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Theory of Probability and Criminal Procedure: A New Perception of Interpretation of Evidences and Court's Ruling

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The purpose of the paper is to consider whether it would be possible to introduce the so-called Bayes' rule in a contemporary criminal procedure of a civil legal tradition. The Theory of probability, usually discussed within mathematics or statistics is rather marginally, if at all, discussed in the Bosnia and Herzegovina legal literature in general, and in criminal law literature in particular, especially with regard to its implementation in criminal trials for the purpose of getting a court's ruling. On the other side, this theory is well known in Common Law countries, and as such is in the focus of legal theory for a long time. According to purpose several questions are asked in this paper, such as: Is it possible to use the Bayes' rule in the application of the law of evidence for the purpose of obtaining court's judgment? If yes: under what conditions? And finally: What would be consequences of the introduction of such rule? Use of Bayes' rule in Criminal procedure was not been deeply researched in Bosnia and Herzegovina, so the practical implications are better understanding possibilities of its use particularly for interpretation of some kind of evidences.

Keywords: Bayes' rule, criminal procedure, evidence law, interpretation of evidences, court's ruling

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1 Introduction

As is well known, the implementation of science-based achievements of different scientific disciplines for the purpose of criminal and judicial process in general, is one of the more prevalent tendencies of contemporary justice. In criminal proceedings, implementation of science-based achievements, in modern times, is expressed in two areas. First, is the area of obtaining evidence, and second, the area of interpretation and evaluation of probative value. In the area of obtaining evidence, scientific and technological development has reached such a level that they not only significantly facilitates the search for evidence thanks to sophisticated forensic procedures, but it also makes it possible to actively generate evidence, as is the case of technical recordings in special investigative techniques, for example. For the purpose of this paper, we are specifically interested in the second area of applying scientific and technological development for the purposes of criminal justice and that is the area of interpretation of evidence and the assessment of its probative value. Although in this area, the application of modern science has increased to such an extent that it has led to the phenomenon being described as the *scientification of courtroom* in the legal literature, there are still many open questions remaining. One of them, which will be the subject of the discussion in this paper, is the possibility of applying a specific mathematical model of probability theory, also known as *Bayes' theorem,* in the interpretation of evidence and the assessment of its probative value. In domestic criminal proceedings, and especially in general legal theory, theory of probability and its implementation in the judicial proceedings has been, marginally or not at all, the subject of consideration. In Common law theory, however, it is the issue very generously treated in academic and professional circles, and that is very conclusive experienced in the few cases that have been argued by high courts of some states. In this context, the aim of this paper is to introduce to scientists and professionals to the basics of this mathematical model, and also the possibilities of its implementation in the framework of interpretation of evidence, and the judicial decision-making process. In this regard, the paper introduces the need for a better understanding of these issues connected with basics of probability theory. The paper findings will analyze a theoretical point of view on the possibilities of its application in crimi-

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nal proceedings, as well as the relevant court rulings that have direct connections to specific criminal cases in which this and some other probability models are implemented. Also, it will refer to some empirical studies that have been conducted on this topic. Finally, it is very important at the introduction of this paper, to note how none of the authors is a mathematician or statistician, rather criminal law and investigation researchers and professionals. Accordingly, this paper should only be considered from the criminal law and investigation point of view, and not from the view of mathematics or statistics. This can be a limiting factor, but in general this is also a limiting factor for every investigator, prosecutor or judge who makes decisions on a daily basis in the real world. Because of that, we are aware of our weaknesses and will use them to learn more about the issues we highlighted in this paper, and on the other side, therein, where we are on our scientific and professional field we will try to be more critically oriented, all for purposes of the better understanding of this matter.

