Evaluation of Causal Arguments in Law: the Case of Overdetermination

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ABSTRACT

In many legal disputes, determining and evaluating cause-in-fact is a crucial step in the liability attribution. It is, however, difficult and opaque. In this paper, we analyse the cases of overdetermination, where there is more than one cause for the outcome. The proposed framework (FCA) employs logic-based argument modelling. It distinguishes individual contributors in overdetermination cases by using a new set of critical questions based on argument schemes from *effect-to-cause*. To illustrate the use of the FCA, the *Heneghan v Manchester Dry Docks* lung cancer case with multi-party contributions is analysed.

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1 INTRODUCTION

In this paper we present progress towards a framework [14] that is able to support legal reasoners in identifying and evaluating cause-in-fact in law. In particular, we focus on the problem of overdetermination that occurs when there is more than one cause for the outcome. We outline a two step procedure by first modelling the causal arguments of the case in a logic-based semi-formal framework. In the second step, we evaluate the causal arguments based on the coherence of the models, level of support by the evidence, and critical questions based on causal argument schemes. The contribution of this paper lies in the integration of the NESS test (necessary element of a sufficient set of causes), an approach that is able to distinguish between different causes in overdetermination cases. In addition, this paper validates the use of our methodology in a new domain: employment related asbestos exposure cases.

The motivation for this study stems from the ongoing issues around the concept of a 'legal cause' [11, 15] and the limited accuracy of the traditional but-for test in overdetermination cases. There is a divide in views between the legal scholars [15, 17, 20] and practitioners[1] in how the problem cases of multiple contributors should be handled. The current exception policy-based exception can be applied in cases where the breach is not the sole and principal cause of the damage, but it must have *materially contributed* to the effect [1]. However, the concrete limits of what is meant by a 'material contribution' have not yet been defined raising criticism on the exception's validity and consistency. The aim of our analysis is to distinguish between evidence-based causal arguments made in the initial stage of the analysis from the later stages involving policy and norm based reasoning.

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2 BACKGROUND

Artificial intelligence. Research on causality in artificial intelligence [4, 13] has undergone significant developments with the introduction of structural causal models and causal inferences from statistical data [3, 9, 16], as well as the use of non-monotonic logic [7]. Each of these advances has a potential in improving causal analysis in law [9]. However, the application of the formal theories in legal reasoning remains limited. [3] represents NESS in logical causal language.

Evidential reasoning. There has also been discussions of causal elements in law in the sub-field of evidential reasoning [18]. For instance, the hybrid theory [2] uses causal stories and evidential arguments in analysing competing positions in legal disputes. It not only provides an overview of the arguments in the case in a structured manner, but also facilitates the evaluation of the strength of the claims based on the evidence available. However, these approaches have limited means to analyse causal links in cases.

Argument schemes and critical questions. Argument schemes [19] aim to capture common reasoning patterns in arguments, while the critical questions help in evaluating the strength of the arguments based on topic-specific criteria. For instance, in the 'arguments from expert opinion evidence' scheme:

> 'E is an expert in domain D.
> E asserts that A is known to be true.
> A is within D.
> Therefore, A may plausibly be taken to be true.' [19]

The argument scheme captures the general structure of the argument, but the argument's strength and coherence can be further assessed by asking questions on the expert's credibility, consistency, and other characteristics: *How credible is E as an expert source? Is A*

[1] *Fairchild v Glenhaven Funeral Services* [2002] UKHL 22.

consistent with what other experts assert? The current argumentation methods distinguish three types of causal argument schemes: 'cause to effect', 'effect to cause', and 'correlation to causation', each completed by a list of critical questions. The FCA captures these reasoning paths in the causal and evidential rules. However, both the argument schemes and the current version of FCA are unable to capture the differences between causal arguments in direct causal scenarios versus the causal links in overdetermination cases.

In this paper, we aim to build upon the developments in these three fields of research by proposing a list of evaluation criteria in form of critical questions.

3 CAUSAL ARGUMENT EXTRACTION AND MODELLING: THE *HENEGHAN* CASE

The motivation for choosing the *Heneghan v Manchester Dry Docks*[2] case stems from the complex nature of causes in asbestos exposure cases, e.g. multiple contributors, long latency period for developing lung cancer, various alternative causes and confounders. We apply the the framework for causal arguments[14] showing its usefulness in modelling causal arguments in different legal domains.[3]

3.1 The *Heneghan* Case Introduced

Facts of the Case. In 2011 Mr Heneghan started developing lung cancer related symptoms. After his death of adenocarcinoma (a type of cancerous tumour) of the lung in 2013 his family sought to sue six of the 10 employers for the period worked between 1961 and 1974. The deceased had a long-standing smoking habit. The deceased's family (the claimant) applied to the court seeking compensation for the damages caused by the exposure to asbestos fibres at work.

