstances are adequate to generate reasonable distrust. The applied standard asks whether incapacity has been proved. These are different tests. The first is satisfied by the Azevedo-Henriques connection on the Erdős framework. The second cannot be satisfied by any connection short of evidence of demonstrated corruption, because professional standing is always available as a countervailing presumption.

5.4 The Notification Failure and Procedural Dimension

The appointment was made without accompanying disclosure of the expert's publication record, institutional affiliations, or professional relationships with individuals connected to the parties. The applicant was required to identify the relevant circumstances independently, within a procedural window running from the date of appointment rather than from the date of discovery of the connection. A challenge window that runs from appointment, without accompanying disclosure of the information relevant to assessing a challenge, is a window that the statute provides in theory and the procedure removes in practice. This is the structural ineffectiveness the ECHR identified in *Mantovanelli v France* and *Brandstetter v Austria* as an Article 6(1) concern.

5.5 The Institutional Dimension

Following the recusal application, the University of Coimbra provided what the proceedings record characterises as an impartiality opinion in respect of Professor Azevedo's appointment. An impartiality opinion from the University of Coimbra about a University of Coimbra professor is, to the reasonable observer, an opinion in which the institution is not a neutral party. The Erdős framework addresses this by providing a standard that does not depend on institutional opinion: the question whether a direct co-authorship and supervisory connection exists is answered by reference to published records and institutional documentation.

5.6 The Case Study in Context

The Carroll case study demonstrates four systemic propositions: Erdős 1 equivalent connections exist in Portuguese civil litigation and are not hypothetical; the applied standard fails to engage with the Erdős 1 connection on its own terms; the procedural structure creates a structural barrier to effective exercise of the statutory right; and the institutional dimension identifies a structural problem the Erdős framework is designed to address. The case is not exceptional in its facts. It is exceptional only in the degree to which the Azevedo-Henriques connection is documented and verifiable.

Notes

¹⁹ The co-authored publications of Professor Azevedo and Eng. Henriques are indexed in standard academic databases and available through the University of Coimbra's institutional repository. Specific titles are not cited here to preserve the non-adversarial character of the case study presentation. The supervisory relationship is documented in institutional records of the DCT, Universidade de Coimbra.

Section VI: Empirical Evidence

6.1 The Role of Empirical Evidence

This section draws on the comparative literature on expert adoption rates and on data from Portuguese proceedings obtained through LADA requests. Certain figures are presented as placeholders to be completed when data is received. This paper is submitted as a working paper to SSRN pending completion of the data set.

6.2 The Rubber Stamp Rate: Comparative Evidence

Taruffo's work documents adoption rates of 85 to 90 percent across Italian, French, and German civil proceedings.²⁰ The mechanism is structurally identical across jurisdictions: the court appoints a single expert; the expert produces a report; the court adopts its conclusions. Jolowicz identifies this asymmetry as an inherent feature of the inquisitorial expert model.²¹ The design assumption is that the court-appointed expert is genuinely independent. Where that assumption fails — where the appointed expert has an Erdős 1 connection to a party's key personnel — the inquisitorial model's structural dependency becomes a structural vulnerability. The Italian reform experience documented by Consolo and De Cristofaro demonstrates that reform is achievable and has been achieved elsewhere.²²

6.3 The Erdős Classification LADA Framework

The LADA request provides the compiler with a five-level classification schema — E1 through E5, from direct co-authorship and supervision to no documented professional connection — and asks for the aggregate distribution of filed applications and the grant rate within each category. [LADA Data — Erdős classification of expert challenge applications: expected Q3 2026.]

Predicted findings: challenge filing distribution skewed toward E1-E2, consistent with the mathematical prediction that qualifying connections are rare and parties file challenges when genuine connections exist rather than opportunistically; grant rate flat across E1-E5 categories, consistent with application of an incapacity standard that does not

distinguish between connection strengths. If confirmed, the data simultaneously falsifies the chaos hypothesis at the filing level and demonstrates systemic misapplication of the statutory standard at the grant rate level.

6.5 Synthesis

Courts adopt expert conclusions at rates of 85 to 90 percent or above. Expert challenge grant rates are near zero under the applied standard. A court that adopts expert conclusions at 85 to 90 percent and applies a challenge standard producing near-zero grant rates has, in functional terms, delegated its judgment on technical questions to a person whose impartiality cannot in practice be challenged. Where that person has an Erdős 1 connection to a party's key technical personnel, the conflict flows directly into the judgment. The appearance standard exists to prevent this outcome. The applied standard ensures it.

