Wamel Case Study: Evaluating a Method for Reasoning with Legal Evidence

L.A. Noteboom • C.S. Vlek • B. Verheij

University of Groningen

l.a.noteboom@student.rug.nl • c.s.vlek@rug.nl • b.verheij@ai.rug.nl

Abstract

In a criminal trial, a judge or jury needs to reason with the available evidence to find out what happened before they can reach a verdict. In Vlek et al. (2014) a method was developed to assist reasoning with legal evidence. This method uses Bayesian networks and scenarios, where the Bayesian network is used for a probabilistic approach and the scenarios are used for a narrative approach. In this project we have tested the method from Vlek et al. (2014) on a case study of the Wamel murder. The evaluation of the method is based on several criteria that address common difficulties in legal reasoning.

1 Introduction

Before a criminal case can go to court there needs to be a suspect. To find a suspect, it is important to have an idea about what has happened. To get this idea scenarios can be used to describe the circumstances that have led to the crime. For finding a good suspect, evidence needs to be collected. This evidence can be a dead body, a murder weapon, witness statements and many other things. All this evidence should lead to one or more coherent scenarios about possible suspects. In this paper a method that combines scenarios with Bayesian networks will be evaluated and discussed. The method, designed by Vlek et al. [6], helps to decide which scenario is best by using Bayesian networks. The scenarios are not concerned with the rules of law, but look at the evidence that is available to draw a conclusion about what happened. Which means that we only look at what happened and not what verdict should follow.

The question we are concerned with in this paper is: "How well is the method, as described in Vlek et al. (2014), capable of modeling a complex legal case?" To answer this question we will first explain the method in Section 3. We will evaluate the method by modeling the Dutch Wamel case [3] according to the method. We have conducted several criteria on which our evaluation of the method is based, these are described in Section 1.2.

1.1 Previous Research

In previous research there are three main approaches to reasoning with legal evidence. The first approach is based on argumentation and uses different arguments that can be attacked by other arguments as described by Bex et al. in [1]. In the second approach, which is based on scenarios, alternatives are compared to find which scenario is best [1]. The third approach is probabilistic reasoning, a method that is often used for this approach is a Bayesian network. These networks combine (causal) structures with probabilities. Vlek et al. [6] developed a method that combines narratives and Bayesian networks, in particular to model scenarios in a Bayesian network. With this method multiple scenarios are modeled in one network and through probabilities these scenarios are compared to find which one fits the evidence best.

The paper of Vlek et al. addresses three common difficulties in reasoning with evidence. These difficulties are: (1) tunnel vision, (2) the problem of a good scenario pushing out a true scenario and (3) finding the relevant variables for a model of the case. Vlek et al. suggest that the method will help to handle these difficulties by introducing idioms and a roadmap. Idioms are specific structures that are ready to use within a network and the roadmap specifies how the idioms can be used to construct a network. In legal reasoning the networks are of course always different, but with these idioms the structure of the networks become more general. Vlek et al. introduce four narrative idioms, about which they say: "The aim of narrative idioms is in particular to capture the notion of coherence of a scenario." We will give a short summary of these idioms in Section 3. Besides the idioms that Vlek et al. have developed, in their paper they also make use of the idioms suggested in the paper of Fenton et al. In their paper [2] they provide idioms for modeling typical structures such as the accuracy of evidence. This structure consists of a node that is attached to an evidence node, to model uncertainty about this piece of evidence.

1.2 Test Criteria

The goal of this current research is to evaluate the method described in Vlek et al. [6] We will model the Wamel case [3] to see how the method handles several aspects of analyzing a case, and thereby finding an answer to the question of how well the method is capable of modeling a complex legal case. We will formulate criteria, inspired upon the three common difficulties as discussed in [6]. These criteria are described here.

1. Does the method help with the problem of tunnel vision?
   Once an investigator has an idea or hypothesis about what has happened, he will tend to only search for evidence that supports this idea or hypothesis. This phenomenon leads to an incomplete investigation. With this criterion we will evaluate whether the method helps to reduce tunnel vision in an investigation.

2. Does the method help with the problem of a good scenario pushing out a true scenario?
   One of the pitfalls of the narrative approach is the problem of a good scenario pushing out a true scenario. People tend to believe what sounds as a good scenario over a true scenario that sounds less appealing. With this criterion we will evaluate whether the method helps to avoid this pitfall.

3. Does the method help with finding the right structure for a model of the case?
   Converting a scenario into a network can be difficult. A starting point needs to be found and new nodes need to be added to come to a good representation of the scenarios.

4. Does the method help with finding the relevant variables for a model of the case?
   Not everything needs to be modeled in the network. There need to be boundaries so that irrelevant details are left out to make the network clear and understandable. On the other hand, all the relevant variables should be modeled in the network, making sure it represents the scenarios in a correct way.

5. Is it possible to model different kinds of cases?
   In the article of Vlek et al. [6] they have explained and tested the method with a case study. But can the method be applied to cases that differ from the case that they have modeled? Or is the method too specific so that it only can be used to model one type of case?

While keeping these criteria in mind, we will model a case by using the method. Eventually we will discuss if this method meets the criteria mentioned above. In the next section we will give a short explanation of Bayesian networks, followed by an explanation of the method from Vlek et al. (2014) in Section 3. In Section 4 we will build a network of the Wamel case [3]. We will end with a discussion about our findings and a conclusion with suggestions for further research, in Sections 5 and 6 respectively.

2 Bayesian Networks

Bayesian networks consist of acyclic directed graphs together with probability tables for each node [4]. The network and the probability tables provide a way to have a compact representation of a Joint Probability Distribution. Bayesian networks can be used as expert systems, which are systems in which information about some domain is stored. The information that is stored in such systems, is knowledge that human experts have about the domain. This information is then used to derive conclusions, which can help with coming to objective conclusions.
In the field of artificial intelligence one of the goals is for computers to assist humans with coming to conclusions based on the information that is available to them, especially in real world problems. One important part of this is dealing with uncertainty, for which Bayesian networks are one of the solutions.
One example of the problems that expert systems have to deal with is that of *explaining away*. A small Bayesian network without probability tables is shown Figure 1. In this graph the arrows represent causal connections, where the node at the end of the arrow is the observable effect of the node where the arrow is coming from.
What we see in this graph is the way that evidence and causes can be represented. When we, for example, observe that the window is broken, we can think of two different causes, namely someone wanted to break in and a child kicked a ball through the window. With explaining away, the observation of a loose brick in the house gives us more evidence for the cause that someone wanted to break in. Then it becomes less likely that a child kicked a ball through the window. Bayesian networks can provide us with an intuitive way to do this.