Legal Grounds and Precedent. To qualify for a compensation in employment related lung cancer cases the claimant must demonstrate a causal link between their illness and the asbestos exposure at work.[4] Therefore, the but-for test that the claimant must satisfy is: "on the balance of probabilities cancer would not have occurred but for the asbestos exposure". The judge identified that this case is unique as the question on how to compensate the lung cancer[5] victims in cases with multiple-parties has not been answered in the past. The two options in such cases is either the conventional approach with strict burden of proof or choosing the *Fairchild*[6] precedent that relaxes the burden of proof in exceptional multi-party asbestos cases.

Expert Witness Testimonies. Three expert witnesses testified for the causal link between the deceased's lung cancer and the asbestos exposure by the employers. The engineering expert, Mr Raper, gave "reasonably solid inferences of the likely levels of asbestos exposure" based on the deceased's work history and tasks undertaken. He concluded that six defendants are responsible for the cumulative exposure of 86.2 fibres/ml years, equating to 35.2% of the total exposure. Further, it was possible to calculate estimates of each defendant's individual contribution that ranged from 2.5% to 10.1%.[7] Medical experts in the case, Dr. Moore-Gillon (for the defendants) and Dr. Rudd (for the claimant), largely agreed on the causal link between the asbestos exposure and the deceased's lung cancer. They also agreed on the risk rates in the following scenarios: if the deceased had not smoked and had not been exposed to asbestos his baseline risk of developing lung cancer would have been 0.5%. If the deceased was a smoker, then the risk is increased four times (2%). If the deceased was exposed to asbestos and he was a smoker then the risk of lung cancer is increased more than twenty times (more than 10%), because asbestos and smoking are considered to multiply the risk. However, as stated by Dr. Moore-Gillon: "the current state of medical science simply cannot permit one to say how many fibres were involved and from where they were derived" leaving the court with the challenge of attributing individual liability in the case.

3.2 Causal Argument Framework: Rule Summary

In this section we summarise the rules of the framework for causal arguments [14] that will be used to model causal arguments in the case study. It consists of basic knowledge structures that include propositions; causal links and inference rules; and general rule schemes that allow building causal arguments with the elements of the basic knowledge structures.

3.2.1 Basic Knowledge Structures. There are three basic knowledge structures: factual propositions; causal links, and inference rules.

Factual Propositions. A factual proposition has the form

$$\pm H(X)$$

where X is a positive or negative literal. $H(X)$ states that the literal X *holds* and $\neg H(X)$ that this was not the case. We assume that $H(X)$ and $H(\neg X)$ are incompatible, and that $H(\neg X)$ is equivalent to $\neg H(X)$. For instance $H(\neg AsbExp)$ is equivalent to $\neg H(AsbExp)$.

Causal Links. Causal links are represented as

$$C(L, X, Y)$$

where L takes values 1 or 2, X and Y are factual propositions and in temporal order Y follows X. $L = 1$ indicates that cause X always (necessarily) produces effect Y, and $L = 2$ indicates that cause X usually (normally) produces effect Y. The causal links and levels of causal links loosely correspond to the language used by the reasoners.[8] For instance, $C(1, AsbExp, FibresLodge)$ is an expression that $AsbExp$ and $FibresLodge$ have the *always causal* relation, as the witnesses present it.

[2] *Heneghan v Manchester Dry Docks* [2014] EWHC 4190 (QB).
[3] The framework was originally designed to model vaccine injury cases, but the causal relations have been defined in a sufficiently general manner to allow for transfer between different areas of law and jurisdictions.
[4] Law Reform (Miscellaneous Provisions) Act 1934 and the Fatal Accidents Acts 1976.
[5] It is important to note that in the past the exception has only been applied to cases concerning mesothelioma, a lung cancer than is caused through a different process than adenocarcinoma.
[6] *Fairchild v Glenhaven Funeral Services Ltd* [2003] 1 AC 32.
[7] Given the Helsinki criteria for the mixed fibres exposure, any amount larger than 40 f/ml years is to be considered to significantly increase the risk of lung cancer. In the given case, the engineering evidence estimated the risk to be increased five times. Helsinki criteria www.julkari.fi/bitstream/handle/10024/116909/Asbestos_web.pdf?sequence=1<last accessed 22.01.2019.>
[8] The first steps in argument modelling involve an analysis and annotation of the decision text. Causal terms and accompanying hedging expressions are ranked in two groups corresponding to strict and defeasible causal links. For instance, it is agreed that 'asbestos exposure *always* causes fibres to lodge in the lungs'.