Notes

²⁰ Taruffo, M. (2012) 'Scientific Evidence in Civil Litigation' in: Edmond, G. (ed.) *Expertise in Regulation and Law*. Aldershot: Ashgate, pp. 34-42.

²¹ Jolowicz, J.A. (2000) *On Civil Procedure*. Cambridge: Cambridge University Press, pp. 174-193.

²² Consolo, C. and De Cristofaro, M. (2012) 'The New Italian Rules on Civil Procedure,' *Civil Justice Quarterly*, 31, pp. 348-371, at pp. 358-365.

Section VII: ECHR Jurisprudence

7.1 Article 6(1) and the Right to an Independent Expert

Article 6(1) ECHR guarantees the right to a fair trial before an independent and impartial tribunal. The ECHR jurisprudence establishes three propositions: the right to challenge a court-appointed expert effectively is a Convention right; the test for expert impartiality is objective — the appearance of independence to a reasonable observer; and where the court-appointed expert functions as a de facto decision-maker, the equality of arms guarantee requires genuine independence.

7.2 *Mantovanelli v France* (1997): Structural Ineffectiveness

Mantovanelli v France is the leading ECHR authority on court-appointed expert impartiality.²³ The Court found a violation of Article 6(1) without finding that the expert was actually biased. It found that the procedural mechanism was structured in a way that denied the applicants a meaningful opportunity to address the expert's conclusions. The *Mantovanelli* principle extends to the challenge dimension: if the challenge mechanism is structured in a way that renders effective challenge practically impossible — whether through a disclosure failure or through a standard of proof that no challenge can satisfy — the structural ineffectiveness problem is engaged. The incapacity standard is structurally ineffective in precisely this sense.

7.3 *Sara Lind Eggertsdóttir v Iceland* (2007): The Objective Appearance Test

Sara Lind Eggertsdóttir v Iceland is the most direct ECHR authority for the specific argument of this paper.²⁴ The Court applied the objective test explicitly: the question was not whether the expert committee was actually biased, but whether the circumstances were such that a reasonable observer would have doubts about independence. The institutional connection was sufficient. This is the appearance standard. If an institutional connection satisfies the objective test, a direct Erdős 1

personal connection — co-authorship and doctoral supervision — satisfies it a fortiori.

7.4 Bönisch v Austria (1985) and Brandstetter v Austria (1991)

Bönisch v Austria addresses the consequence of the rubber stamp rate.²⁵ The Court's concern was that the expert's opinion would carry decisive weight and that the connection meant decisive weight was placed on a compromised foundation. At an 85 to 90 percent adoption rate, the court-appointed expert is the decision-maker on technical questions. Brandstetter v Austria established that equality of arms requires not merely the formal availability of a challenge right but a meaningful opportunity to exercise it in practice.²⁶ The meaningful opportunity principle applies directly to the notification failure and to the incapacity standard.

7.5 The Erdős Framework as the Precision Tool for ECHR Compliance

The four cases together establish the Article 6(1) framework within which the Erdős threshold operates. The Erdős framework does not create new Convention obligations. It provides a tool for discharging obligations the Convention already imposes. Where domestic courts apply a standard the ECHR's objective appearance test has already superseded, the structural incompatibility is a recurring source of Article 6(1) violations that domestic legislative reform could address at source.

Notes

²³ Mantovanelli v France (1997) 21 EHRR 253, Application No. 21497/93. Structural ineffectiveness analysis at paragraphs 33-36.

²⁴ Sara Lind Eggertsdóttir v Iceland (2007) Application No. 31930/04. Objective appearance test at paragraphs 44-47.

²⁵ Bönisch v Austria (1985) 9 EHRR 191, Application No. 8658/79. Inequality of arms at paragraphs 31-35.

²⁶ Brandstetter v Austria (1991) 15 EHRR 378, Application No. 11170/84. Meaningful opportunity principle at paragraphs 66-68.