In the book of Kjærulff and Madsen [4] they say that Bayesian networks most often represent causal statements of the kind $X \rightarrow Y$ where Y often takes the role of an observable effect of X. In this case X typically cannot be observed itself. Therefore we need to calculate the posterior probability $P(X|Y = y)$ given the observation $Y = y$ and the prior probability $P(X)$. This can be done with Bayes' rule.

$$P(X|Y = y) = \frac{P(Y = y|X)P(X)}{P(Y = y)}$$

Bayes' rule provides a way to infer the probability of a cause once its effect has been observed

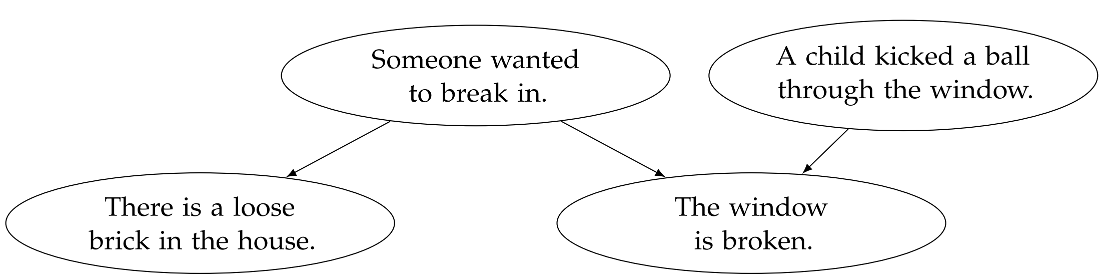
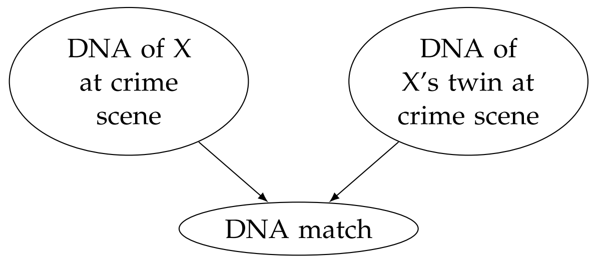


Figure 1: *An example of a Bayesian Network without probability tables. The arrows represent causal connections between the nodes. The node at the end of the arrow is the observable effect of the node where the arrow is coming from.*

and for this reason the rule plays a central role in statistical inference. [4]

CS X = True	CS X = False
0.2	0.8



Tw X = True	Tw X = False
0.02	0.98

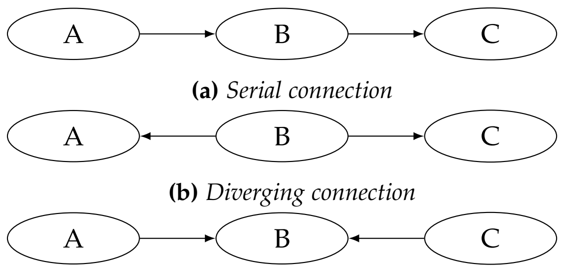
	Twin = False		Twin = false	
	CS X = True	CS X = False	CS X = True	CS X = False
Match = True	0.01	0.01	0.999	0.001
Match = False	0.99	0.99	0.001	0.999

Figure 2: *An example of a Bayesian network, including the probability tables. The probability tables of the two upper nodes are the prior probabilities of the nodes. The probability table of the bottom node represents the posterior probabilities of this node.*

Figure 2 is an example of a Bayesian network. Each node in the network has its own conditional probability table. This table describes the probability distribution of a node A based on its parents $(P_1, ..., P_n)$, which are nodes with an arrow pointing towards node A. If a node has no parents, we call the probability of that node, the prior probability of the node. The probability table of A takes into account all the possible values that its parents can have, so that $P(A|P_1, ..., P_n)$. Each node in the network has a finite set of mutually exclusive possible states. In the example of Figure 2 there are three nodes. The first one is the node `DNA match` which tells us if the DNA that was found on the crime scene matches the DNA of a person X. This node has two parents namely `DNA of X at the crime scene` (abbreviated to CS X) and `DNA of X's twin at the crime scene` (abbreviated to X's Twin), that respectively represent if the DNA of person X actually was at the crime and if the DNA of X's twin was at the crime scene.
In this network each node has only two possible states, namely true or false. The arrows describe dependencies between the nodes. If there is evidence for `DNA match` that tells us that `DNA match` is true, then we say that `DNA match` is instantiated. This influences the probabilities of the parents of `DNA match`. Bayes' rule enables us to calculate the probability of `CS X` and `X's Twin` given the probability of `DNA match`.

From the graph of a Bayesian network (in)dependencies can be read. Influence between variables can change after observing certain other variables. The term used to express whether there is an influence after observing a variable is d-connectedness. Figure 3 represents three possible chains in the graph of a Bayesian network, where d-connection is expressed in terms of active paths between the nodes. If there are no active paths between two nodes, these nodes are d-separated. Figure 3a represents a structure in which A is connected to B and B is connected to C. The arrows between the nodes represent direct influence between nodes. In Figure 3a, evidence about A will influence the certainty of B which will in turn influence the certainty of C. The influences will also work backwards, which means that evidence about C will influence the certainty of A through B. In that case the chain is active and we say that A and C are d-connected.

If, in this case, the value of B is instantiated, A and C become d-separated .



(a) *Serial connection*

(b) *Diverging connection*

(c) *Converging connection*

Figure 3: *Possible structures that can occur in a Bayesian network.*

The situation in Figure 3b is called a diverging connection and is similar to the serial connection. Influence can pass between node A and node C as long as node B is unobserved. This chain is active if B is unobserved, and then we say that A and C are d-connected. As soon as B is observed, A and C become d-separated.
Figure 3c shows a converging connection. Converging connections are different than the diverging and serial connections. The nodes A and C are d-separated when nothing is known about B. When we find evidence for one of the nodes A and C, this will not influence the certainty of the other through B. However if B is instantiated, this influence does occur. This chain is active if B is observed, making A and C d-connected. As long as B is not observed, A and C are d-separated.
In short this means that in serial and diverging connections with three nodes, the outermost nodes, are d-connected if the middle node is not instantiated. In converging connections the outermost nodes are d-separated if the middle node is not instantiated.

This can all be summarized in the formal definition of d-separation. [5]

Definition *d-separation*. Two distinct variables A and B in a causal network are d-separated if for all paths between A and B, there is an intermediate variable V (distinct from A and B) such that either

- the connection is serial or diverging and V is instantiated
  or
- the connection is converging, and neither V nor any of V's descendants have received evidence.

If A and B are not d-separated, we call them *d-connected*.

The structure of the Bayesian network of Figure 2 corresponds with the structure in Figure 3c. The nodes `CS X` and `X's twin` are d-separated as long as `DNA match` is unknown. This is because there is no active chain between `CS X` and `X's twin`. Once `DNA match` is instantiated the chain becomes active and `CS X` and `X's twin` are said to be d-connected. For our example this implies that when we know that the match is the result of the DNA of person X being at the crime scene, makes the probability that X's twin was at the crime scene drop.

3 Method

The method of [6] uses three different concepts in their method to combine the narrative and probabilistic approach. These concepts are idioms, unfolding and a roadmap. We will give a short

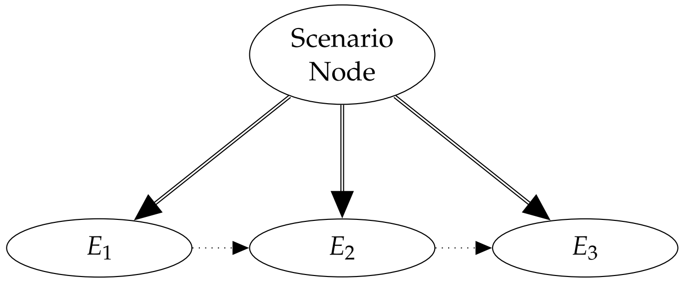


Figure 4: *The scenario idiom [6]. The double lined arrows indicate that all the nodes that are attached to the scenario node must be true if the scenario is true. The dotted arrows indicate explicit influence between nodes.*

	ScN = true	ScN = false
E_i = true	1	...
E_i = false	0	...

