Analysis of Evidence in International Criminal Trials Using Bayesian Belief Networks

McDermott , Yvonne; Aitken, Colin

Law, Probability and Risk

DOI:
10.1093/lpr/mgx007

Published: 04/09/2017

Peer reviewed version

Analysis of Evidence in International Criminal Trials Using Bayesian Belief Networks

Yvonne McDermott* and Colin Aitken**

As with trials in any other jurisdiction, trials of those charged with the most serious international crimes – namely genocide, crimes against humanity, and war crimes[1] – before international criminal courts involve the creation and analysis of legal arguments, where hypotheses and the evidence supporting those hypotheses are presented to the court. What sets the international criminal trial apart is the challenging evidentiary environment in which these arguments are presented. Typically, trials take place in a location that is geographically distant from where the incidents under examination took place.[2] A degree of temporal distance is also common, with some trials taking place up to 40 years after the events in question.[3] In addition, many international criminal tribunals rely heavily on witness testimony, and problems with such witnesses' accounts (which might be attributed to trauma, lost memory with the passage of time, interference, or ulterior motives) have been well documented.[4] The volume of evidence and breadth of the charges presented also creates some unique challenges.[5]

In spite of these difficulties, the processes of fact-finding by international criminal tribunals have traditionally received relatively little attention. The tribunals' common

* Associate Professor of Law, College of Law and Criminology, Swansea University, UK. Email Yvonne.McDermottRees@swansea.ac.uk. I am grateful to the British Academy for a Quantitative Skills Acquisition Award, which enabled earlier parts of this research.
** Professor of Forensic Statistics, School of Mathematics, University of Edinburgh, UK.

[1] Some international criminal tribunals, such as the Special Tribunal for Lebanon (STL) and Special Court for Sierra Leone (SCSL), have or had jurisdiction over domestic crimes, while the International Criminal Court (ICC) will likely have jurisdiction over the crime of aggression in the future.

[2] The ICC and STL are located in The Hague, as is International Criminal Tribunal for the former Yugoslavia (ICTY). The International Criminal Tribunal for Rwanda (ICTR) is located in Arusha, Tanzania.

[3] The Extraordinary Chambers in the Courts of Cambodia (ECCC) is currently trying defendants for their role in the Khmer Rouge regime from 1975 to 1979. The ICTR has conducted trials for the genocide in Rwanda and related atrocities up to 20 years after the events in question. The ICTY has tried individuals for crimes up to 20 years after their alleged commission, and up to 10 years between the atrocities had passed before individuals were put on trial by SCSL.

[4] Nancy Combs, *Fact-Finding without Facts: The Uncertain Evidentiary Foundations of International Criminal Convictions* (Cambridge: Cambridge University Press, 2010).

[5] For example, the trial record in *Prlić et al.* extended beyond one million pages: *Prosecutor v.* Judgment, Case No. IT-04-74-T, Trial Chamber III, 29 May 2013. See further, Yvonne McDermott, 'Inferential Reasoning and Proof in International Criminal Trials: The Potentials of Wigmorean Analysis' (2015) 13 *Journal of International Criminal Justice* 507.

assertion that judgments are based 'on the totality of the evidence', and that, even where particular pieces of evidence have not been explicitly referenced, they have been taken into account,[6] were accepted as a reflection of the intuitive exercise of fact-finding. More recently, however, researchers have begun to examine the processes of proof,[7] either by advocating more formalistic methods for charting arguments, such as Wigmorean analysis,[8] or dissecting concepts such as 'robustness' or Keynesian weight in the context of the international criminal trial.[9]

With the exception of two notable authors in this field, however, no international criminal law scholarship has yet examined the possibility of applying Bayesian probability theory to international criminal trials. Mark Klamberg nests a brief discussion of Bayes' theorem under a broader exposition of mathematical ('Pascalian') approaches,[10] noting that these approaches can be seen as 'methods of evaluation [which] may provide a check against the judge's intuition'.[11] Simon De Smet, in his discussion of diverse methods for formalising fact-finding, includes Bayesian analysis amongst those methods, and notes that the Bayesian approach brings with it the advantages of enhanced rigour and transparency.[12] However, these relatively brief accounts have not provided any practical examples of how Bayesian probability theory could be applied in practice.

By contrast, this piece seeks to advocate the use of Bayesian Networks ('Bayes Nets'), which are graphical models of the probabilistic relationships between

---

[6] Amongst many others, see *Prosecutor v. Đorđević*, Judgment, Case No. IT-05-87/1-T, 23 February 2011, para 18; *Prosecutor v. Nyiramasuhuko et al.*, Judgment, Case No. ICTR-98-42-T, 24 June 2011, para 190; *Prosecutor v. Perišić*, Judgment, Case No. IT-04-81-T, 6 September 2011, para 41.

[7] Two symposium issues have recently been co-edited by John D. Jackson and Yvonne McDermott: 'Proof in International Criminal Trials' in (2015) 13 *Journal of International Criminal Justice* 475-624, and 'Evidence and Proof in the International Criminal Tribunal for Rwanda' (2015) 26 *Criminal Law Forum* 347-418.

[8] Paul Roberts, 'The Priority of Procedure and the Neglect of Evidence and Proof: Facing Facts in International Criminal Law' (2015) 13 *Journal of International Criminal Justice* 479; McDermott (n 5); Terence Anderson and William Twining, 'Evidential Reasoning in the International Criminal Tribunal for Rwanda: a Case Study of Tharcisse Muvunyi' (2015) 26 *Criminal Law Forum* 373.

[9] Mark Klamberg, 'The Alternative Hypothesis Approach, Robustness and International Criminal Justice: A Plea for a 'Combined Approach' to Evaluation of Evidence' (2015) 13 *Journal of International Criminal Justice* 535.

[10] Mark Klamberg, *Evidence in International Criminal Trials: Confronting Legal Gaps and the Reconstruction of Disputed Events* (Leiden: Nijhoff, 2013) 161-164.

[11] *Id.* 159.

[12] Simon De Smet,'The International Criminal Standard of Proof at the International Criminal Court – Beyond Reasonable Doubt or Beyond Reason?' in Carsten Stahn (ed.), *The Law and Practice of the International Criminal Court* (Oxford: Oxford University Press, 2015), 861, 873.

hypotheses and pieces of evidence,[13] as being a potentially useful tool in both the examination of international criminal judgments and the processes of trial preparation and fact-finding before international criminal tribunals. We illustrate this point with a practical case study based on a completed case from the International Criminal Tribunal for the former Yugoslavia (ICTY). Part I discusses how different actors in international criminal trials could use the method to enhance their practice, and defends against some possible criticisms that may arise against the use of Bayes Nets in this context. Part II demonstrates the potential applicability of Bayes Nets to international criminal trials with the aid of a case study from a completed trial before the ICTY. It is our firm belief that both an understanding of the principles underpinning Bayes Nets, and a utilisation of the method in practice, have the potential to strengthen judges' confidence in their findings, to assist lawyers in preparing for trial, and to provide a tool for the assessment of international criminal tribunals' factual findings.