Section VIII: The Reform Proposal

8.1 The Architecture of Reform

The reform proposal addresses the problem at three levels. First, substantive: the adoption of an Erdős-equivalent proximity threshold as a legally operable measure of the appearance standard. Second, procedural: the reform of the appointment and disclosure mechanism. Third, the sanctions and burden framework: replacing the current arrangement — in which every burden falls on the party who identifies the conflict — with a principled reversal that places the burden where it belongs. The framework is deliberately simple: one declaration, one declarant, one burden, one set of consequences.

8.2 The Substantive Reform: The Erdős Three-Tier Threshold

Tier One: Erdős 1 — Automatic Satisfaction

A court-appointed expert who has a direct co-authorship relationship or a doctoral supervisory relationship with a party's key technical personnel — where that relationship concerns the subject matter or the geographical context of the dispute — automatically satisfies the appearance standard under Article 120(1) CPC and its equivalents. No additional evidence of actual bias is required. No presumption of professional objectivity rebuts the finding. The appointment is void.

Dense Network Rule: Two or More Erdős 1 Connections

Where the appointed expert has two or more Erdős 1 equivalent relationships with personnel connected to a single party — through multiple co-authorship relationships, supervisory relationships, or a combination — the dense network rule applies. The expert is embedded within the same dense professional structure as the party's key personnel. Dense network conflicts attract automatic nullification without case-by-case assessment, and engage the full sanctions framework of Section 8.6.

Tier Two: Erdős 2 — Heightened Scrutiny

A court-appointed expert with an Erdős 2 connection is subject to heightened scrutiny. The Erdős 2 connection does not automatically satisfy the standard. It requires the applicant to demonstrate additional factors: membership of the same institutional department; a prior professional relationship on the same subject matter; a pattern of mutual citation or shared projects; or any relationship of professional dependency.

Tier Three: Erdős 3 and Beyond — Statutory Standard Restored

Professional connections at Erdős 3 or greater are assessed under the general appearance standard as formulated in Article 120(1) CPC, without the additional burden of proving incapacity. The reform at Tier Three is the removal of the illegitimate elevation: courts apply the statutory test — are the circumstances adequate to generate reasonable distrust in the reasonable observer — without importing the incapacity presumption the applied standard currently mandates.

8.3 The Pre-Appointment Expert Declaration

The procedural heart of the reform is a pre-appointment declaration by the expert, completed before the appointment is confirmed. The declaration places the burden precisely where it belongs: on the expert who knows their own professional network, who accepts the quasi-judicial role, and who is uniquely positioned to identify and disclose the connections the appearance standard is designed to catch. The four questions are:

- 1. Do you have a direct co-authorship relationship with any party, or with any technical personnel employed by or retained by any party, on subject matter relevant to this dispute? If yes, identify the co-author and the publication.*
- 2. Have you supervised, or been supervised by, any party or any technical personnel employed by or retained by any party at doctoral or postdoctoral level? If yes, identify the individual and the period of supervision.*
- 3. Are you currently employed by, or institutionally affiliated with, any body that has a contractual, advisory, or funding relationship with any party? If yes, identify the body and the nature of the relationship.*

4. Do you have two or more of the above relationships with persons connected to any single party in these proceedings? If yes, identify all such relationships.

The declaration is signed under the same duty of accuracy that governs all statements made to the court. An expert who answers accurately and completely has discharged their disclosure obligation in full. The burden this places on the expert is proportionate to their role. The court-appointed expert is not a passive witness. They are a quasi-judicial officer whose conclusions will be adopted in the substantial majority of cases without independent scrutiny. A court-appointed expert asked to assess hydrogeological evidence in a borehole dispute knows whether they supervised the doctoral training of the defendant's technical director.

8.4 The University's Role: Cooperative Authority and the Quiet Sanction

The university's role is not the maintenance of a conflict register, not the bearing of external compliance obligations, and not exposure to negligence findings for the natural professional relationships of its faculty. Universities will resist — and should resist — any framework that treats them as presumptively complicit in the small-world professional dynamics that network science tells us are structural features of all specialist academic communities.

The university retains, within its own existing disciplinary framework, the authority to remove a faculty member from future expert appointments where that member has been found to have provided an inaccurate or incomplete pre-appointment declaration. This is the quiet sanction. It does not require external imposition. It does not require legislation. It requires only that the university exercise the disciplinary authority it already possesses under the Estatuto da Carreira Docente Universitária.²⁷ Removal from future expert appointments is a significant professional consequence: expert appointments carry status, supplementary income, and professional visibility. The quiet sanction is effective precisely because it is applied within the institution rather than imposed upon it.