2 Understanding Probability and its Connection to Criminal Justice

In general, the theory of probability in modern science can be considered as the study of mathematical models of random phenomena (Parzen, 1960: 5–8). Learning about probability started to develop in the Middle Ages, driven by gambling. Among the first written works that have reffered to this issue are the works of Girolamo Cardano, then the correspondence between Blaise Pascal and Pierre de Fermat, prompted by a letter addressed to Pascal by the Chevalier de Méré, and later Bernoulli's work, as well as other authors (Bertsekas & Tsitsiklis, 2008: 17; Ore, 1960: 411–412). It is believed that the modern arithmetic system developed by the Hindus and Arabs, together with new Renaissance ideas facilitated the development of the first scientific "thinking" in this area (Bertsekas & Tsitsiklis, 2008: 17). The essence of the above works mainly addressed solving probability problems in games of chance.[4] It has been noted that despite the long history of defining probabilities, thanks to Russian mathematician A. N. Kolmogorow in 1933, we received the first satisfactory definition of probability theory in which probability figures as a function on subsets of so-called sample space, where sample space represents the set of all possible outcomes of the experiment (Tijms, 2012: 229). Today the mathematics of probability has a wide field of application in physics, biology, engineering, medicine, economics and great many other areas.

Now we can ask a question: what is the connection between mathematical probability and criminal justice? Probability theory, as we mentioned above, has found its range of applications in virtually all areas of human life, and almost any event can be calculated and predicted by applying the appropriate formula. All of this, of course, speaking in the language of mathematics. In this sense, one can imagine guilt as a specific event. So, through using specific principles of probability theory, it is possible to accurately calculate the probability of someone's guilt; again, in mathematical not legal language.

As a particularly good tool for this calculation, modern scientists use the achievements of Thomas Bayes (1701–1761), an English priest, philosopher and mathematician who in *An Essay towards solving a Problem in the Doctrine of Chances,* which was edited after his death, and then published by his friend Richard Price, developed a model based on the principle of probability. In addition to a large number of other scientific areas, it can also be applied to the interpretation and evaluation of evidence in judicial proceedings.

As R. Price explained in his letter to John Canton: "*In an introduction which he (Mr. Bayes) has writ to this Essay, he says, that his design at first in thinking on the subject of it was, to find out a method by which we might judge concerning the probability that an event has to happen, in given circumstances, upon supposition that we know nothing concerning it but that, under the same circumstances, it has happened a certain number of times, and failed a certain number of times.*" (Bayes & Price, 1763: 1–2)

The work of Thomas Bayes presented in the aforementioned essay as Bayes' theorem or Bayes' rule, is one of the most significant achievements in the field of probability theory and so-called conditional probability. Some authors refer to Bayes' approach using the term "likelihood approach" or "likelihood *ratio* approach" (Aitken, 2012; Ligertwood, & Edmond, 2012; Nordgaard & Rasmusson, 2012; Robertson, & Vignaux, 1995). It is important to note that Bayes' rule can be used for interpretation and evaluation of evidence in criminal procedure. In general, this rule allows us to correct the so-called "*prior* probability" of an event after we subsequently brought some evidence, and in this way to receive the so-called "*posterior* probability" of that event. According to O'Hagan (2007) most legal systems, and we are in agreement, acknowledge that guilt can rarely (if ever) be established beyond any doubt at all, instead we use phrases like "beyond all reasonable doubt" or "on

[4] A good example of that is de Méré letter to Pascal in which he explains his confusion about the so-called dice problem, or when one throws with two dice, how many throws must one be allowed in order to have a better than even chance of getting two sixes at least once. De Méré believed this number has to be 24, but his own experience had shown him that 25 throws were required. As it was latter resulted from correspondence between Pascal and Fermat, de Méré was right (Ore, 1960: 411–412).

the balance of probability" which make explicit reference to probability as a basis for judgment (O'Hagan, 2007: 18). Today, there is a great number of variations in presenting Bayes' rule for the purposes of its application in criminal justice, as we found in the literature. Here we choose a few of them considered as simple and understandable to everyone with at least a basic knowledge of mathematics.