This discussion is timely, not just because it fits with a wider focus on judicial decision-making and the need for rigour in reasoning that has emerged in the specific field of international criminal law in recent years.[14] The method could also be extended across a range of legal disciplines that deal with complex fact-finding issues, and to other complex areas of law, such as fraud trials, other serious crimes, and civil litigation, and our illustration highlights the practicability of applying Bayes Nets to real cases. Recent research has highlighted the need to move beyond misconceptions about Bayes' theorem and the resistance to Bayesian methods amongst the legal community more generally.[15] This article, by providing a clear illustration of how Bayes Nets could be used in such complex trials as those before international criminal tribunals, represents a step in that direction.

---

[13] Norman Fenton, David Lagnado and Martin Neil, 'A General Structure for Legal Arguments Using Bayesian Networks' (2013) 37 *Cognitive Science* 61, available online at https://www.eecs.qmul.ac.uk/~norman/papers/legal_arguments_final_submitted.pdf, 40.

[14] As well as those cited above, notes 3-11, see e.g. Marjolein Cupido, *Facts Matter: A Study into the Casuistry of Substantive International Criminal Law* (The Hague: Eleven International Publishing, 2015).

[15] Norman Fenton, Martin Neil and Daniel Berger, 'Bayes and the Law' (2016) 3 *Annual Review of Statistics and Its Application*, available online at http://www.eecs.qmul.ac.uk/~norman/papers/bayes_and_the_law_revised_FINAL.pdf.

I. Applying Bayes Nets to International Criminal Trials

Readers of this journal will already be familiar with the fundamentals of Bayesian probability theory and the role of Bayes Nets in calculating probabilities in a complex system.[16] The method of constructing Bayes Nets to automate probability calculations has been applied to such diverse fields of inquiry as DNA inclusion,[17] speaker recognition systems,[18] and traffic accident reconstructions.[19]

It is our argument that, in the context of the international criminal trial, judges could benefit from both the tool, and an understanding of the principles of probability underpinning Bayes Nets. Given the volume of the evidential record in these trials, Bayes Nets could enable judges to calculate probabilities in a manner that would be impossible on a straightforward reading of the trial record. International criminal judgments are particularly suited to this type of scholarly analysis, given the volume of reasoned opinion derivable from judgments – it is not uncommon for judgments to exceed several hundred pages, outlining the factual background to the crimes charged, the elements of each crime, and the reasons why the mixed mass of evidence presented before the Trial Chamber either convinces it of the guilt of the accused or fails to reach the required standard of proof.[20] This amount of available information enables probabilities to be more informed. In addition, the trial records of these cases are freely available online, enabling the observer to use information from the trial record to calculate probabilities, as we have done below.

It has been noted elsewhere that the standard of proof in international criminal trials has not been adequately enunciated, and there does seem to be a difference in the understanding of what the standard entails between differently-constituted Chambers

[16] For a general introduction, see Philip Dawid, David Schum and Amanda Hepler, 'Inference Networks: Bayes and Wigmore' in Philip Dawid, William Twining and Mimi Vasilaki (eds.), *Evidence, Inference and Inquiry* (Oxford: Oxford University Press, 2011) 119.

[17] Alex Biedermann, Franco Taroni, and William C. Thompson, 'Using Graphical Probability Analysis (Bayes Nets) to Evaluate a Conditional DNA Inclusion' (2011) 10 *Law, Probability and Risk* 89.

[18] Jose Juan Lucena-Molina, Marina Gascon-Abillan, and Virginia Pardo-Iranzo, 'Technical Support for a Judge when Assessing *A Priori* Odds' (2015) 14 *Law, Probability and Risk* 147.

[19] Gary A. Davis, 'Bayesian Reconstruction of Traffic Accidents' (2003) 2 *Law, Probability and Risk* 69.

[20] For example, the 24 March 2016 trial judgment in *Prosecutor v. Karadžić* (Case No. IT-95-5/18-T) totaled over 2500 pages.

of the same tribunals.[21] Perhaps the best example of this comes from the *Ngudjolo* Appeals Chamber judgment before the ICC, where the two dissenting judges considered that the majority had taken an 'excessively fragmentary' approach to the evidence, in considering each piece of evidence on its own merits, instead of looking at the evidence as a whole.[22] The Prosecutor, in her appeal, had complained that proof beyond reasonable doubt 'does not require proof beyond any doubt and does not require the Chamber to search for and then reject all hypothetically possible contrary inferences, however unrealistic or unsupported', and that the Trial Chamber had exceeded the 'reasonable doubt' standard in its judgment. The dissenting Appeals Chamber judges appeared to concur, finding that, if all of the evidence as a whole was taken together, this 'might have sufficed for the Trial Chamber to establish Mr Ngudjolo's control over the Lendu militia of the Bedu-Ezekere *groupement* at the relevant time.'[23] This appears to highlight not only the apparent difference in opinion between judges as to what level of certainty is needed to satisfy the 'beyond reasonable doubt' standard, but also the potential benefits of Bayes Nets in this context, given that they enable the judge to determine the effect of each subsequent piece of evidence on the odds of guilt. If a greater understanding of probability were more widespread, it may give rise to a much-needed debate in international criminal law on the precise percentage of confidence in a finding that is required to meet the 'beyond reasonable doubt' standard.[24]

Arguably, this debate is even more necessary in international criminal tribunals than in domestic trials, as the international tribunals incorporate different standards of proof for different stages of proceedings. It would be valuable to attempt to quantify

[21] De Smet (n 12), 871; Yvonne McDermott, 'The ICTR's Fact-Finding Legacy: Lessons for the Future of Proof in International Criminal Trials' (2015) 26 *Criminal Law Forum* 351.
[22] Joint Dissenting Opinion of Judge Ekaterina Trendafilova and Judge Cuno Tarfusser, Judgment on the Prosecutor's Appeal against the Decision of Trial Chamber II entitled 'Judgment Pursuant to Article 74 of the Statute', *Chui* (ICC-01/04-02/12-271-AnxA), Appeals Chamber, 7 April 2015, paras 44-51.
[23] Joint Dissenting Opinion of Judges Trendafilova and Tarfusser, *ibid.*, para 46.
[24] This is a debate that has been well-rehearsed amongst criminal law scholars in the United Kingdom and United States of America: see e.g. Jon O. Newman, 'Quantifying the Standard of Proof Beyond a Reasonable Doubt: A Comment on Three Comments' (2006) 5 *Law, Probability and Risk* 267, and Peter Tillers and Jonathan Gottfried, 'Case Comment: *United States v. Copeland* 369 F. Supp. 2d 275 (E.D.N.Y. 2005): A Collateral Attack on the Legal Maxim That Proof Beyond Reasonable Doubt is Unquantifiable?' (2006) 5 *Law, Probability and Risk* 135.

the level of confidence required for the standards of 'reasonable grounds to believe',[25] 'substantial grounds to believe',[26] and 'no case to answer',[27] as well as 'beyond reasonable doubt'. Again, the jurisprudence from the International Criminal Court highlights a marked difference of opinion between judges on the level of certainty required to reach the requisite standard of proof for each of these stages of proceedings.[28] This assumption that an understanding of the basics of Bayesian probability would help judges to articulate their differing opinions in this regard, and to reach a mutually agreeable conclusion, is perhaps over-optimistic. However, it is clear from several well-publicised failures to understand conditional probability[29] that there are considerable benefits to be had in the administration of criminal justice from a greater understanding in this regard.