8.5 The Automatic Nullification Rule

Where the applicant establishes by documentary evidence that the appointed expert has an Erdős 1 equivalent connection to a party's key technical personnel on the subject matter of the dispute, the appointment is automatically nullified. There is no discretionary assessment. The appointment is void — of no legal effect from the point the conflict is established. Any expert conclusions produced prior to nullification are inadmissible. The rationale for automatic nullification is threefold: the mathematical framework establishes that Erdős 1 connections on the subject matter are sufficiently rare that discretionary assessment adds no value; the ECHR jurisprudence establishes that the appearance test is objective; and judicial discretion in this area has been demonstrably captured by training doctrine that applies the incapacity standard.

8.6 The Sanctions Framework and Burden Reversal

The Current Position and Its Injustice

Under the current regime, every procedural and evidential burden falls on the party who identifies the conflict. The opposing party — whose technical personnel has an Erdős 1 connection to the expert — bears no burden whatsoever. The procedural architecture treats the conflict as the applicant's problem and the appointment as the default, when the logic of the appearance standard runs entirely the other way: an appointment that generates reasonable distrust of impartiality is presumptively defective, and the party who has benefited from it should bear the burden of explaining why it should stand.

The Proposed Burden Reversal

Upon establishment by documentary evidence of an Erdős 1 or dense network connection, the burden of proof reverses entirely. The party who has benefited from the conflicted appointment must establish one or more of the following: that they had no knowledge of the connection and no reasonable enquiry would have revealed it; that they took no steps to seek, encourage, or facilitate the appointment; or that the connection, while established at Erdős 1 in formal terms, carries no practical significance in the specific professional context where the subject matter does not overlap with the dispute. Failure to satisfy any

of these grounds on the balance of probabilities results in automatic nullification and the full costs framework.

The Costs Framework

Where the burden reversal is engaged and the benefiting party fails to discharge it, that party bears: all costs of the nullified expert appointment including fees already paid; all costs of the reappointment process; all costs incurred by the applicant in identifying and documenting the conflict; and in dense network cases, a contribution to the court's administrative costs. The cost allocation is the costs-follow-the-event principle applied to the procedural sub-event of the expert appointment.

The Removal of the Expert Phase as Ultimate Sanction

In the most serious cases — where a dense network conflict is established, the burden reversal is not discharged, and the circumstances indicate that the conflicted appointment was sought or facilitated with knowledge of the connection — the court retains the power to decline to reappoint an expert at all. The party who manufactured or exploited the conflicted appointment has forfeited the procedural benefit of the expert phase. Only the party whose conduct corrupted the mechanism loses access to it.

8.7 The Doctrinal Coherence of the Burden Reversal

The burden reversal is the application to the expert appointment context of principles established in Portuguese and European civil procedure. The principle that the party relying on a fact bears the burden of establishing it is expressed in Article 342 of the Código Civil. The principle that costs follow procedural misconduct is expressed in Articles 527 and 542 CPC. The principle that a party who benefits from a procedural irregularity bears the burden of demonstrating that they did not cause it underlies the *litigância de má fé* provisions of Article 542 CPC. The reform requires no new principles.

8.8 The Italian Model and DCFR Framework

The Italian legislative reforms of the early 2010s established the principle that professional connections between the appointed expert and party-connected personnel constitute grounds for recusal without

requiring proof of actual bias.²⁸ The Draft Common Frame of Reference addresses expert independence in civil proceedings through principles that align with the appearance standard.²⁹ Aligning Portuguese civil procedure with the DCFR framework places Portugal within the mainstream of European civil law development.

Notes

²⁷ Estatuto da Carreira Docente Universitária (ECDU), Decree-Law No. 448/79, amended by Lei n.º 7-A/2016 de 30 de Março.

²⁸ Consolo, C. and De Cristofaro, M. (2012) 'The New Italian Rules on Civil Procedure,' *Civil Justice Quarterly*, 31, pp. 348-371, at pp. 360-363.

²⁹ Von Bar, C. and Clive, E. (eds.) (2009) *Principles, Definitions and Model Rules of European Private Law: Draft Common Frame of Reference (DCFR)*. Munich: Sellier. Expert independence provisions in Book VI, Chapter 5.