The first one discussed comes from O'Hagan, (2007) and it is shown below as:

$$\frac{PG\ x\ LG}{(PG\ x\ LG) + (1 - PG)\ x\ LI}$$

Where the PG is *prior* probability of guilt, 1 - PG, *prior* probability of innocence, LG, likelihood of guilt and LI likelihood of innocence. Using this formula, it is possible to compute someone's guilt in light of the evidence here noted as *posterior* probability (O'Hagan, T. 2007: 18–19). He also noted that probability for a proposition can be a number between 0 and 1, where 0 means that the proposition is certainly false and 1 means that is certainly true, and probabilities between these limits measure different strengths of the belief of the proposition.

There is also Thompson and Schumann's (1987) presentation of the same rule for the "computation" of someone's guilt and it is shown as:

$$p\left(\frac{H}{D}\right) = p(H)p(\frac{D}{H})/[p(H)p\left(\frac{D}{H}\right) + p(\overline{H})p\left(\frac{D}{\overline{H}}\right)]$$

Where: p(H) presents *prior* probability and reflects one's initial estimation of the probability that suspect is guilty in light of everything that is known before receiving evidences D; D presents associative evidence; and p(H/D) presents *posterior* probability and indicates what one's revised estimate of probable guilty should be in light with everything that is known after receiving D (Thompson & Schumann, 1987: 170–171).

Finally, one of the recent and very comprehensive approaches in presenting the possibilities in the implementation of Bayes for the purposes of interpretation of evidence is one from Robertson and Vignaux, (1995). In their example:

Prior odds x Likelihood *ratio* -----> *Posterior* odds

prior odds (*prior* probability) presents our assessment without the evidence; likelihood *ratio* is the probability of the evidence supposing that our assertion is true divided by the probability of the evidence that the assertion is not true; and *posterior* odds (*posterior* probability) is the probability we want to know, and the odds in favor of the hypothesis after taking into account the new piece of evidence (Robertson & Vignaux, 1995: 17).[5]

As to how all these variations of Bayes and probability in general can be implemented in the courtroom and what impact it would have on interpretation and evaluation of evidence, we shall discuss later in this paper. However, it should be noted that Bayes' approach can be used not only for the purposes of interpretation of evidence at trial, but in criminal investigations as well. One of the examples of this is the study conducted by Blair and Rossmo (2010). In this study, using three types of evidence: "witness", "confession" and "physical evidence" (because of few justified reasons, they decided as a physical evidence to take a fingerprint), they made a complex analysis of a single element of evidence, multiple elements of evidence in agreement and conflicting elements of evidence, using Bayes, which resulted with very interesting findings. For example, in the analysis of single elements of evidence, the presence of fingerprint evidence resulted in *posterior* probability of guilt over 95% at an *a priori* probability of 28%, confession evidence at an *a priori* probability of 45%, and eyewitness evidence at an *a priori* probability of 49% (Blair & Rossmo, 2010: 126–132).

If probability over 95% in the aforementioned example, we bring in context with the fact that probability for the proposition can be any number between 0 and 1 it is not hard to conclude how the stated hit rate is very close to which can be "mathematically" concluded as certain. They emphasized that for an accurate assessment of someone's guilt, given a particular element of evidence using Bayes' rule, it is necessary to know three numbers: First, the hit rate of the tool that generated the element of evidence (i.e., how likely is it that a suspect would be identified in a photographic lineup when the suspect is in fact the person who committed a crime); Second, the false positive rate of the tool (i.e., how likely is it that a suspect would be identified in a photographic lineup when the suspect is in fact not the person who committed the crime); and Third, the *a priori* probability that the suspect is guilty (Blair & Rossmo, 2010: 125). However, the same authors also noted limitations of the study connected to the overestimation of hit rates and underestimation of false positive rates.[6] As we can see, the mathematics of probabilities and Bayes'

[5] According to mentioned authors if the likelihood *ratio* is more than 1 the evidence tells in favour of the hypothesis, if the *ratio* is less than 1 then it tells against hypothesis, finally if the *ratio* is exactly 1 in that case evidence is neutral. For more details and particularly good explanations of many parameters in the field of Bayes use in forensics see Robertson and Vignaux (1995).