Table 1: *Probability table for an element of the scenario idiom. The main characteristic of the scenario idioms can be seen in the first column of the table.*

explanation of these concepts. Vlek et al. introduce four different idioms, an idiom is a structure that can be reused in the same form in different networks. The different sorts of idioms that will be used in this article are the scenario idiom, the subscenario idiom and the merged scenario idiom. The fourth idiom is the variation idiom, but since this idiom is not used in this case study, this idiom will not be explained here. All of these idioms are narrative idioms. Narrative idioms provide coherent structures that express (a part of) a scenario. The second concept introduced by [6] is unfolding. With unfolding, the network is expanded by adding new idioms to the network. Thirdly, the roadmap is used to guide the modeler through the process of building a network, by making use of the different idioms and unfolding. We will now briefly explain the different idioms. For a detailed description see [6].

3.1 Scenario Idiom

The scenario idiom models one of the scenarios of the network. An example of the scenario idiom is shown in Figure 4. The scenario idiom consists of a scenario node that has only outgoing arrows to the element nodes. In this example there are three element nodes that express variables in the scenario. The scenario idiom is structured in a way that it captures the coherence of the scenario. Besides the outgoing arrows of the scenario node, there can also be arrows between the element nodes. These arrows represent explicit influence between the element nodes and are expressed here with dotted lines. The table shown in Table 1 is the probability table of one of the element nodes of the scenario node. One of the most important properties of the probabilities of the scenario idiom is that if the scenario is true, all elements must be true. This property is indicated in the network by double lined arrows. In Table 1 this characteristic can be seen in the first column. When the scenario node is true, the probability that element *i* is true is one, and the probability that element *i* is false is zero. When the scenario node is false, the element can still be true. It can be any value depending on the likelihood of the element itself. With this structure of double arrows and their corresponding probabilities, there is always an influence between nodes of the scenario, and thereby the structure ensures coherence.

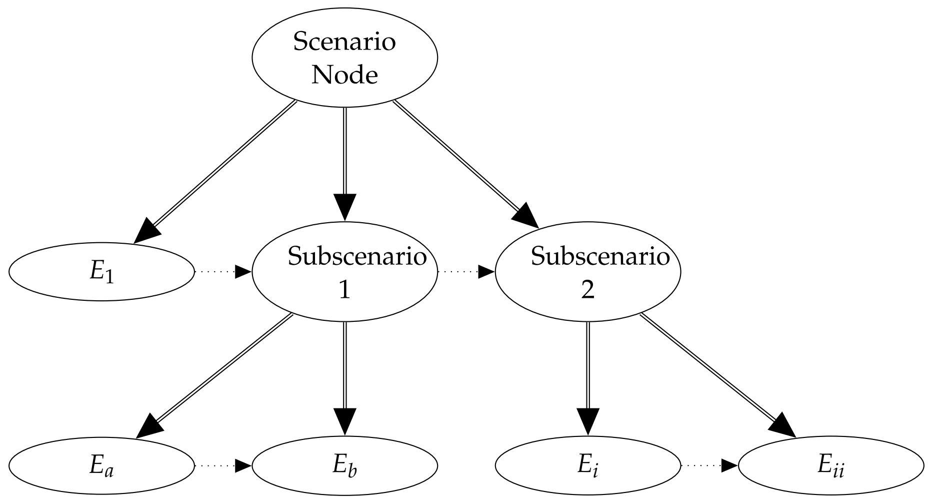


Figure 5: *The scenario node combined with the subscenario node [6]. Two of the element nodes of the scenario idiom are replaced with subscenario idioms. This is done with the process of unfolding.*

3.2 Subscenario Idiom

Sometimes there is need for more details in a scenario. These details can be modeled by using the subscenario idiom. With the subscenario idiom element nodes of a scenario can be replaced with a subscenario idiom. This replacement is one of the examples of unfolding. The subscenario idiom basically works the same as the scenario idiom except that it always has to be part of a larger scenario. An example of subscenarios can be seen in Figure 5. With a subscenario the element node is treated as a scenario on its own without loosing the coherence of the scenario idiom. The element nodes that are attached to the subscenario node form a coherent structure. If necessary these elements can be unfolded into subscenarios again.

3.3 Merged Scenario Idiom

Once all the scenarios of the case are determined and unfolded they can be merged into one network. For the network to be useful there can be only one scenario that is true. This means that all the scenarios have to be mutually exclusive. In the network this can be achieved by using the merged scenario idiom, which consists of a constraint node. An example of the merged scenario idiom is modeled in Figure 6. The probability table that corresponds to the constraint node can be seen in Table 2. This probability table is different than the probability tables of the other idioms, because the merged scenario idiom has a different aim. As can be seen in Table 2 the constraint node does not take on the values “True” and “False”, but the has the different scenarios and “NA” as values instead. When the constraint node has the value “NA” it means that the value is Not Applicable. When instantiating the constraint node one needs to make sure that `Constraint = NA` can never occur. This can be done by setting the evidence of the constraint node in such a way that `Constraint = NA` is false and instantiating the values for the different scenarios to $1/i$ where i is the number of scenarios. Thus the constraint node is set as soft evidence and as a result it makes sure that only one of the scenarios ScNi can be true.

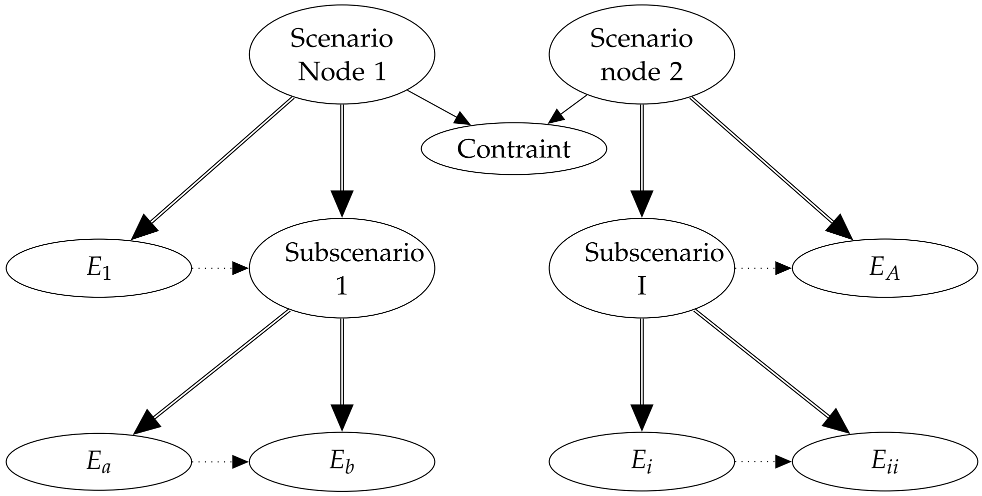


Figure 6: *The scenario idiom and the subscenario idiom combined with the merged scenario idiom [6]. The merged scenario idiom consists of a constraint node that makes sure that there is always exactly one scenario that is true.*

	ScN1 = True		ScN1 = False	
	ScN2 = True	ScN2 = False	ScN2 = True	ScN2 = False
Constraint = ScN1	0	1	0	0
Constraint = ScN2	0	0	1	0
Constraint = NA	1	0	0	1

Table 2: *Probability table for the constraint node. Instead of the values "True" and "False" it takes the values "ScN1", "ScN2" and "NA". The value "NA" is instantiated as "false" and will therefor never occur.*

3.4 The Roadmap

To further assist in the process of modeling scenarios in a Bayesian network, Vlek et al (2014) have developed a roadmap. This roadmap is presented below.