³⁰ IBA Guidelines on Conflicts of Interest in International Arbitration (2014, revised 2024). The four-question declaration structure draws on the IBA's categories of disclosable relationships, calibrated to the academic co-authorship and supervision context.

Section IX: Conclusion

9.1 The Law as Written Should Prevail

This paper has advanced a single central argument with three supporting pillars. The argument is that the statutory standard for expert impartiality in civil law systems — the appearance of impartiality to a reasonable observer — is systematically overridden by judicial training doctrine that applies a materially higher and legislatively unauthorised threshold. The three pillars are legal, mathematical, and empirical. Each independently supports the central argument. Together they make it conclusive.

The legal pillar establishes that Article 120(1) CPC enacts the appearance standard without ambiguity. The text asks whether circumstances exist adequate to generate reasonable distrust of impartiality in a reasonable observer. It does not ask whether incapacity has been demonstrated. Those questions belong to a different standard — the applied standard, embedded in training doctrine, transmitted through the CEJ — that has no legislative authority.

The mathematical pillar establishes that the chaos hypothesis is false. Scale-free network theory demonstrates that direct professional connections follow a power law distribution in which Erdős 1 connections are rare by mathematical necessity. The average Erdős number of 4.7 is not consistent with a world in which direct connections are common. The chaos hypothesis conflates average path length with direct connection frequency. The Erdős number distribution provides the mathematical refutation the chaos hypothesis has never been required to answer.

The empirical pillar, to be completed with LADA data anticipated in Q3 2026, will confirm what the mathematical framework predicts: that challenge applications are concentrated at the direct-connection end of the proximity spectrum; that grant rates are near zero under the applied standard regardless of connection strength; and that the chaos hypothesis predicts has not materialised in any documented

jurisdiction where the appearance standard has been applied with greater rigour.

9.2 The Erdős Framework: What It Does and Does Not Claim

The Erdős threshold does not lower the standard for expert recusal below the statutory level. It does not treat any professional connection, however remote, as automatically disqualifying. It does not introduce a blacklist, a university register, or any mechanism that treats institutions as presumptively negligent for the professional relationships of their faculty members.

What it does is provide a mathematically grounded, documentarily verifiable, and judicially administrable operationalisation of the standard the legislature already enacted. An Erdős 1 equivalent connection on the subject matter of the dispute is, by the mathematics of professional networks, among the rarest and strongest forms of professional relationship in academic life. A reasonable observer, informed of these facts, does not require proof of actual bias to experience reasonable distrust. The circumstances are adequate. The standard is satisfied.

9.3 The Expert Declaration: Where the Burden Belongs

The procedural heart of the reform is four questions, answered honestly, by the person best placed to answer them. The expert who accepts a court appointment knows their own professional network. The pre-appointment declaration formalises an obligation the expert already carries as a matter of professional ethics. Where the expert's declaration is accurate and complete, the university bears no institutional burden beyond what it already carries. Where the declaration is inaccurate and a conflict is subsequently discovered, the expert bears the primary consequence. The allocation — expert declaration, university quiet sanction, court automatic nullification, burden reversal to the benefiting party — correctly distributes responsibility among those who have the relevant knowledge, authority, and incentive.

9.4 The Systemic Significance

The argument of this paper is not limited to Portuguese civil procedure. The structural problem operates across civil law Europe wherever court-appointed experts exercise quasi-judicial authority in technically complex proceedings. The ECHR jurisprudence applies across all forty-six Council of Europe member states. The mathematical framework applies to every academic co-authorship network in every jurisdiction. The reform is portable.

The Italian legislative experience demonstrates that reform is achievable. The ECHR jurisprudence demonstrates that reform is required by existing Convention obligations. The mathematics demonstrates that reform is proportionate: it will produce precisely the modest number of legitimate challenges the statutory standard was designed to produce, and none of the chaos the training doctrine has used to justify departing from it.

The law as written should prevail over training doctrine that has no legislative authority. The chaos hypothesis is an extraordinary empirical claim that has never been subjected to the burden of proof it demands of those who appear before the courts that recite it. It is mathematically false. The Erdős-equivalent proximity threshold provides an objective, scientifically validated, legally proportionate, and institutionally administrable standard for giving effect to what the legislature enacted, what the ECHR requires, and what the reasonable observer — standing outside the professional community being assessed, informed of the facts, and asking the straightforward question the statute poses — has always known.

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