[6] For detailed account of their findings and limitations see Blair and Rossmo (2010).

rule can be a very useful tool in interpretation of evidence during the criminal investigation stage. Although we see at this stage using mathematics of probability for any assumption of someone's guilt, even for the lower degree of guilt of the sort required in the course of the investigation, can be disputed and we can't neglect the potential benefits of using this approach. For those who know what a criminal investigation means, it is well known that rarely is the investigation black or white and commonly needs to be composed of great number of pieces that should be put in their places. The modalities of connecting these pieces into a single logical unit usually can be mind "heavy", and are sometimes unconventional. It rarely happens that we start the investigation full of useful information that interested us. So regarding the question: does probability approach need to be used in investigation on the way mentioned above or similar, we can ask another question. For example, in Bosnia and Herzegovina police agencies conduct polygraph testing at the pretrial stage to get any possible information in the course of investigation, but at the same time, cannot use the results of testing as legally admissible evidence. So why conduct it at all?

But using Bayes' rule at this stage of the criminal proceedings is not our current concern, although it is very difficult to separate investigation from the trial, especially in the criminal proceedings in Bosnia and Herzegovina, and we'll go on mathematics of probability at criminal court, leaving all outstanding issues regarding the investigation likely for our subsequent work.

3 Probability in Criminal Court

It is very important to note that the probability in criminal procedure, as any other science or knowledge we are using for the purposes of interpreting evidence, must be used in accordance with the procedural rules in the case. Only then in our case of use of mathematics of probability, can one talk about the so-called probabilistic evidence which can be accepted or not by a court or jury. Generally, any information might be used as evidence in the proceedings, but it first must meet certain, very rigorous, procedural, and evidence rules. There are differences if we consider criminal procedure and evidence rules in Civil or Common law tradition. Generally speaking common for both is that the expertise must be conducted in the form of expert testimony as party or court evidence, and it has to be based on appropriate professional knowledge and provide answers to factual not legal questions.[7] For the purposes of this paper, we assumed that these rules, in the case of using Bayes are accomplished, so that further in the paper we can focus on substance, but there could be a problem. Sometimes, it is not easy to make distinction between formal admissibility of expert testimony as evidence, and a court's willingness to accept that expert testimony on the grounds of believing in a specific scientific approach used to provide the testimony. A good example of this is the opinion of Court of Appeal in R *v* T in which: "*The principles for admissibility and provision of expert evidence are clear, but courts cannot apply them if they are not made aware of the way in which an expert has reached his opinion through the provision of a full and transparent report.*" (R *v.* T [2010] EWCA Crim 2439, 109) Whenever we talk about the implementation of these and similar techniques in criminal procedure, we should bear this in mind.

One of the earliest reported cases in the literature of the use of probability for the interpretation of evidence was the case of Alfred Dreyfus, French artillery officer in the General Staff, from 1894. In this case, Dreyfus has been convicted for espionage for Germany on the basis of a comparison of the frequency of certain words from his correspondence with his brother, with the content of the disputed document that ended up in German hands. Based on the existence of obscure lexicographical and graphological coincidences in the document itself, the prosecution witnesses indicated that there is a high probability of its disguised character and of its use to convey coded information (Tribe, 1971: 1332). Few years later, Dreyfus was pardoned. A subsequent review of the expertise conducted by the prosecutor's witnesses established that the mathematical basis for the assumption of the high probability that Dreyfus was the author of the document was pointless.