Inference Rules. We use strict and defeasible inference rules represented as

$$X_1 \dots X_n \rightarrow Y$$

for strict rules, and

$$X_1 \dots X_n \Rightarrow Y$$

for defeasible rules, where $X_1, \dots X_n, Y$ are literals.

To capture the reasoning of the experts in our cases, we need to supplement the general framework above with some schemes for rules.

3.2.2 General Rule Schemes. There are general rule schemes for causal rules, similarity, and evidence (including abduction).

Causal Rules. Rule schemes R1 and R2 capture the inferential relevance of causal relations

$$[R1.]\ H(X) \wedge C(1, X, Y) \rightarrow H(Y)$$

captures the inferential meaning of necessary causal links. If the precondition holds and the causal link is level 1, we strictly conclude that the effect holds.

$$[R2.]\ H(X) \wedge C(2, X, Y) \Rightarrow H(Y)$$

captures the inferential meaning of defeasible causal links. If the precondition holds and the causal link is level 2, we defeasibly conclude that the effect holds, but can have exceptions.

3.3 The *Heneghan* Case Model

Based on a close reading of the case, we compare the asbestos exposure model to the smoking and evidential models that can be built on what was available to the reasoners.

Factual Atoms

$LungCanc$ - lung cancer
$AsbExp$ - exposure to asbestos fibres and dust
$Smoking$ - smoking habits of the patient
$FibresLodge$ - asbestos fibres lodging in the lung tissue
$LatentPeriod$ - latent period for developing lung cancer is 15-35 years
$CellMutation$ - harmful cell mutation
$Symp$ - symptoms observed on the patient, e.g. coughing, shortness of breath, weight loss
$Fibres_x$ - asbestos fibres attributed to one of the companies
$DamageTissue$ - lung tissues are damaged

In this representation, the factual atoms have the binary value of 1 or 0, when the factual claim is true or false. The atom can take only one value at a time, i.e. the patient either has (*LungCanc*) or he does not ($\neg$*LungCanc*). However, as it will be shown with the risk considerations proportional values are possible based on statistical analysis of the evidence in the case.

Causal Links in the Case

The following causal links represent the case-specific 'cause to effect' structures and their relative strengths based on the language of the reasoners in the case. For instance, $C(1, AsbExp, FibresLodge)$ represents the relationship between asbestos exposure and fibres *always* lodging on the lung tissue. While $C(2, FibresLodge \wedge LatentPeriod, CellMutation)$ represents the causal link between the fibres lodging and latent period *usually* causing the cell mutation, showing a defeasible link that can be questioned if new, contradicting evidence becomes available.

C1. $C(1, AsbExp, FibresLodge)$
C2. $C(2, FibresLodge \wedge LatentPeriod, CellMutation)$
C3. $C(2, CellMutation, LungCanc)$
C4. $C(2, LungCanc, Symp)$
C5. $C(1, Smoking, DamageTissue)$
C6. $C(2, DamageTissue, LungCanc)$

Asbestos Exposure Model

The asbestos exposure model represents the explicit and implicit assumptions and reasoning steps from asbestos exposure to lung cancer symptoms. The following model can be considered general, as it does not specify the source of the fibres involved in the process. The reasoning starts from the explicit assumption of the asbestos exposure. Both medical experts agree on the causal link between the asbestos exposure and asbestos fibres lodging in the lung tissue. With the addition of the latency period of over 30 years it can be defeasibly inferred that the harmful cell mutation took place. From the particular cell mutation the lung cancer developed and the deceased started displaying lung cancer related symptoms.