1. Collect: gather relevant scenarios for the case;

2. Unfold: for each scenario, model an initial scenario with the scenario idiom. Then unfold this scenario by repeatedly asking the three questions:

   (a) Is there evidence that can be connected directly to the element node?
   If so, no unfolding is required.

   (b) Is there relevant evidence for details of a subscenario for this element?
   If so, unfolding is required.

   (c) Would it be possible to find relevant evidence for details of the subscenario for this element?
   If so, unfolding is required.

   Use the subscenario idiom to model the unfolding subscenarios and the variation idiom whenever a variation is encountered.

The process of unfolding is finished when the three questions indicate that no more relevant evidence can be added to the structure;

3. Merge: use the merged scenarios idiom to merge the scenario structures constructed in the previous step;

4. Include evidence: for each piece of evidence that is available, include a node and connect it to the element node it supports. Additionally, include nodes for evidential data that is to be expected as an effect of elements in the structure.

In the following sections we are going to apply this roadmap together with the narrative idioms to a legal case. This way we can test if it meets the criteria as proposed in the introduction.

4 The Wamel Case Study

In this section the design method as described in the previous section is used to model the murder of Kevin Moyson. This murder happened in a small village in the Netherlands nearby Tiel, called Wamel. Francis Liebrand, one of Kevin's acquaintances, was convicted. This case was re-investigated by legal scholars in a project called "Gerede Twijfel" (Reasonable Doubt). [3] In this project they investigate if there is a possibility that an innocent person was convicted. The following study is based only on this re-investigation, so the results of the network are influenced by the ideas and assumptions presented by Iraëls. This study is meant to evaluate the techniques presented in Vlek et al. [6] and not to evaluate the case.

4.1 The Case

On the morning of January 6th, 1997 the police received a phone call and were asked to come to the house of Iris Celis, Kevin's girl friend. When they arrived they heard about the murder of Kevin Moyson. Sander Mornie stated that he went to a weed plantation in Wamel with Kevin the night before and that Kevin got shot. Sander told the police that Francis, Kevin and himself were planning on robbing the weed plantation so that Francis Liebrand could pay back the debt he owed to Kevin. We are going to discuss a model of the murder of Kevin Moyson. Below we will introduce some of the most important details about the case. We have narrowed the case down to two scenario's, namely `Francis killed Kevin` and `Sander killed Kevin`. Throughout the following sections we consider these as the only two options, although there could be other alternatives.

4.1.1 The people involved

Kevin Moyson, Sander Mornie and Francis Liebrand are the most important people in this case. These three people all had a criminal record and lived in a small city called Uden. Kevin and Sander were friends, and Kevin and Francis were acquaintances who have committed burglaries together. Francis owed Kevin €5000,– which he planned to pay back with weed. The weed was supposed to be obtained by robbing a weed plantation.
On the night of the fifth of January Kevin and Sander went to a weed plantation to meet Francis Liebrand. By robbing the plantation together Francis was supposed to pay back his debt. Sander wasn't supposed to be there, but Kevin invited Sander to come with him. Kevin got shot at the plantation and Sander fled from the crime scene.

4.1.2 Sander Mornie

The most important source of evidence is the statement given by Sander Mornie, but this statement is not completely reliable. Some parts of his statement can be confirmed with the statements of other people or other evidence, but for some parts the investigation relies solely on Sander's statement. The difficulty lies in the fact that Sander's statement changed during the investigation. It is not possible to model all the different statements that Sander gave, so we have chosen his final statement. Due to his frequent changing statement the reliability of Sander's statement is estimated lower. This can be modeled with an accuracy node as mentioned in Section 1.1. To illustrate why Sander's statement is unreliable and why he was consideded a possible suspect, we present one of the discrepancies of Sander's statements.
According to Sander's final statement, Sander went with Kevin to the plantation in Wamel to meet Francis. Kevin got shot and Sander got away. After hiding during the night, Sander returned to Uden and went to Kim Farruggia. Sander met Kim two days before on a night out and considered her his girl friend although Kim said that they broke up the night before. Kim let Sander in and Sander told her what happened. He said that when he and Kevin arrived at the shelters they saw Francis Liebrand. In his statement to the police at Iris' house he said that they did not see anybody at the shelters and that the gunshots came out of nowhere. Later in the investigation he told a police officer that he saw Francis at the crime scene, but denied this again later.

4.1.3 Francis Liebrand

Francis Liebrand was convicted for the murder of Kevin. During the investigation of his case he did not say anything. He even denied that he owed Kevin money. He told the police that he and Kevin both invested money in a "little business" that went wrong. According to Francis, he and Kevin both lost their investment so there is no debt.
Francis also had a wound on his hand. This could be caused by a broken weapon. The police did find deformed bullet casings at the crime scene, that were probably stuck in a weapon. To get those casings out of a gun can cause a wound. Since Francis denied everything, he also denied this until his appeal. During his appeal he started talking, and told the police that it was caused by repairing a car. Since the appeal took place three years after the murder, no evidence of car reparation could be found to prove this statement.

4.2 Scenario 1: Francis killed Kevin

The first scenario we are considering is the scenario in which Kevin (K) was killed by Francis (F). This is the main scenario in the book "Gerede Twijfel". In this scenario Kevin was killed by Francis and Sander (S) managed to get away safely. This scenario goes as follows:

Francis owed Kevin €5000,–. He was unable or unwilling to pay back the money. Therefore he wanted to pay back his debt with weed. He asked Kevin to come with him to his weed plantation in Wamel so they could rob the plantation together and Kevin would have more than €5000,– worth of weed. Kevin invited Sander to come with him, even though Francis wanted to keep the meeting quiet. After Sander and Kevin arrived at the shelters in Wamel, Sander heard gunshots and saw that Kevin collapsed. There were also a few shots aimed towards Sander, so he fled. Sander did not see the shooter and got away safely. This scenario has three main events, namely `K and S went to a weed plantation to meet F`, `F shot K at the plantation` and `S fled from the crime scene`. These events are modeled in the way shown in Figure 7. Double arrows are used to indicate the characteristic probabilities of the scenario idiom as described in

Section 3.1. Influence between element nodes is represented by a single arrow, as can be seen between `F shot K at the plantation` that influences `S fled from the crime scene`.