As well as enabling judges to quantify the precise level of confidence required to meet the standard of proof, the use of Bayes Nets would enable them to challenge their own impressionistic analyses of the evidence at hand, and determine whether that evidence was sufficient to meet the standard of proof. By committing to estimates of uncertainty (either subjective or objective, numerical or verbal) for each piece of evidence as part of the reasoning process, the exercise of creating a Bayes Net forces the decision-maker to confront the strength of their confidence in their conclusions. Once again, it is emphasised that the creation of Bayes Nets is a method, first, for the illustration of the associations amongst items of evidence and propositions, and the strength of these associations and, second, for the calculation of the probability of a proposition in light of the evidence at hand; the construction of a network is not a substitute for judicial reasoning, nor should it be. The exercises of determining which events are conditional upon one another and allocating appropriate conditional probabilities are fundamentally the task for the decision-maker and, whilst new

[25] Article 58(1), ICC Statute. For an in-depth discussion, see Michael Ramsden and Cecilia Chung, '"Reasonable Grounds to Believe": An Unreasonably Unclear Evidentiary Threshold in the ICC Statute' (2015) 13 *Journal of International Criminal Justice* 555.
[26] Article 61(7), ICC Statute; see further, Klamberg (n 10), 147; Triestino Mariniello, 'Questioning the Standard of Proof: The Purpose of the ICC Confirmation of Charges Procedure' (2015) 13 *Journal of International Criminal Justice* 579.
[27] Rule 98*bis*, ICTY and ICTR RPE; Rule 98, SCSL RPE; Rule 167, STL RPE.
[28] See, as a recent example, the separate opinion of Judge Marc Perrin de Brichambaut in Decision on the confirmation of charges against Dominic Ongwen, *Ongwen* (ICC-02/04-01/15-422), Pre-Trial Chamber II, 23 March 2016.
[29] See, for example, *R v. Clark*, 2003, EWCA Crim 1020, 2003, All ER (D) 223 (Apr),CA and 2000, All ER (D) 1219, CA.

technology can assist with the calculations, neither Bayes' theorem nor Bayes Nets can act as a replacement to the subjective human exercise of reasoning.

Judges in the ICC, and other international criminal tribunals, have to reach a decision based on thousands of pieces of evidence with countless interactions amongst these items. The construction of a Bayes Net for the totality of evidence enables these interactions to be represented as a set of small numbers of interactions, as exemplified in Figure 2 below. In Figure 2, the largest number of conditioning events for which assessments of conditional probabilities have to be made is two. With a Bayes Net consisting of a large number of nodes, careful construction can enable the structure to be such that conditional probabilities never need to be evaluated for more than a few (hopefully three) conditioning events. These assessments can be made with much greater assurance than any attempt to consider the totality of evidence simultaneously would achieve. The evaluation of evidence for the whole network (totality of evidence) can then be determined with propagation of the evidence through the network using an appropriate software programme, such as Genie, as was used here.

For lawyers, Bayes Nets may also prove useful as a trial preparation tool or as part of a summary at the conclusion of a trial. The creation of Bayes Nets allow lawyers on both sides to assess the sufficiency of their evidence in proving their case, and to address gaps in the robustness of that evidence, where possible. In contrast to other means for the graphical representation of evidence, such as Wigmore charts, Bayes Nets include measures of uncertainty. As Roberts and Aitken have previously noted, Bayes Nets 'encourage and facilitate consideration of alternative possibilities, employing different conditional dependencies or registering their absence. This should ideally promote refinement of initial hypotheses and more transparent and productive discussion of inferential reasoning. Disagreements (reflecting divergent standpoints or premises) may well persist, but are now challenged to meet more exacting standards of rational justification. The heuristic power of Bayes Nets, in rendering subjective assumptions and intuitions articulate, is rigorously logical and objective.'[30] Furthermore, a good knowledge of common pitfalls in probabilistic

[30] Paul Roberts and Colin Aitken, *The Logic of Forensic Proof: Inferential Reasoning in Criminal Evidence and Forensic Science Guidance for Judges, Lawyers, Forensic Scientists and Expert*

reasoning (such as the well-known 'prosecutor's fallacy') will be an invaluable asset to lawyers working on appeals where such fallacies in reasoning or the presentation of statistics have seemingly occurred.[31]

Lastly, in the light of a growing amount of literature pointing to deficiencies in fact-finding before certain international criminal tribunals,[32] the method may also be of interest to academics and other observers of international criminal trials. This is not to suggest that academics or other interested parties will be able to prove that a particular finding of fact was incorrect by applying Bayes' theorem to this finding, given that each individual's assumptions and beliefs will be different. However, it does enable the observer to attempt to identify the evidential bases for a finding, where that is frequently opaque or ambiguous,[33] and model them probabilistically.

We are conscious that, as with other analytical techniques, Bayes Nets may be dismissed as being either inappropriate or impossible in the context of international criminal trials. Indeed, in domestic criminal law and scholarship, Bayesianism and other mathematical approaches to proof have met with some scepticism.[34] Some of the potential criticisms that may arise are worthy of a more in-depth analysis.

First, some may argue that Bayesian approaches give the impression of mathematical precision, while they are as imprecise as narrative or intuitive approaches to proof. Yet, Bayesianism does not claim to 'fix' the problems of subjectivity inherent in such approaches; rather, Bayes Nets are tools that allow decision-makers to put numerical values on a range of compounded probabilities and perhaps delve into a deeper examination of those initial intuitions. To dismiss Bayes Nets as irrelevant owing to

---

Witnesses, Royal Statistical Society Practitioner Guide No. 3 (2014), available online at http://www.rss.org.uk/statsandlaw(last visited 3 May 2017), 126.

[31] One of the best-known examples of the prosecutor's fallacy in practice is the wrongful conviction of Sally Clark for the murder of her children, where the expert witness wrongly claimed that there was a probability of 1 in 73 million of the assignation of two deaths to sudden infant death syndrome in the same family; see further, Royal Statistical Society, 'Letter from the President to the Lord Chancellor regarding the use of statistical evidence in court cases' (23 January 2002), available online at: http://www.rss.org.uk/Images/PDF/influencing-change/rss-use-statistical-evidence-court-cases-2002.pdf.

[32] Combs (n 4); Alexander Zahar, 'Pluralism and the Rights of the Accused in International Criminal Proceedings' in Elies van Sliedregt and Sergey Vasiliev (eds.), *Pluralism in International Criminal Law* (Oxford: OUP, 2014) 225, 240.

[33] Cupido (n 14).