Another of the known cases to incorporate probabilities evidence, and later suffered a reversal at the California Supreme Court, is the case of People *v.* Collins from 1968. In this case, an interracial couple (black male and white woman) was accused of robbery. This case is curious because there was no clear evidence that this specific couple committed the alleged offense, and from the testimony it was said that a young blond white woman with a ponytail ran from the crime scene and entered a yellow car driven by a black male with a mustache and beard. A few days, later police arrested Mr. Collins and his wife Mrs. Collins as the couple who matched the description provided by the witnesses. In the proceedings that followed, the prosecutor urged the mathematical instructor to determine if the robbery was committed by a blond white

[7] In general, rules in Civil law tradition bind experts for non-biased testimony, strictly based on the rules of their profession or knowledge, and on the other side, for example in US criminal law, there are rules of evidences and specific standards, Frye and Daubert which define conditions of admissibility of expert testimony in criminal procedure.

women with a ponytail accompanied by a black male with a mustache and beard, and that there was an overwhelming probability that the accused couple were guilty because they matched the detailed description. Without entering further into the explanation of a very complex process of calculating the probability that followed, it was determined by the expert that the probability that any couple possesses the characteristics of the accused are 1 in 12 million, which significantly impacted upon the jury and resulted in a conviction for second degree robbery (People *v*. Collins 68 Cal. 2d319, 438 P.2d 33, 66 Cal. Rptr. 497, 1968).

But how did prosecution witness, an instructor of mathematics from a state college, come to the aforementioned degree of probability of 1:12 million? First, he determined the probability for each of the 6 characteristics of identification as follows:

Characteristic:	Probability:
Partly yellow automobile	1/10
Man with mustache	1/4
Black man with beard	1/10
Girl with ponytail	1/10
Girl with blond hair	1/3
Interracial couple in car	1/1000

Subsequently, he used the criteria of the so called "product rule"[8] of those probabilities as it is shown below:

$$\frac{1}{10} \times \frac{1}{4} \times \frac{1}{10} \times \frac{1}{10} \times \frac{1}{3} \times \frac{1}{1000} = \frac{1}{12 \times 10^6}$$

The final result indicated that the chances that some other randomly chosen couple would possess these same characteristics as the accused couple are, as mentioned before, 1 in 12 million (People *v.* Collins 68 Cal. 2d319, 438 P.2d 33, 66 Cal. Rptr. 497, 1968). After the Court performed its own probability test, it concluded that: "*Even if we should accept the prosecution's figures without question, we would derive a probability of over 40% that the couple observed by the witnesses could be duplicated by at least one other equally distinctive inter racial couple in the area.*" Using this and other arguments that: "*The testimony itself lacked an adequate foundation both in evidence and in statistical theory and that the manner in which the prosecution used it distracted the jury from its proper and requisite function of weighing the evidence on the issue of guilt ...*" the Court reversed judgment of conviction and held: "*That defendant's trial by mathematics so distorted the role of the jury and so disadvantaged counsel for the defense as to constitute in itself a miscarriage of justice that mandated reversal.*" (People *v.* Collins 68 Cal. 2d319, 438 P.2d 33, 66 Cal. Rptr. 497, 1968) It is important to note that in this case, the implementation of Bayes' rule as a model for computing probability, and in general, criteria of conditional probability were ignored, instead the expert used the method of so called "product rule" as we mentioned earlier.

Also one of the recent and well analyzed cases that involved similar controversy about the use of probability at trial is the case R *v.* T and the judgment of the Court of Appeals in the English High Court of Justice relating to it. Despite the obvious differences between this case and the People *v.* Collins case (i.e. cases being tried in different legal systems, under different charges, expert testimony related to different facts, and different probabilistic method used, product rule in People *v.* Collins and Bayes in R *v.* T), the final results in both cases are pretty similar. The higher courts did not accept the expert's interpretation of evidence, considering them inadequate in the process of interpretation, and also in terms of the mathematical models used for their interpretation.