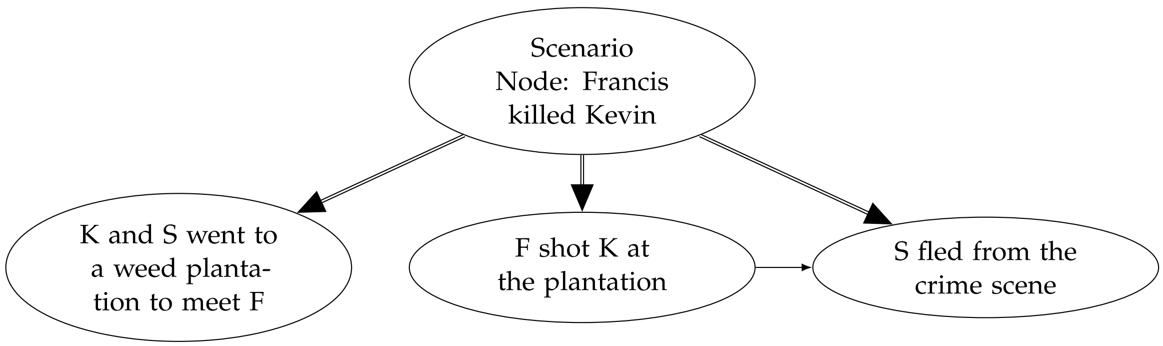


Figure 7: *The scenario idiom of the first scenario. The double arrows indicate that the element nodes are part of the scenario idiom. This represents the main characteristic of the scenario idiom, namely if the scenario idiom is true, all its element nodes must be true as well.*

4.2.1 K and S went to a weed plantation to meet F

Now we are going investigate if the node `K and S went to a weed plantation to meet F` needs to be replaced by a subscenario using the roadmap. The answer to the first question (Is there evidence that can be connected directly to the element node?) is no. The answer to the second question (Is there relevant evidence for details of a subscenario for this element?) is yes. Therefore we need to unfold this scenario, which leads to the part of the network shown in Figure 8. The reason they were at the plantation is modeled in the node `F, K and S were going to rob the plantation`. The reason that they were going to rob the plantation is part of this subscenario as well, in the node `F told K he wanted to pay his debt with weed`. This is the reason for the fact that they were going to the plantation in the first place, so this influence is indicated by an arrow. Another relevant event is modeled in the node `K invited S to come with him`. This is relevant because it clarifies that Kevin wanted Sander to be there and that this was not part of Francis' plan. It is also important because this is the reason that Sander was present at the crime scene and knew about the plan to rob the plantation. These nodes together are a coherent subscenario within the scenario.

4.2.2 F shot K at the plantation

Now we are going to investigate if the node `F shot K at the plantation` needs to be replaced by a subscenario by following the roadmap. The answer to the first question (Is there evidence that can be connected directly to the element node?) is no. The answer to the second question (Is there relevant evidence for details of a subscenario for this element?) is yes. Francis had a wound on his hand that could have been caused by a broken stun gun. Also Kevin's body was found and Francis was supposed to be at the location where Kevin was shot. This is why we need to unfold this scenario, which leads to the part of the network shown in Figure 9.
In this subscenario we see the node `F had a wound on his hand`. This fact is caused by two related events. Namely `F shot K` and `The stun gun was broken`. When Francis shot Kevin with a broken stun gun this could have caused that Francis got hurt. The evidence for this wound is that Francis went to the hospital on the 6th of January with a wound on his hand. The other event that is caused by the event that `F shot K` is the fact that `K died`. Although it seems quite obvious,

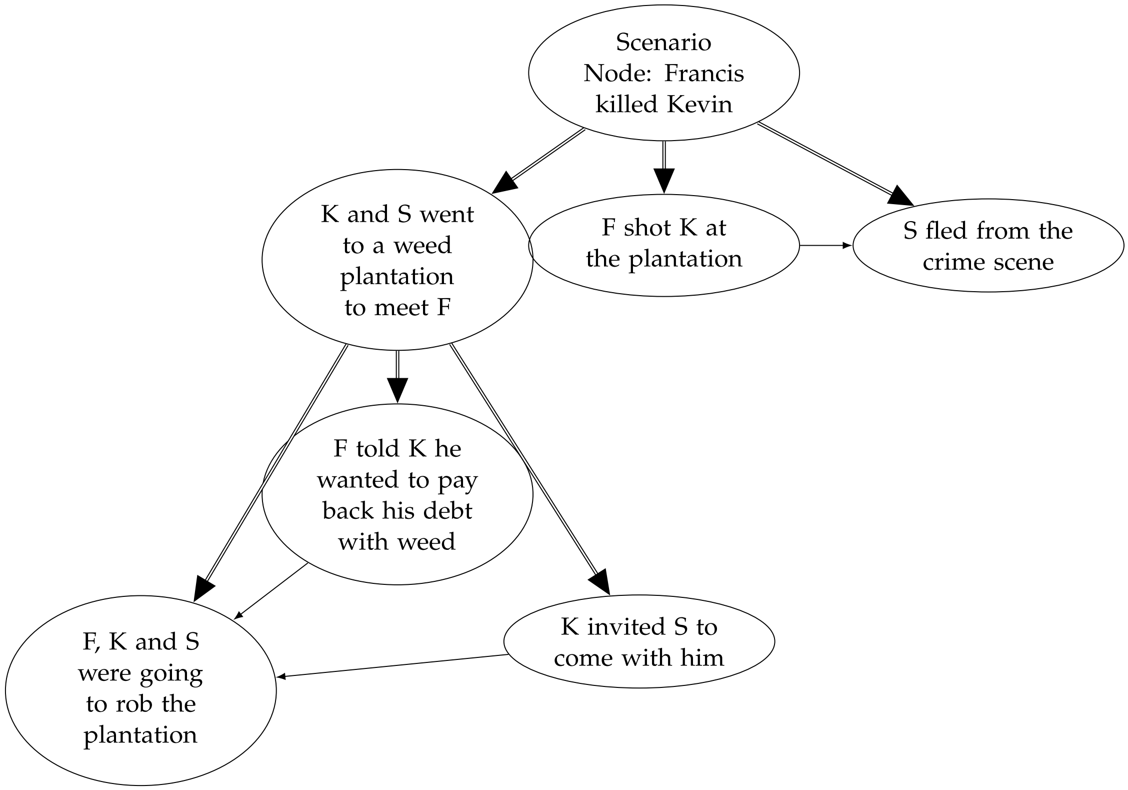


Figure 8: *The unfolding of `K and S went to the weed plantation to meet F`, by replacing this node with a subscenario idiom.*

it is important to model this explicitly, because there is evidence that can be directly attached to this node.
Furthermore there is no direct evidence that shows that Francis was actually at the plantation. Therefor the node `F was at the plantation` was added. This node is connected to the node `F shot K`, because Francis had to be at the plantation to actually shoot Kevin there.

4.2.3 S fled from the crime scene

Now we are going to investigate if the node `Sander fled from the crime scene` needs unfolding by using the roadmap. The answer to the first question (Is there evidence that can be connected directly to the element node?) is yes. The evidence for this event is the statement of Sander.