[34] Perhaps most notably, L. Jonathan Cohen, *The Probable and the Provable* (Oxford: Clarendon Press, 1977).

their inevitable limitations would be akin to throwing the baby out with the bathwater. The fact remains that reasoning in (international) criminal trials is inherently probabilistic, and the international criminal tribunals have evidenced some understanding of the idea of conditional probabilities and their application to international criminal trials in their judgments. In *Milutinović*, for example, the ICTY's Trial Chamber noted that evidence 'is relevant if it tends to make the existence of any fact that is of consequence to the determination of an issue in a case more or less probable than it would be without the evidence.'[35]

A related argument may be raised that even if probability is mathematical in principle,[36] it is difficult to measure in the context of a criminal trial because of an absence of statistics and the difficulty in determining its subjective equivalent as a measure of belief.[37] It should be clarified that the method is not only suitable for those cases where the probability of a particular piece of evidence can be independently scientifically verified, as with a DNA profile. The method can also be used when subjective probabilities are involved. This may be seen as a somewhat unscientific application of a scientific method, but of course where a judge or juror has to consider issues such as the fact that the defendant fled as part of their deliberations, they must assess what that specific piece of information tells them about the likelihood of an outcome. The application of the language of mathematics simply helps the decision-maker to clarify the measure of belief that attaches to a particular intuition, and it would do such decision-makers a disservice to exclude subjective probabilities from the application of Bayes' theorem.[38]

Further, some may argue that Bayes Nets are beyond the limits of lawyers' capacities. Lempert has pointed out that people are not natural statisticians, and cannot be expected to come up with probabilities for outcomes that are objectively incapable of measurement.[39] There is a school of thought that 'to introduce Bayes Theorem, or any similar method, into a criminal trial plunges the jury [or judge] into inappropriate and

---

[35] *Prosecutor v. Milutinović et al.*, Judgment, Case No. IT-05-87-T, 26 February 2009, para 36.
[36] Cf. Cohen (n 34), arguing that some probability judgments could be reached and analysed on the basis of non-mathematical ('Baconian') criteria.
[37] Klamberg (n 10), 163.
[38] Richard O. Lempert, Samuel R. Gross & James S. Liebman, *A Modern Approach to Evidence* (3rd edn., St. Paul, MN: West Group Publishing, 2000) 228-232.
[39] Richard Lempert, 'The New Evidence Scholarship: Analyzing the Processes of Proof' (1986) 66 *Boston University Law Review* 439, 444-446.

unnecessary realms of theory and complexity deflecting them from their proper task.'[40] Psychological research, however, has pointed out that humans may well be intuitive statisticians,[41] which calls this assumption into question. Indeed, in our day-to-day lives, we all use phrases like 'I am quite certain'; 'I am not sure' and 'I am positive', each of which highlight an innate ability to differentiate between distinct levels of certainties. Even those without any mathematical training will understand basic concepts of probability, such as if A is probable and B is very probable, the probability of both occurring is less than the probability of A alone.[42] Even if we were to accept that peoples' capacity to reason on probabilistic matters is necessarily limited, this would arguably provide a greater reason to encourage the use of more formalistic methods, rather than leaving such matters to their intuitive impressions or guesswork.[43] An illustration of a well-known principle of Bayes Theorem is given by David Eddy:

> The probability that a woman at age 40 has breast cancer is 1%. According to the literature, the probability that the disease is detected by a mammography is 80%. The probability that the test misdetects the disease although the patient does not have it is 9.6%. If a woman at age 40 is tested as positive, what is the probability that she indeed has breast cancer?[44]

Eddy reported that 95 out of 100 doctors estimated this probability to be between 70% and 80%, whereas the correct answer (following Bayes' theorem) is much lower, at under 8%. Assuming that this does illustrate a broader difficulty with probabilistic reasoning that presumably extends to the legal profession as well, is that not all the more reason to encourage a more formalistic approach to probabilities, by applying the theorem in practice?

Further, by today, a number of software programmes, including Hugin™, AgenaRisk™, and GeNIe™,[45] are available to do the calculations. The use of the

---

[40] *R v. Adams* [1998] 1 Cr App R 377.
[41] Leda Cosmides and John Tooby, 'Are humans good intuitive statisticians after all? Rethinking some conclusions from the literature on judgment under uncertainty' (1996) 58 *Cognition* 1.
[42] Glanville Williams, 'The Mathematics of Proof - I' [1979] *Criminal Law Review* 279. Compare Amos Tversky and Daniel Kahneman, 'Extensional Versus Intuitive Reasoning: The Conjunction Fallacy in Probability Judgment' (1983) 90 *Psychological Review* 293.
[43] *Ibid.*, 299.
[44] David M. Eddy, 'Probabilistic Reasoning in Clinical Medicine: Problems and Opportunities' in Daniel Kahneman, Paul Slovic and Amos Tversky (eds), *Judgment under Uncertainty: Heuristics and Biases* (Cambridge: Cambridge University Press, 1982) 249.
[45] Hugin Expert, available online at http://www.hugin.com; AgenaRisk, available online at: http://www.agenarisk.com; GeNIe, available online at http://www.bayesfusion.com/.

GeNIe software for analysing a Bayesian network is demonstrated in the case study below. Evidence can be taken into account (a process known as 'instantiation') and the Bayes Net software calculates (a process known as 'propagation') the updated posterior probabilities from which the posterior odds and hence the likelihood ratio may be calculated. In this sense, these technologies not only apply a logical mathematical method to determine revised probability determinations; they also help us 'to visualize the causal relationships between different hypotheses and pieces of evidence in a complex legal argument'.[46] The beauty of the network and the theory for updating probabilities is that correct transposed conditional probabilities may be calculated.

A further possible criticism of mathematical approaches is that they create uncertainty. Consider the following example of the confusion that may arise if probabilities of guilt are determined for two pieces of evidence E1 and E2. Let Hp denote the proposition that the suspect is guilty. For both E1 and E2, suppose the court determines Pr(Hp | E1) and Pr(Hp | E2) to be 0.7. On a balance of probabilities, E1 and E2, separately, imply the guilt of the suspect. The court then multiplies these together, a multiplication which assumes some sort of independence, to produce a probability of $0.7^2 = 0.49$. This last probability is less than 0.5. Superficially, this seems to imply that two pieces of evidence, which separately imply the guilt of the suspect, when combined imply the innocence of the suspect. This apparent contradiction is part of the basis of the criticism by Cohen of the relevance of the calculations of standard probability (Cohen's term is Pascalian).[47] However, Dawid explained how a rigorous Bayesian analysis is able to counter this criticism.[48] By applying Bayes' theorem, Dawid demonstrates how the combined probability of guilt in light of the two pieces of evidence is in fact 0.84, which of course is greater than the probability of each of the individual pieces of evidence.[49]

The final potential criticism that may be raised is that the method is inappropriate in the context of the international criminal trial because the stakes are so high for both the individual whose liberty is at risk and the community at large. However, the