In the R *v.* T, the appellant was tried for the murder, was convicted and appealed on issues connected to the extent to which expert evidence on footwear marks is reliable as well as the way in which it was put before the jury. As it was noted, the real issue in the footwear marks was the use of likelihood *ratios* in forming an evaluative opinion on the degree of likelihood that a mark had been made by a particular item of footwear (R *v.* T [2010] EWCA Crim 2439 15). As stated in the judgment: "*Appeal raised an issue of some importance in relation to the use of likelihood ratios in the provision of an evaluative opinion where statistical data available were uncertain and incomplete.*" In short, the expert in this case came to his conclusions by examining the marks and the footwear regarding four factors: 1) the sole pattern, 2) the size, 3) the wear and, 4) any damage noted. His formula is shown below:

P x C x W x D with values of 5 x 10 x 2 <1 = ~ 100

The values P, C, W, and D represent appropriate frequencies of these four factors, which he then multiplied the likelihood *ratios* for each of the factors to get an overall likelihood *ratio* of 100. His conclusion presented to the jury was that there is a moderate degree of scientific support for the view that (the Nike trainers) made those marks, (R *v.* T [2010] EWCA Crim 2439 29., 35., 36.,37., 41.). Similar to People *v* Collins, the Appeals Court in this case also overturned the previous judgment arguing against the way the expert tes-

[8] According to noted rule the probability of the joint occurence of a number of mutually independent events is equal to the product of the individual probabilities that each of the events will occur (People *v*. Collins 68 Cal. 2d319, 438 P.2d 33, 66 Cal. Rptr. 497, 1968).

timony has been presented, the non-transparency of using likelihood *ratios* in this specific case, and lack of a proper statistical basis for that kind of expertise. However, it should be noted that Court opinion recognized the importance of Bayes for DNA analysis, when stated that: "*Acceptance of a mathematical approach to the calculation of a match probability in DNA cases is based on the reliability of the statistical database, though an element of judgment is required.*" (R *v.* T [2010] EWCA Crim 2439 80.)

The cases analyzed here are not the only ones which incorporate the probability controversy. There is a great number of other cases which can be found in judicial archives and literature, like for example R *v.* Clark (R *v.* Clark [2003] EWCA Crim 1020), where a mother was convicted of the murder of two her babies and the Court of Appeals in The Supreme Court of Judicature of England and Wales concluded that the convictions were unsafe and must be set aside. But we found that questions arose in those we presented were completely enough to understand the whole complexity of the issue of probabilistic evidence and its use in court.

4 Repercussions

In consideration of all possible outcomes with the use of Bayes in criminal trials, and in general in criminal procedure, it has to be noted that debating the accurate nature of the court's judgment is a difficult task. That task has two sides, that from the standpoint of legal system for our purposes we call objective and one subjective, from the standpoint of parties at trial. From an objective point of view, the final court decision (*res iudicata*) is correct and we can accept this on the level of principle. The legal system of each country that respects fundamental human rights and freedoms, incorporates a large number of formal mechanisms that should provide a fair and equitable trial along with the required presumption of innocence*, the in dubio pro reo* principle*, the* right to appeal (right to legal remedies), along with many others. By meeting all of these requirements in each particular criminal case its objective nature will be realized. On the other hand, from a subjective point of view a court judgment will never be correct, except in some cases for example where the accused pleads guilty or in the case of plea bargaining. The party that loses the case will represent the idea that it has been impaired and that the judgment is neither fair nor legally correct. In criminal trials, objectivity is therefore based on the parties' subjective standpoints carefully reviewed by a court or jury. Those standpoints have to be based on evidence and now we arrive at the question, what if the evidence is based on probability? Some authors think that there could be a problem and that the costs of attempting to integrate mathematics into the fact-finding process of a legal trial outweigh the benefits (Tribe, 1971: 1377). As it can be seen, having analyzed some relevant cases in this paper, it seems safe to conclude that the judiciary is not prone to such experimentation with evidence in criminal trials.