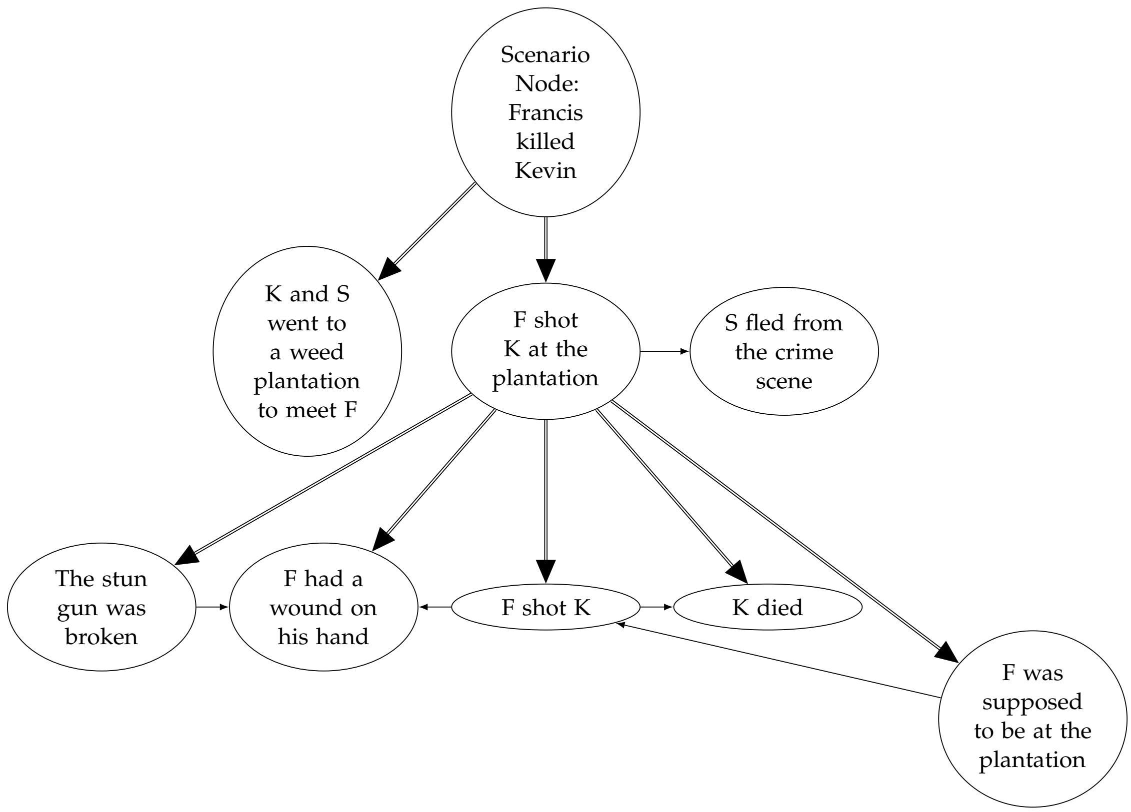


Figure 9: *The unfolding of* `F shot K at the plantation`*, where this node is replaced with a subscenario idiom.*

4.3 Scenario 2: Sander killed Kevin

Francis never confessed that he killed Kevin, so there is still a possibility that somebody else has killed Kevin. The most obvious alternative is that Sander killed Kevin. The police already considered him a suspect and he was a fugitive during the investigation. A possible motive for Sander to kill Kevin is that Sander was part of a larger conspiracy. Sander is a opportunist and does what other people tell him to do. There are a lot of people who had disagreements with Kevin and might have wanted him dead. We are going to model this scenario with this motive.

This scenario has three main events, namely `S shot K at the plantation` and `S made up the story about F` which caused `S tries to lead the attention away from himself as a suspect`. In the following sections we are going to model this scenario, using the narrative idioms and the roadmap of Vlek et al. [6]

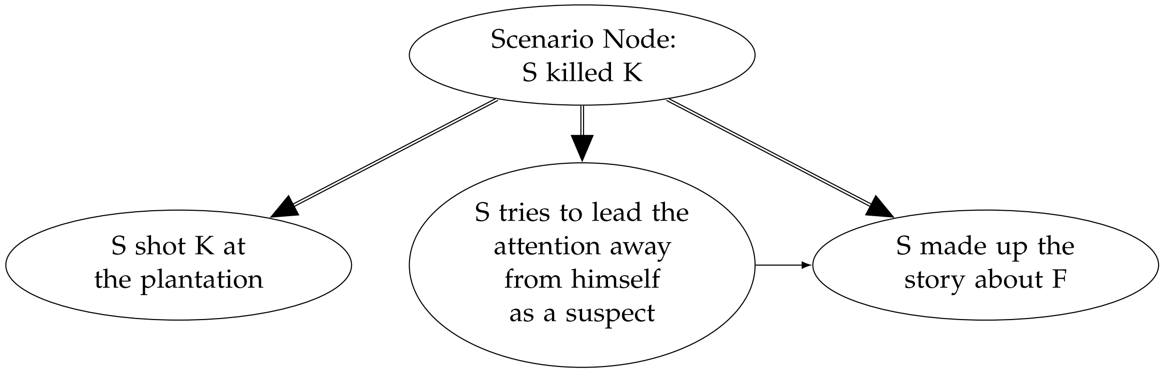


Figure 10: *The scenario node of the second scenario, where it is Sander who shot Kevin.*

4.3.1 S shot K at the plantation

We are now going to investigate if the node `S shot K at the plantation` needs unfolding by following the roadmap. The answer to the first question (is there evidence that can be connected directly to the element node?) is no. The answer to the second question (Is there relevant evidence for details of a subscenario for this element) is yes. So this node needs unfolding. The unfolding of `S shot K at the plantation` is shown in Figure 11.

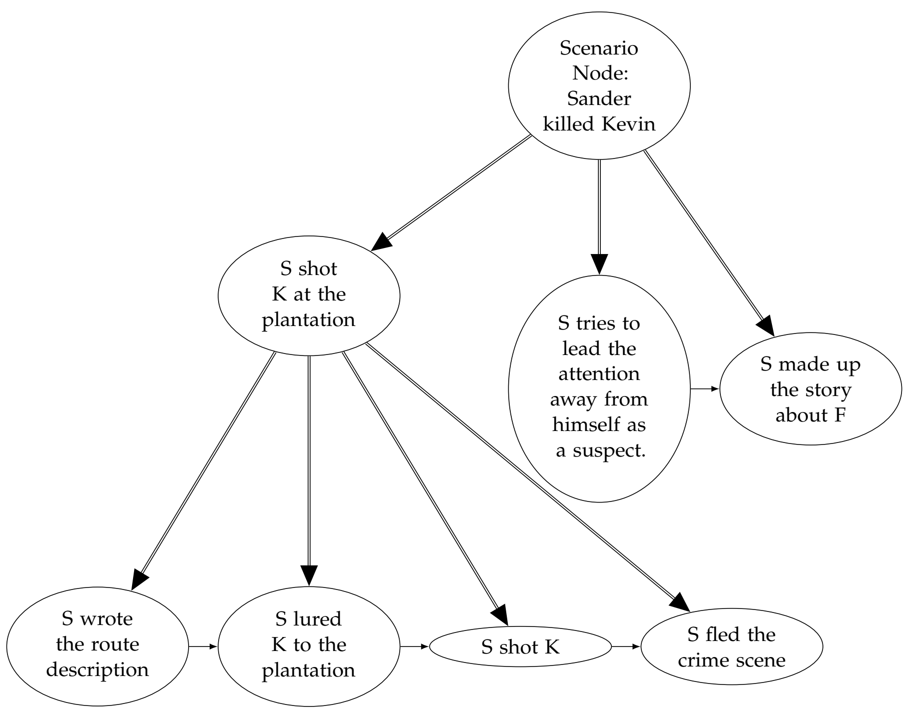


Figure 11: *The unfolding of `S shot K at the plantation`, by replacing this node with a subscenario idiom.*

This results in the coherent subscenario where `S fled the crime scene` is influenced by `S shot K`, because this is the reason that Sander fled. `S shot K` is influenced by `S lured K to the plantation` because in order for Sander to shoot Kevin at the plantation, they need to be at the plantation first. To get to the plantation they needed a route description. In this scenario it was Sander who wrote this description. Evidence of element can be attached directly to this node. Kevin's sister stated that the handwriting on the route description to the plantation looked a lot like Sander's. When Sander lured Kevin to the plantation, he has to be the one that has written the route description. So the node `S wrote the route description` influences `S lured K to the plantation`. For the node `S wrote the route description` there is no further unfolding required since evidence can be connected directly to this node (the answer to the first question is yes), namely if there is actually a handwriting match.