[46] Norman Fenton, Martin Neil and David A. Lagnado, 'A General Structure for Legal Arguments About Evidence Using Bayesian Networks' [2012] *Cognitive Science* 1.
[47] Cohen (n 34).
[48] A. P. Dawid, 'The Difficulty About Conjunction' (1987) 36 *The Statistician* 91.
[49] *Id.*

method has found use in such (equally important) tasks as diagnosing particular medical conditions on the basis of the patient's symptoms, determining the requisite strength of a proposed structure, in light of the probability of extreme weather events, and countless others.[50] If anything, the serious consequences of the decisions involved provides further justification for the application of the method, in order to enable judges, with all of their inherent human fallibilities in reasoning processes, to improve the quality of their decision-making and to challenge some of the common pitfalls that can arise when reasoning is left solely to the limits of human capacity.[51]

A key point on the applicability of the theorem to any criminal trial ought to be made at this juncture. This is that the method categorically does *not* tell a judge or juror what the 'right decision' is to be. As is illustrated by the example below, the application of Bayes' theorem relies on the individual decision-maker quantifying prior probabilities based on their own intuition.[52] Thus, 'any resulting inferences of probative value extracted from Bayes nets can only be as good, or as bad, as the initial human inputs'.[53] The reader should avoid the temptation to believe that the application of the method results in incontestability, or correctness, of the ultimate probabilities that result.[54] Bayes Nets should be seen as a tool to assist thinking; they should not be viewed as a substitute to that thinking.[55]

II. Case study: *Prosecutor v. Krnojelac*

Bayes Nets are closely related to another form of graphic representation of the complex inter-relationships between pieces of evidence, inferences and generalizations in criminal trials, the Wigmore chart, or 'Wigmorean analysis'.[56] The main difference between the two methods is that the Wigmore chart does not attach

[50] Roberts and Aitken (n 30).
[51] For a similar argument, see McDermott (n 5).
[52] Roberts and Aitken (n 30), 104.
[53] *Id.*
[54] Craig R. Callen, 'Notes on a Grand Illusion: Some Limits on the Use of Bayesian Theory in Evidence Law' (1982) 57 *Indiana Law Journal* 1.
[55] For a similar point on Wigmorean analysis, see McDermott (n 5), 519.
[56] John Henry Wigmore, *The Principles of Judicial Proof as given by Logic, Psychology, and General Experience, and Illustrated in Judicial Trials* (Little Brown & Co., 1913). For a contemporary application of the method, see, *inter alia*, Terence Anderson, William Twining and David Schum, *Analysis of Evidence* (2nd edn, Cambridge: Cambridge University Press, 2005); David A. Schum, *The Evidential Foundations of Probabilistic Reasoning* (Evanston, IL: Northwestern University Press, 2010) 167.

any value or weight to the individual or to related items of evidence that are pictorially represented, whereas the Bayes Net expressly represents the probabilities of a variety of outcomes.[57]

Given this close relationship, if a Wigmore chart has already been prepared for a particular part of a case, it represents an excellent starting point for identifying the potential nodes of a Bayes Net. In our example, part of a Wigmore chart prepared by McDermott[58] formed the basis of a study of Bayes Nets prepared by Aitken. The ultimate probandum in this inquiry was point 2 in the larger chart – namely, that Krnojelac knew that Halim Konjo was murdered by guards in the KP Dom detention facility where the accused was commander.

The relevant part of the chart is as follows:

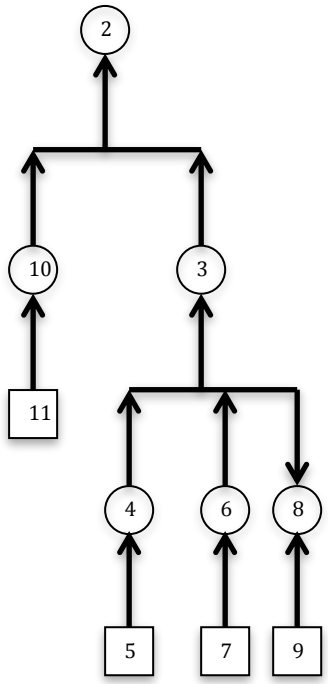

Figure 1: A subset of a Wigmore chart for *Krnojelac*

The related key list is:

2 Krnojelac knew of murder of Halim Konjo by KP Dom guards.

[57] Roberts and Aitken (n 30), 111.
[58] Published in McDermott (n 5).

3. Halim Konjo was murdered by KP Dom guards.
4. Halim Konjo was taken away by KP Dom guards on 12 June 1992 and was never seen again.
5. Testimony of FWS-69; RJ; FWS-139; FWS-54 to 4.
6. Halim Konjo succumbed to a beating and died.
7. Testimony of FWS-69; RJ; FWS-139; FWS-54 to 6.
8. Halim Konjo died of a heart attack or stroke.
9. Hearsay testimony of Muhamed Lisica to 8.
10. Krnojelac knew that Halim Konjo was dead.
11. Testimony of Krnojelac and RJ to 10.

In Wigmore charting, arrows pointing to a node signify that the connected node tends to prove that node, whereas arrows pointing away from the node lead to a node that tends to disprove it. The Bayes Net presented here in Figure 2 is only loosely based on the Wigmore chart in Figure 1, which forms the basis for a Bayes Net but no more. Seven nodes were selected to represent the evidence of the section of the Wigmore diagram illustrated in Figure 1. They are described in Table 1. Each node was chosen to be binary in that two, and only two, possible outcomes were considered for each node. For example, the possible outcomes for node K, representing K's knowledge, were taken to be that he was murdered or that he died of natural causes. The possibilities that he died in an accident or committed suicide were not considered here, though such alternatives could be considered with a straightforward extension of the procedure.

The network in Figure 2 arose from the considerations of the evidence of six nodes and one node (node K) to represent the ultimate probandum (the ultimate issue to be proved), with corresponding descriptions in Table 1. Table 1 describes the nodes, their binary outcomes and the associated conditional probabilities. A subsequent narrative provides a justification for the choices of the probabilities. The testimonies of FWS_69, RJ, FWS_139 and FWS_54 are taken to be dependent on (a) K's knowledge (whether he knew or did not know of the murder of HK), and (b) the testimony of RJ as to whether K talked, or did not talk, with RJ about the causes of death of HK. Of course, testimony is fallible, and on occasion, we assigned lower probability to a point outlined in testimony where we thought that point seemed unlikely. This is outlined in the narrative below Table 1, outlining the reasoning behind the assigned probabilities therein.

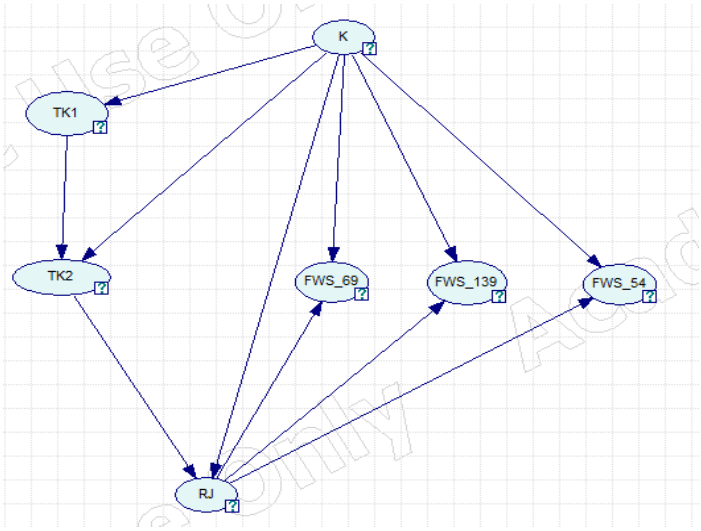

Figure 2: Bayes net for relationships amongst seven nodes as described in Table 1.