1. $H(AsbExp)$ [explicit assumption]
2. $C(1, AsbExp, FibresLodge)$ [from C1]
3. $H(AsbExp) \wedge C(1, AsbExp, FibresLodge) \rightarrow H(FibresLodge)$ [strict implication from Level 1 causal rule]
4. $H(FibresLodge)$ [from 1, 2, and 3]
5. $H(FibresLodge \wedge LatentPeriod$ [implicit assumption made explicit]
6. $C(2, FibresLodge \wedge LatentPeriod, CellMutation)$ [from C2]
7. $H(FibresLodge \wedge LatentPeriod) \wedge C(2, FibresLodge \wedge LatentPeriod, CellMutation) \Rightarrow H(CellMutation)$ [defeasible inference from Level 2 causal rule]
8. $H(CellMutation)$ [from 5, 6, and 7]
9. $C(2, CellMutation, LungCanc)$ [from C3]
10. $H(CellMutation \wedge C(2, CellMutation, LungCanc) \Rightarrow H(LungCanc)$ [defeasible inference from Level 2 causal rule]
11. $H(LungCanc)$ [from 8, 9, and 10]
12. $C(2, LungCanc, Symp)$ [from C4]
13. $H(LungCanc) \wedge C(2, LungCanc, Symp) \Rightarrow H(Symp)$ [defeasible inference from Level 2 causal rule]
14. $H(Symp)$ [from 11, 12, and 13]

Smoking Habit Model

In addition to the agreed asbestos exposure figures, a different type of lung cancer trigger was present in the case: the deceased's long standing smoking habit. The parties state that the claimant's habit could be considered as an instance of 'contributory negligence through smoking'. Smoking and asbestos exposure weaken and harm the lungs in different ways, therefore the causes can be considered as alternative.

1. $H(Smoking)$ [explicit assumption]
2. $C(1, Smoking, DamageTissue)$ [from C5]
3. $H(Smoking) \wedge C(1, Smoking, DamageTissue) \rightarrow H(DamageTissue)$ [strict implication from Level 1 causal rule]
4. $H(DamageTissue)$ [from 1, 2, and 3]
5. $C(2, DamageTissue, LungCanc)$ [from C6]

6. $H(DamageTissue) \wedge C(2, DamageTissue, LungCanc) \Rightarrow LungCanc$ [defeasible inference from Level 2 causal rule]
7. $H(LungCanc)$ [from 4, 5, and 6]
8. $C(2, LungCanc, Symp)$ [from C4]
9. $H(LungCanc) \wedge C(2, LungCanc, Symp) \Rightarrow H(Symp)$ [defeasible inference from Level 2 causal rule]
10. $H(Symp)$ [from 7, 8, and 9]

Current research on lung cancer [12] shows that the effects of asbestos exposure and smoking habits increase the risk of lung cancer fivefold. The judge has received criticism for dismissing the smoking habit argument and solely focusing on the asbestos exposure. Furthermore, with the increased accuracy of the calculations of the risk factors based on these two components, it would be useful to add proportional values to these causal models, i.e. the asbestos and smoking models combined [5, 6, 8].

Evidential Considerations: Individual Contributions

The evidential arguments can strengthen or weaken causal models in FCA and support the decision maker in the comparison of competing arguments. While some level of uncertainty is inevitable in legal decision-making, it is important to make a distinction between evidence-based and policy-based considerations. As shown by the research done on different types of human biases [10], overreliance on expert witness testimonies and policy discussions disguised as non-policy ones can lead to grave miscarriage of justice.

The medical experts in the case acknowledged that it cannot be known which fibres exactly caused the cell mutation and led to the lung cancer. In other words, the causal link between an individual employer and the particular cell mutation could not be proven based on the evidence and analytical tools available. Due to these limitations, purely evidence based reasoning was insufficient in this case, as it would have led to a disproportionate burden on the behalf of the claimant. Therefore, the main arguments presented from the claimant's side are policy-based, making a case for using the relaxed burden-of-proof, 'material contribution' exception.

4 CAUSAL ARGUMENT EVALUATION CRITERIA

Clear definitions of exceptions to the conventional rules in law are essential for transparent and coherent decision-making. So far the 'material contribution' exception has been applied only in a limited number of cases, one of the landmark decisions being the *Heneghan*. In this section, we propose an alternative path for the use the exception based on causal argument evaluation criteria following the NESS standard. The advantages of such criteria are twofold: they provide a systematic, logic-based way of analysing cases of overdetermination before the 'material contribution' exception is invoked, and they support the assessment of competing argument models in FCA.

Arguments can be evaluated based on different criteria, including their coherence, evidential support and context-dependent criteria. Here, we argue that cause-in-fact arguments can be evaluated based on the underlying structure of the causal link and whether it satisfies a list of five criteria (s. 4.1).