What does this practically mean? Does it mean that the mathematics of probability should be considered as some sort of number playing game commonly used in criminal procedure when one side in trial (the prosecutor, but also the defense), does not have other convincing evidence, and by the way of so-called "mathematical tricks" tries to prove its claims? No it does not. In connection with that, it has to be noted that in legal theory misusing probability by the prosecutor, to prove questionable facts is known as a "prosecutor's fallacy". This term identifies the logical mistakes of treating the probability of the occurrence of the available evidence given the innocence of the accused as if it were the probability of innocence given the available evidence (Pundik, 2013: 95). The corresponding term relative to the defense is known as "defense attorney fallacy". But the mathematics of probability is also a serious scientific discipline and scientists and professionals from that field have to be taken into serious consideration. Some of them share the opinion that in some cases, the Bayesian approach may not be an appropriate model for the interpretation of certain evidence, but that does not mean that essentially probability needs to be rejected in criminal proceedings. This is particularly evident in the debate that developed after the ruling in the R *v.* T case. In his response to the court's opinion and critics of the Bayes approach in the R *v.* T case, Aitken (2012: 255) stated: "*As a strong advocate of the likelihood approach, I was anxious to learn more about other approaches to evidence evaluation and interpretation and understand them better.*" Contrary to Aitken (2012), Ligertwood and Edmond, (2012) are willing (under specific conditions) to accept different approach but they expressing their disbelief that this is possible because of minor judicial support for converting the standard of proof into mathematical terms (Ligertwood & Edmond, 2012: 290).

Also, very important is the question of the way in which the court makes its decision and the possibility that the decision is, in the end wrong. Or what if mathematical formulas are right, but the court cannot interpret them as such? One of the studies related to considerations of possible errors in judicial rulings suggested that judicial decision making is generally qualitative and often intuitive, and thus far apart from the theory of decision making under uncertainty, with its quantitative and rational orientation, and its game theory extensions (Sonnemans & van Dijk, 2011: 687). It is exceptionally significant to emphasize the seriousness of the review of the judgment by a higher court. "What would happen if the

defendant in the case of People *v.* Collins did not appeal as did his co-defendant wife?" The answer is simple: "The Collins couple would stay in jail for some time and that would be a thing that fears all of us." In this sense, some authors see the importance of the decision in People *v.* Collins because the judges took the prosecutor's statistical sortie seriously enough to comment at length on the problem of statistical evidence and to attempt a mathematical demonstration of the correct form for such analysis (Finkelstein & Fairley, 1970: 489). Although in all cases that we have had the opportunity to analyze, the judgments have been reviewed by higher courts which rejected expert testimony that were based on probabilities, and on Bayes as well; this does not mean that cases where such expert testimonies were upheld by courts do not exist or will not appear soon.

Accordingly, we would agree with Friedman (1996) who in his review of three books significant in the field of understanding probabilities in criminal law, refering to Robertson and Vignaux contend that logic, probability and inference provide the language in which layers and scientists should communicate with each other, pointed out: "*I agree, though, that this is more easily said than done.*" (Friedman, 1996: 1838)

5 Conclusion

As we have seen in this paper, the mathematics of probability and Bayes as well, have their places in contemporary science but whether on the basis of so-called probabilistic evidence we can establish a fair and fact-based judgment. This is not an easy question to answer. In criminal procedure the interpretation and evaluation of evidences must comply with the rules of logic. Sometimes, in a storm of arguments and counter arguments as well as complex procedural rules, it may be difficult to see logic but the process of judicial decision-making in all its parts has a syllogistic nature. According to that, a court's judgment has to be a logical judgment. Logic is always connected with truth, or we can say logic is truth. In criminal procedure, logic often does not mean real, material truth but so-called procedural truth or as we call it "proved truth". The rules of criminal procedure, irrespective of the outcome of the proceedings, strictly forbid taking some evidence which could potentially significantly contribute to establishing the truth. In this respect, it should be noted, for example, the right of the accused to remain silent, also the procedural impossibility to question some other persons whose statements could serve as a valuable source of factual knowledge, inadmissibility of evidence because of formal reasons and such like. Due to that, the difficult task of determining the truth becomes even more complex and more demanding for judicial bodies. Some of the tools they use for decision-making and achieving the truth, at least "proved truth", are scientific approaches and (whether we are willing to admit it or not) the court's decisions in the future will become more quantitative than qualitatively based, and more scientific than intuitive.