Table 1: Node labels, a description of the nodes with their outcomes and associated conditional probabilities

Node Label	Description	Outcomes	Probabilities required	Probs.
K for Krnojelac (**ultimate probandum)**	Knowledge K had of murder of HK	K knew of murder of HK. K did not know of murder of HK.	These probabilities are not important. They form the prior odds. Propagation of evidence throughout the network provides posterior odds. The ratio of prior to posterior odds is the likelihood ratio.	0.50 0.50
TK1	Testimony of K, part 1	Heard HK committed suicide. Did not hear HK committed suicide.	1. Pr(Heard HK committed suicide **given** K knew of murder) 2. Pr(Heard HK committed suicide **given** K did not know of murder)	0.20 0.90
TK2	Testimony of K, part 2	Told RJ that HK committed suicide. Did not tell RJ that HK committed suicide	1. Pr(Told RJ that HK committed suicide **given** (a) TK1 (K) heard HK committed suicide and **given** (b) K knew of murder) 2. Pr(Told RJ that HK committed suicide **given** (a) TK1 (K) heard HK committed suicide and **given** (b) K did not know of	0.20 0.80

			murder) 3. Pr(Told RJ that HK committed suicide **given** (a) TK1 (K) did not hear that HK committed suicide and **given** (b) K knew of murder) 4. Pr(Told RJ that HK committed suicide **given** (a) TK1 (K) did not hear that HK committed suicide and **given** (b) K did not know of murder)	0.40 0.10
FWS_69	Testimony of FWS_69	RJ told FWS_69 that K had told him that HK had died in solitary confinement RJ did not tell FWS_69 that K had told him that HK had died in solitary confinement	1. Pr(RJ told FWS_69 that K had told him that HK had died in solitary confinement **given** (a) that K knew of murder and **given** (b) K refused to talk about cause of death of HK with RJ) 2. Pr(RJ told FWS_69 that K had told him that HK had died in solitary confinement **given** (a) that K did not know of murder and **given** (b) K refused to talk about cause of death of HK with RJ) 3. Pr(RJ told FWS_69 that K had told him that HK had died in solitary confinement **given** (a) that K knew of murder and **given** (b) K talked about cause of death of HK with RJ)	0.10 0.20 0.80

			4. Pr(RJ told FWS_69 that K had told him that HK had died in solitary confinement **given** (a) that K did not know of murder and **given** (b) K talked about cause of death of HK with RJ)	0.90
RJ	Testimony of RJ	K refused to discuss death of HK with him. K discussed death of HK with him	1. Pr(K refused to discuss death of HK with RJ **given** (a) that K knew of murder and **given** (b) K told RJ that HK committed suicide) 2. Pr(K refused to discuss death of HK with RJ **given** (a) that K did not know of murder and **given** (b) K told RJ that HK committed suicide) 3. Pr(K refused to discuss death of HK with RJ **given** (a) that K knew of murder and **given** (b) K did not tell RJ that HK committed suicide) 4. Pr(K refused to discuss death of HK with RJ **given** (a) that K did not know of murder and **given** (b) K did not tell RJ that HK committed suicide)	0.05 0.20 0.95 0.80
FWS_139	Testimony of FWS_139	RJ told FWS_139 that K had told him that HK had died as result of beatings RJ did not tell	1. Pr(RJ told FWS_139 that K had told him that HK had died in solitary confinement **given** (a) that K knew of murder and **given** (b) K refused to discuss death of HK with RJ)	0.10

		FWS_139 that K had told him that HK had died as result of beatings	2. Pr(RJ told FWS_139 that K had told him that HK had died in solitary confinement **given** (a) that K did not know of murder and **given** (b) K refused to discuss death of HK with RJ) 3. Pr(RJ told FWS_139 that K had told him that HK had died in solitary confinement **given** a) that K knew of murder and **given** (b) K discussed death of HK with RJ) 4. Pr(RJ told FWS_139 that K had told him that HK had died in solitary	0.20 0.80 0.90
FWS_54	Testimony of FWS_54	RJ told FWS_54 that K had told him that HK had died as result of beatings. RJ did not tell FWS_54 that K had told him that HK had died as result of beatings	1. Pr(RJ told FWS_54 that K had told him that HK had died in solitary confinement **given** (a) that K knew of murder and **given** (b) K refused to discuss death of HK with RJ) 2. Pr(RJ told FWS_54 that K had told him that HK had died in solitary confinement **given** (a) that K did not know of murder and **given** (b) K refused to discuss death of HK with RJ) 3. Pr(RJ told FWS_54 that K had told him that HK had died in solitary confinement **given** (a) that K knew	0.10 0.20 0.80

			of murder and **given** (b) K discussed death of HK with RJ)	
			4. Pr(RJ told FWS_54 that K had told him that HK had died in solitary confinement **given** (a) that K did not know of murder and **given** (b) K discussed death of HK with RJ)	0.90

It is important to note that no significance need be attached to the probabilities assigned initially to node K. These are prior probabilities and their ratio is the prior odds in favour of murder. With equal prior probabilities (both equal to 0.5), the prior odds are 1. Once evidence is set and propagated through the network, the probabilities for K are changed and become posterior probabilities. The ratio of posterior probabilities is the posterior odds in favour of murder and its value is proportional to the prior odds. The likelihood ratio is the ratio of posterior odds to prior odds. The prior odds have been chosen here to be equal to one. This is for numerical convenience. With prior odds of 1, the likelihood ratio is equal to the posterior odds.

If the prior odds are different from one, chosen to be equal to a constant *m* say, then the posterior odds are changed also by a factor of *m.* When their ratio is taken, the constant *m* cancels and the resultant likelihood ratio is independent of *m.* The conditional probabilities required are determined by the structure of the network. For example, node TK2 has two arrows entering it, one from TK1 and one from K. Thus conditional probabilities for TK2 are required for the four possible combinations of conditioning events as listed in Table 1.

The authors agreed upon the probabilities for the conditioning events listed in Table 1 for the reasons set out below. If a reader were to disagree with any of the below probabilities, the figures could be very easily modified in the software, and new posterior probabilities could be calculated on that basis.

Narrative for probabilities in Table 1:

TK1 = If K knew of the murder of HK, it is not very likely that he heard that the cause of death of HK was suicide from one of the guards; hence the event is given a probability of 0.2. It is much more likely (probability 0.9) that he would have heard that the cause of death was suicide if he had not known of the murder.