4.3.2 S tries to lead the attention away from himself as a suspect.

For the node `S tries to lead the attention away from himself as a suspect` there is one important piece of evidence, namely his own statement about the whole situation. So when we apply the method to this node, the answer to the first question (is there evidence that can be connected directly to the element node?) is yes, so no further unfolding is required.

4.3.3 S made up the story about F

The node `S made up the story about F` has no direct evidence that can be connected to this node, so according to the method further unfolding is required because the answer to question one is no. However when we look at question two and three of the method ("Is there relevant evidence for details of a subscenario for this element" and "Would it be possible to find relevant evidence for details of the subscenario for this element?") the answers are no. Which means no further unfolding is required.

4.4 Merging the Scenarios

Now that both scenarios are modeled, they need to be combined and evidence needs to be added. Once this is done it is possible to calculate which scenario is more likely. Since we are only concerned with the process of building a network and not with the specification of probabilities we will omit the probabilities in this paper.
The scenarios, that have been developed in this paper, are merged by using the merged scenario idiom. This results in the network as shown in Appendix A. In this network the constraint node is added to connect the two scenarios, thereby ensuring that there is always exactly one scenario that is true. Furthermore, both scenarios contained a node with the variable: `S fled from the crime scene`. According to the method, these nodes need to be merged into one, whilst keeping the connections from both nodes.
The next step in the construction of the network is the addition of evidence and their accuracy nodes, resulting in the network as shown in Appendix B. In this network the evidence can be instantiated to obtain the posterior probability of each scenario node. The accuracy nodes make sure that the reliability of the evidence is taken into account. In the future a full representation of the network, combined with its probabilities can be found at `lottenoteboom.nl/projects/bachelorproject/network`.

5 Discussion

In Section 1 we proposed several criteria to evaluate the method that we have used. A recap of these criteria and the problems that the criteria correspond to is presented below.

1. Does the method help with the problem of tunnel vision?
   With tunnel vision the investigator only investigates one hypothesis.

2. Does the method help with the problem of a good scenario pushing out a true scenario?
   A scenario that sounds good might be chosen over a scenario that is more likely.

3. Does the method help with finding the right structure for a model of the case?
   The Bayesian network should be modeled in a structured and clear way.

4. Does the method help with finding the relevant variables for a model of the case?
   Not every variable needs to be modeled in the network, a selection of relevant variables needs to be made.

5. Is the method able to model different kinds of cases?
   Criminal cases differ from each other, but the method should be capable of modeling various types of cases.

Based on the work from the Section 4, we now discuss our findings for each of these criteria.

1. Tunnel Vision

When applying the method to a case multiple scenarios need to be modeled. This causes one to actively search for different views. During the testing of the method we found ourselves trapped in tunnel vision, but we needed to step out of this to be able to model the second scenario. Because of this it can be said that the method helps to solve the problem of tunnel vision. One of the things with regard to tunnel vision that the method does not help with, is finding the second scenario. Luckily, in our case, the re-investigation by Israëls [3] provided us with an alternative scenario and suspect.

2. Good story versus true story

In this case study, the Bayesian network was not used to decide on a scenario, so no conclusion can be drawn. But, as [6] mentions, while the narrative approach helps to find several scenarios, the probabilistic approach makes it possible to analyze the scenarios based on their likelihood, which should resolve this problem.

3. Structure

One of the things that we encountered during this case study was that it is difficult to just start building a network. The method provided us with two concepts that made it easier to find the right structure for the network. (1) The idioms provided a way to model the different aspects of the case in a coherent way, and (2) the process of unfolding together with the roadmap assisted in the process of combining the idioms in a structured way.

Although the method makes it easier to find the right structure, there is no point you have to work towards. This means that you have no idea where you are going or what to unfold, which might be difficult. As a solution it could be interesting to add the evidence at the bottom of the network without attaching it to the other nodes, so that the only thing that needs to be done is filling up the gaps between what is already modeled and the evidence. It then is important to not attach the evidence nodes directly to the network, because then the network, including its probabilities, needs to be altered every time a new node is added.

4. Variables

The method from Vlek [6] claims to help find the relevant variables. Although taking scenarios as a starting point does help, a lot of input is still needed from the modeler. It is tempting to think that everything is relevant and thereby unfold to much, resulting in an inconveniently large network. Therefor it might come in handy to summarize the scenario in a few sentences, say 5 to 6 sentences. If every sentence then corresponds to a node in the network, the scenario will be coherent and contain only the most relevant variables of this scenario. If every node in this scenario is then summarized in a few sentences itself and these sentences are then added in a subscenario, each scenario will be coherent and only contain relevant variables. Whenever the summary of a scenario contains evidence, this variable does not need to be unfolded according to the method. During our case study we combined the method with the summaries of the scenarios. This helped us with finding the right variables and not adding too many variables.

5. Different Cases

In the paper by Vlek et al. [6] the method was evaluated on a different case than in this paper. In both evaluations it was concluded that the method was applicable to model the case. It seems like the method is able to model different kinds of cases, although the sample is small.

There are a few other noteworthy things about the method that should be discussed. For instance, as we encountered during our evaluation, it is hard to add time to the model, even if the time is relevant to the scenario. There is no easy way to make clear that something happened before or after something else. Secondly the probabilities can only be acquired by making informed guesses. The numbers are based on personal interpretation and are therefore subjective. As a result the outcome of the network can not be interpreted as objective, which is something that is desirable in investigating a legal case. However, it could be that, even with the current methods of reasoning with legal evidence, this is no feasible.

6 Conclusion

In this paper we have evaluated a method that combines two approaches to reasoning with legal evidence. The approaches that are combined are the narrative approach, using scenarios, and the probabilistic approach, using Bayesian networks. The method introduces several idioms that are meant for constructing a structured and clear network that represents several scenarios. At the same time the method also provides a roadmap that serves as a guideline to use the idioms. The evaluation of the method is done with a case study of the Wamel case [3], which is a Dutch murder case.

In order to answer the question about how well the method, as described in Vlek et al. (2014), is capable of modeling a complex legal case, we have formulated several criteria. The first criterion, about tunnel vision, showed us that the method is capable of avoiding tunnel vision, but does not provide a way to find alternative scenarios. The second criterion gave us an answer to the question if the method can help with the problem of a good story pushing out a true story. Because we were not concerned with the probabilities we were unable to evaluate this criterion, but as argued in [6], probabilities can help to find the most probable scenario. As for the third criterion, the method provides an adequate guideline to finding a good structure with its idioms and roadmap. Still a goal to work towards is missing and not provided by the method. The fourth criterion, concerned with finding the relevant variables, showed that the method helps with finding the right variables, but did not provide help with defining and formulating the variables. Lastly, based on the fifth criterion, it is worth wondering if different kinds of cases can be modeled with the aid of the method. For now there are only two case studies that have been done. It seems to be possible to model different kinds of cases although the sample is small.