This fact in the case of probabilities and Bayes on one hand means that lawyers, more specifically judges, and in some systems the jury will probably be incapable of dealing with complex formulas and that is worrying. On the other hand, scientists and non-legal professionals who are good at their fields are probably not as good in dealing with the criminal law and investigation. But there is a difference, in criminal cases expert witnesses are giving their specific professional expertise, not legal opinions, based on the rules of appropriate science. They are not worried about law *ignorantia* because the application of law is not their task. This is the judges' task. This brings us back to the beginning; somehow mathematics is a coldly exact science, where errors are rare and can be easily solved once you recognize them. In criminal cases, errors resulted with victims of injustice and rarely are there ways to correct them after the injustice has been done. It is for this reason that our thinking through the analysis presented in this paper has changed after we experienced a series of arguments against our initial attitude which was on some way perhaps *in favor* of Bayesian approach. We are now very cautious about the possibility of its application generally in criminal proceedings and specifically in criminal justice in Bosnia and Herzegovina. And it is very difficult to predict what would be the consequences of its use in our system of criminal procedure apart from nowadays commonly used DNA evidence. It seems paradoxical, but it is precisely the rule which permits the correction of *prior* probability with subsequent evidence, which in our case turned out to be accurate. However, we still think that Bayes' rule and probability should not be excluded from the process of making judicial decisions, nor it would of course be possible given that there are areas such as DNA analysis, for the purposes of criminal and other legal proceedings, which has proved to be one of the most important and reliable sources of evidence today, and which is based on the principles of mathematical probability. On the other hand, neither decision makers should be bound by the *a priori* acceptance of expert opinions, even when it is clearly in line with the best knowledge and points to only one, certain result. Finally, we see this paper as the first step in consideration of this very intriguating field of research. Our next step will definitely be an empirical study in connection with some specific implication for the use of Bayes in criminal procedure in Bosnia and Herzegovina. At least it seems soothing that the Bayes approach, despite all the criticisms made against it, nevertheless gave us the boundaries of 0 and 1, and in between we can seek the truth.

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Teorija verjetnosti in kazenski postopek: novo dojemanje interpretacije dokazov in odločanje sodišča

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Namen prispevka je preučiti, ali bi bilo v sodobni kazenski postopek s civilnopravno tradicijo mogoče uvesti tako imenovano Bayesovo pravilo. Teorija verjetnosti, večinoma predmet razprave znotraj matematike in statistike, je precej obrobno, če sploh, obravnavana v pravni literaturi v Bosni in Hercegovini na splošno ter zlasti v kazenskopravni literaturi, še posebej v zvezi z njenim izvajanjem v kazenskih postopkih za namen odločanja sodišča. Na drugi strani je ta teorija dobro znana v državah anglosaksonskega prava in kot taka že dolgo časa v središču pravne teorije. Glede na namen smo v prispevku zastavili različna vprašanja, kot so: Ali je mogoče uporabiti Bayesovo pravilo pri uporabi zakona o dokazih za namen pridobitve sodbe sodišča? Če da, pod kakšnimi pogoji? In ne nazadnje: Kakšne bi bile posledice uvedbe takšnega pravila?

Uporaba Bayesovega pravila v kazenskem postopku v Bosni in Hercegovini ni bila podrobno preučena, zato je dobljena praktična uporabnost boljše razumevanje možnosti njegove uporabe, zlasti za interpretacijo določene vrste dokazov.

Ključne besede: Bayesovo pravilo, kazenski postopek, zakon o dokazih, interpretacija dokazov, odločanje sodišča

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