TK2 = It is assumed that the probability assigned to TK2 cannot be higher than the probability assigned for TK1. If K knew of the murder, it is unlikely (probability 0.2) that he told RJ it was suicide, especially if he had heard this from someone else and yet knew it was murder. It is more likely (probability 0.8) that he would have told RJ this if he heard that it was suicide and he did not know it was murder and believed it to be suicide.

If K knew of the murder and had not heard that HK had committed suicide, he may have told RJ it was suicide anyway (even if he had not heard this from elsewhere), as an excuse not to tell RJ the truth (probability 0.4). It is less likely (probability 0.1) that he would have said this if he had not heard that HK had committed suicide and, not knowing of the murder, had nothing to hide.

FWS_69, 54 and 139 =The probability that RJ told these witnesses that K told him HK died in solitary confinement is low (0.1), if K refused to talk about the cause of death with RJ and K knew it was murder. It depends what is meant by 'discussed' – K could have told RJ that HK died in solitary confinement, but still have refused to discuss the death (i.e. talk about the cause of death). The probability of this event is also low but not so low (hence probability 0.2) if K did not know of the murder and refused to talk about the cause of death. Regardless of the cause of death (murder/suicide/stroke) and K's knowledge of the same, the probability that K told RJ that HK died in solitary confinement is high (0.8), if he was willing to discuss the death with RJ. It would be a higher probability (0.9) if he knew of the murder but discussed the death with RJ

RJ = The probability that K refused to discuss the death with RJ is very low (0.05) given that K knew of the murder and told RJ that HK committed suicide. Again, this depends on what is meant by 'discuss'. Our reading of the transcripts suggest that when the term 'discuss' is used, it means any discussion, however brief, and would also include cause of death. It is more likely (probability 0.95) that K did not discuss the death if he did not tell RJ of cause of death and also if he knew of murder.

There is a lower probability (0.8) that, if K did not know of the murder, that he would not discuss the death with RJ, as presumably he would wish to find out more. Less likely still is the suggestion, found only in K's own testimony, that he did not know of the murder but that he told RJ that HK committed suicide. The probability of this is 0.2. It is somewhat higher than the first probability in this section of the table – the probability that K refused to discuss the death with RJ given that he knew of the murder and that he told RJ that HK committed suicide – because that element is internally inconsistent (it would be close to impossible for K both to tell RJ that the cause of death was suicide and to refuse to discuss the cause of death). Despite the same inconsistencies in the element to which a probability of 0.2 attaches, the probability here is slightly higher because of the support provided by the conditioning elements. RJ's testimony, which stated that K refused to discuss the death with him, is conditioned on K not knowing of the murder and K telling RJ that HK had committed suicide.

For each event in Table 1 for which a probability is requested there is a complementary event for which the probability is known, once the probability requested is given. Two events are complementary if they are mutually exclusive and exhaustive; their probabilities add up to one. For example, for node FWS_54 and the probability that RJ told FWS_54 that K had told him that HK had died in solitary confinement **given** (a) that K knew of murder and **given** (b) K refused to discuss death of HK with RJ), the complementary event is "RJ did not tell FWS_54 that K had told him that HK had died in solitary confinement **given** (a) that K knew of murder and **given** (b) K refused to discuss death of HK with RJ". The probability of the complementary event is {1 - Pr(RJ told FWS_54 that K had told him that HK had died in solitary confinement given that K knew of murder and K refused to discuss death of HK with RJ)}.

In practice, the choice of probabilities can be very subjective and may be fraught with difficulties. The probabilities are best chosen in a consultation involving a subject expert and the statistician, as was the case with the example presented above. The advantage of the Bayes Net is that the effect of choices on the probability of the ultimate probandum 'K knew of murder of HK' can be investigated very quickly. The procedure has the considerable benefit that it is transparent and is easy to discuss in

court. If the procedure is challenged in court, then the expert witness (a subject expert or statistician) will be expected to justify the choice. If a different choice is suggested, say, by a judge or counsel, then it is a simple matter to investigate the effect of that choice on the likelihood ratio for the ultimate probandum (that HK was murdered in this example).

It may be that the subject expert is unhappy about the use of numbers to represent their measure of belief. In such a situation, it is possible to use verbal descriptors and then convert these to numbers for input to the network. For example, the descriptors (extremely likely, very likely, likely, equally likely, unlikely, very unlikely, extremely unlikely) could be converted to (0.95, 0.9, 0.7, 0.5, 0.3. 0.1, 0.05). Such a conversion from a verbal scale to a numerical scale is not ideal but is better than not doing it.

The conversion of a verbal scale to a numerical scale can also operate in the reverse direction. Given a numerical value for a likelihood ratio, a verbal equivalent is used. The European Network of Forensic Science Institutes has provided some guidelines for evaluative reporting in forensic science.[59] The guidelines suggest the following verbal equivalents:

- $1 < LR \leq 10$ provides slight or limited support for the first proposition against the alternative;
- $10 < LR \leq 100$: moderate support;
- $100 < LR \leq 1000$: moderately strong support;
- $1000 < LR \leq 10000$: strong support;
- $LR > 10000$: very strong support.

Once the network and the associated probabilities have been established, it is possible to investigate the support certain pieces of evidence may have for the ultimate probandum, whether K knew or did not know of the murder. This investigation may appear to be one that benefits from hindsight. The evidence is known before the

[59] *ENFSI Guideline for Evaluative Reporting in Forensic Science: Strengthening the Evaluation of Forensic Strengthening the Evaluation of Forensic Results across Europe (STEOFRAE) Results across Europe (STEOFRAE)*, March 2015, 17, available online at: http://enfsi.eu/sites/default/files/documents/external_publications/m1_guideline.pdf (last accessed 20 July 2016).

network is constructed. However, what is not known is the overall strength of the support provided by the evidence in total for the ultimate probandum for the evidence.

The construction of the network requires an assumption that the investigators can make subjective judgements of conditional probabilities for small groups of nodes, no more than three nodes in a group in the network in Figure 2. The application of the software can then inform the investigators of the overall strength of the support based on their inputted conditional probabilities. It is also possible to conduct a sensitivity analysis of the change in support for the ultimate probandum based on changes in the values of the initial conditional probabilities.

The likelihood ratio in favour of the proposition that K knew of the murder of HK provided by certain evidence is given in Table 2 below.

Table 2. The likelihood ratio (LR) in favour of the proposition that K knew of the murder of HK provided by certain evidence. Likelihood ratios in normal font are support for the proposition that K knew of the murder of HK, those in italic font are support for the proposition that K did not know of the murder of HK. Likelihood ratios are given to one decimal place. The node or nodes specified in the column headed 'Node' are those for which evidence has been instantiated. No evidence is known for those nodes not specified.