As mentioned above there is still room for improvement, we will now discuss some suggestions for further research. First of all the method does not help with finding an alternative scenario. Even though this is not an aim of the method, it might be worth to investigate a way to do so. Secondly, a suggestion made in this paper, is the suggestion of providing a way to work towards evidence. At the moment the method starts at the top of the network and the evidence is added once the network is complete. An alternative to this order might be to start with a scenario node at the top and several evidence nodes at the bottom, without attaching them to the rest of the network yet. This way the method is more about filling up the gaps between the evidence and the current story, which might be more convenient than come across the evidence in the process of unfolding of the (sub)scenario idioms. Thirdly we have used short summaries of the scenarios in order to define and formulate the relevant variables in the network. This is not a practice mentioned and developed in the method, but to us it was valuable assistance in the process. It can be helpful to formalize this method of summarization. Lastly more case studies should to be done. The method is relatively new and therefor a lot of advantages and disadvantages might still be unknown. During a case study these pros and cons could be revealed and therewith the method can be improved.

A Full network without evidence

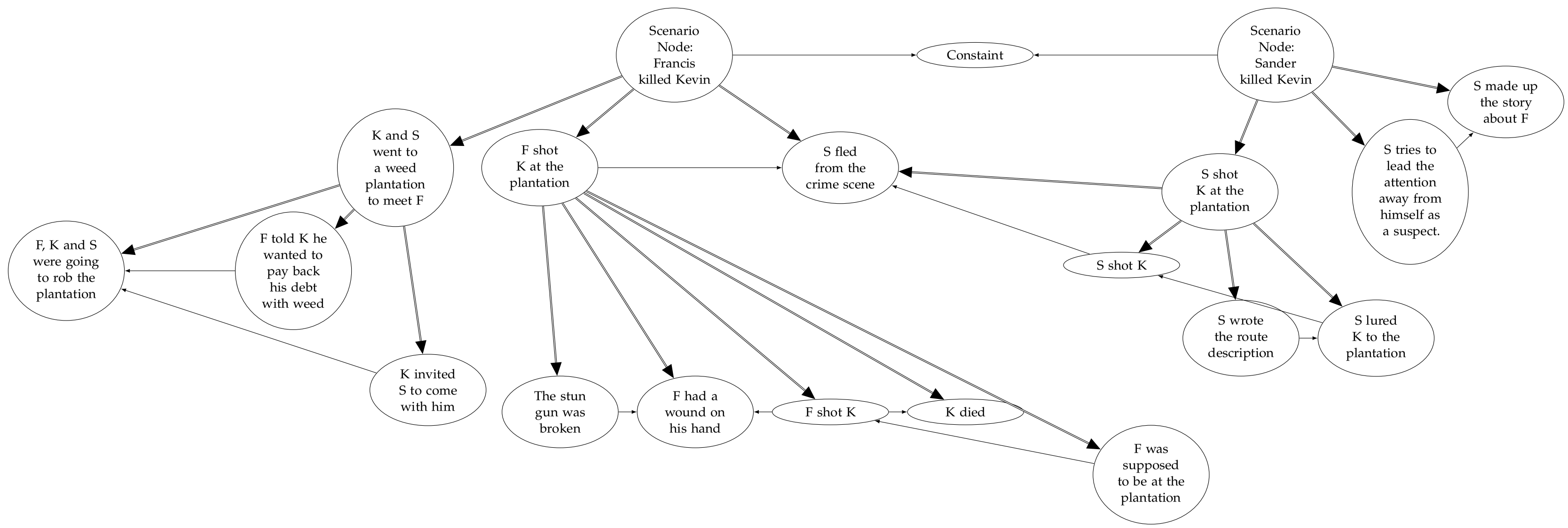


Figure 12: *The merged scenarios of the Wamel case without evidence and accuracy.*

B The complete network including evidence and accuracy nodes.

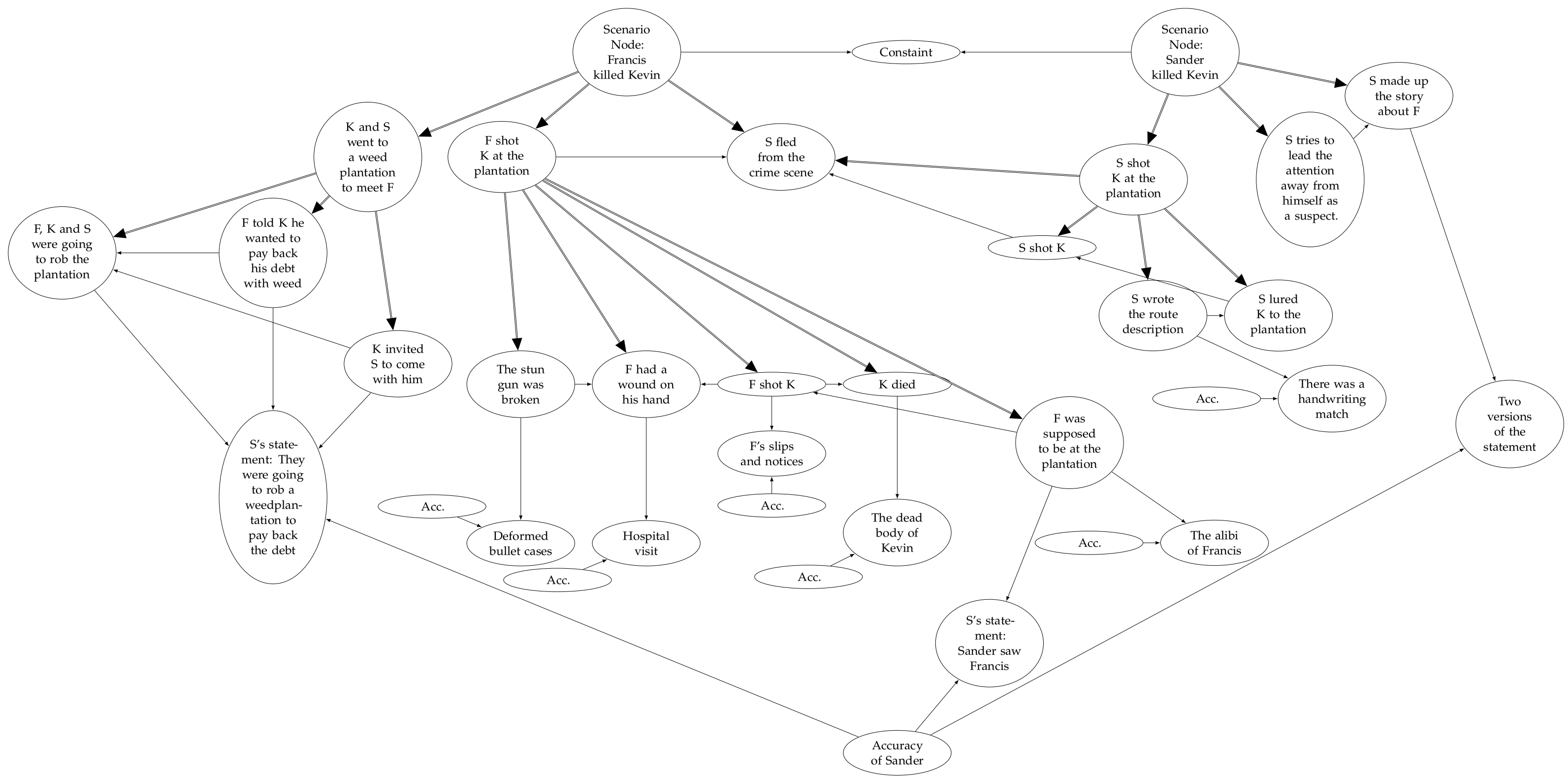


Figure 13: *The merged scenarios of the Wamel case with evidence and their accuracy added.*

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