Index	Node	Evidence	LR
1	TK1	K heard HK had committed suicide	*4.5*
2	TK1	K did not hear that HK had committed suicide	8.0
3	TK2	K told RJ that HK had committed suicide	*2.0*
4	TK2	K did not tell RJ that HK had committed suicide	2.4
5	TK1, TK2	K heard HK had committed suicide and that he told RJ that HK had committed suicide	*18.0*
6	TK1, TK2	K heard HK had committed suicide and that he did not tell RJ that HK had committed suicide	*1.1*
7	TK1, TK2	K did not hear that HK had committed suicide and that he told RJ that HK had committed suicide	*32.0*
8	TK1, TK2	K did not hear that HK had committed suicide and that he did not tell RJ that HK had committed suicide	5.3
9	RJ	K refused to discuss death of HK with RJ	1.7

10	RJ	K discussed death of HK with RJ	*1.7*
11	FWS-69, FWS-139, FWS-54	All three were told by RJ that K had told him that HK had died in solitary confinement	*2.4*
12		Two were told by RJ that K had told him that HK had died in solitary confinement, one was not told by RJ that K had told him that HK had died in solitary confinement	*1.2*
13		One was told by RJ that K had told him that HK had died in solitary confinement, two were not told by RJ that K had told him that HK had died in solitary confinement	1.2
14		All three were not told by RJ that K had told RJ that HK had died in solitary confinement	2.5

A sensitivity analysis of the effect of changes in the conditional probabilities for node TK1 on the likelihood ratio (support) for the proposition that K knew of the murder of HK is given in Table 3 below. Note that the values for the LR in the lower triangular part of the table are the reciprocal of the values in the upper triangular part of the table. The value for the LR on the diagonal is one as the evidence is neutral when the probability that K testified that he had heard that HK committed suicide, given he knew of the murder of HK is equal to the probability that K testified that he had heard that HK committed suicide, given he did not know of the murder of HK. The likelihood ratios are not very large as only one piece of evidence is under consideration.

Table 3. The likelihood ratios (LR) in favour of the proposition that K knew of the murder of HK for various conditional probabilities for the testimony that K had heard that HK had committed suicide. The conditioning events are (a) that K knew of the murder and (b) that K did not know of the murder. The conditional probabilities range from 0.2 to 0.9. Likelihood ratios in normal font are support for the proposition that K knew of the murder of HK, those in italic font are support for the proposition that K did not know of the murder of HK. Likelihood ratios are given to one decimal place.

Likelihood ratios		Probability K heard HK had committed suicide given that K knew of the murder of HK							
Probability		**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**

K heard that HK had committed suicide given that K did not know of the murder of HK	**0.2**	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5
	0.3	*1.5*	1.0	1.3	1.7	2.0	2.3	2.7	3.0
	0.4	*2.0*	*1.3*	1.0	1.2	1.5	1.8	2.0	2.2
	0.5	*2.5*	*1.7*	*1.2*	1.0	1.2	1.4	1.6	1.8
	0.6	*3.0*	*2.0*	*1.5*	*1.2*	1.0	1.2	1.3	1.5
	0.7	*3.5*	*2.3*	*1.8*	*1.4*	*1.2*	1.0	1.1	1.3
	0.8	*4.0*	*2.7*	*2.0*	*1.6*	*1.3*	1.1	1.0	1.1
	0.9	*4.5*	*3.0*	*2.2*	*1.8*	*1.5*	*1.3*	*1.1*	1.0

Now consider the support for the ultimate probandum if all other nodes have evidence instantiated. Two cases are given, one in which all nodes are set at the first level and one in which all nodes are set at the second level. The initial probabilities are set at the values given in Table 1. A full investigation of the effect on the ultimate probandum of the different possible instantiations would require $2^6 = 64$ combinations.

The first case, in which all nodes are set to the first level, has the following evidence:

1. K heard HK had committed suicide;
2. K told RJ that HK had committed suicide;
3. RJ told FWS_69 that K had told him that HK had died in solitary confinement;
4. RJ told FWS_139 that K had told him that HK had died in solitary confinement;
5. RJ told FWS_54 that K had told him that HK had died in solitary confinement;
6. K refused to discuss the death of HK with RJ.

For this set of evidence, the likelihood ratio is 96.0 in support of the proposition that K did not know of the murder of HK. Using the verbal scale above, this means that there is moderate support for the proposition that K was unaware of the murder of HK. The ICTY Trial Chamber ultimately concluded that the evidence failed to prove, beyond reasonable doubt, that K was aware of the murder of HK,[60] and the calculations here, based on our initial probabilities, show that this conclusion was well-founded.

[60] *Prosecutor v. Krnojelac*, Judgment, Case No. IT-97-25-T, 15 March 2002, para. 348.

The second case, in which all nodes are set to the second level, has the following evidence:

1. K did not hear that HK had committed suicide;
2. K did not tell RJ that HK had committed suicide;
3. RJ did not tell FWS_69 that K had told him that HK had died in solitary confinement;
4. RJ did not tell FWS_139 that K had told him that HK had died in solitary confinement;
5. RJ did not tell FWS_54 that K had told him that HK had died in solitary confinement;
6. K discussed the death of HK with RJ.

For this set of evidence, the likelihood ratio is 1.1 in support of the proposition that K did know of the murder of HK. A value this close to 1 is effectively neutral, thus this combination of testimony provides no support for either proposition. It is disappointing that this combination of evidence, set of testimonies, does not provide more definitive support for one proposition than the other. However, the outcome provides an example of the benefit of the network. With our selection of initial conditional probabilities, the overall evidence is neutral. Again, this shows that the ICTY's refusal to enter a finding, beyond reasonable doubt, that Krnojelac knew of the murder was well-founded.

Conclusion

This article argued that the use of Bayes Nets by various actors in international criminal trials, and an understanding of the fundamentals of probability by such actors, would enhance the quality of fact-finding in international criminal law. This argument is situated in a wider context on the reliability of findings of fact in international criminal law. Whilst many authors have pointed to challenges to fact-finding in the context of international criminal trials, and to particular findings of fact that are not supported by the evidence at hand, few have provided practical solutions to these issues. Even fewer have illustrated how formal methods and tools to assist decision-making could be used in practice.

By providing a practical example of the process of devising a Bayes Net from an international criminal case, we have illustrated how one such method could be used in

practice by international criminal judges, their staff, and by prosecution and defence counsel. Our small exploratory study focused on a limited part of the *Krnojelac* Trial Judgment. It is pleasing to note that our analysis agreed with the ICTY's findings on this charge. An ideal use of the Bayes Net would be to incorporate all the evidence in one network. This may appear an unachievable ideal but it may be as achievable as a thorough study of all the evidence by any other way, given the quantity and complexity of the evidence. Any attempt to construct a Bayes Net would concentrate minds on which nodes (pieces of evidence), which links (associations amongst pieces of evidence) and probability values (strengths of association) to include in the consideration of the judgement.

We hope, in this article, to have illustrated the relative ease of applying the method to a complex factual and evidential matrix, in spite of the objections that may be levelled against the use of Bayes Nets, as noted in Part I. With the availability of software to construct Bayes Nets, the otherwise complex task of calculating revised probabilities becomes straightforward, even for cases that are as complex as international criminal cases, and despite the quite unique evidential hurdles faced in international criminal trials. With a small amount of training, judges and lawyers, practicing in all areas of law, would be able to incorporate this methodology into their practice. This article has shown the utility of the methodology and illustrated how it might work in practice.