Causal Argument Scheme, Critical Question Challenges

Three causation specific argument schemes have been distinguished in the literature [19], each emphasising a different characteristic of causal reasoning: forward-looking ('cause to effect'), backward-looking ('effect to cause'), and analytical ('correlation to causation'). Critical questions in these schemes focus on establishing a positive link between the events based on causal generalisations.[9] However, the lack of distinction between necessary and sufficient causes in the schemes lead to similar results to the but-for test analysis. We consider the existing critical questions as a general starting point for developing criteria for the overdetermination cases.

4.1 Evaluation Criteria (FCAv2)

The aim of the evaluation stage (FCAv2) is to formalise practical reasoning with a model that allows for their assessment with argument schemes and critical questions while also accounting for the causal puzzles, which are present in the cases [21].

The NESS standard states that *a is a cause of b, if a is a necessary element of a sufficient set of causes leading to b*. A common criticism of NESS concerns the difficulty of determining what elements in a set of putative causes are necessary for the effect to be produced, i.e. what elements are included in a minimal set producing the effect. For instance in the case at hand, it is hard to determine which employers were in such a set, and which were not. This difficulty may be addressed by assuming that an element is necessary whenever it increases the probability of the event. To use the language of the FCAv2; if there is evidence that an event A belonging to a bigger set of events S increased the probability of an effect B (which took place as a consequence of S), but we cannot say that other elements in S were causally sufficient, then A should be considered causal. This presumption can be defeated, if it can be shown that the causal effect of the event A was pre-empted, i.e., if we show that the other causes in S have already independently generated the effect, which was not the case in *Heneghan*.

Based on this interpretation of the NESS, we propose five critical questions that support the evaluation of whether an element is a contributory cause in a case involving overdetermination.

- CQ1 Is there a positive correlation between the element and the outcome?
- CQ2 Are there alternative concurrent causes present in the case?[10]
- CQ3 Is the element independently sufficient for the outcome?
- CQ4 Does the element concur together with other causes in constituting a set producing the outcome?
- CQ5 Are the other elements insufficient for the outcome? (If so, then the our element should be considered as an 'actual cause'.)

4.2 Overdetermination in *Heneghan*

The analysis of the *Heneghan* case proceeds in several steps. So far we have represented the causal arguments in the FCA following the causal and evidential rules, and uncovered the hidden assumptions in the expert witness and judge's reasoning (section 3). In this section, we present the causal structure of the overdetermination scenario and evaluate the individual causal contributions with the FCAv2 critical questions. Some of the information required for this assessment can be readily found in the FCA models, for instance,

[9] Relevant critical questions: How strong is the causal generalisation? Is there a positive correlation between A and B?

[10] These can be read from the FCA models.

the general causal path from asbestos exposure to the lung cancer symptoms has been defined. It is also helpful to see the strengths of causal links between the events, such as the 'always' link between the asbestos fibres and lodging of the fibres.

Figure 1: Individual contributions

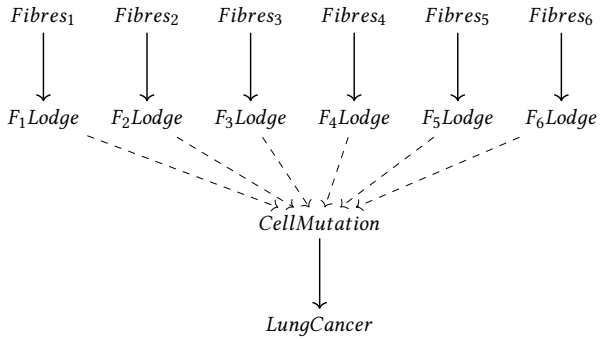

Figure 1 represents an interpretation of the *Heneghan* case: there are six different sources of asbestos fibres ($Fibres_1 - Fibres_6$) that all lodge ($F_{1-6}Lodge$) over a period of time. Each of the fibres that has lodged in the lungs contributes to the risk of causing the harmful cell mutation leading to cancer. While the causal link between the asbestos fibres exposure and lodging is strict ($\rightarrow$), the link between the lodging and cell mutation is defeasible ($\dashrightarrow$). The following diagram further clarifies the complicated causal relationship between the events.

We now assess whether the $Fibres_1$ can be considered a contributory cause by answering the FCAv2 critical questions:

- CQ1 Yes, there is a positive correlation between the exposure to asbestos fibres and the lung cancer. 'Asbestos fibres' here also includes the $Fibres_1$ as a possible cause.
- CQ2 Yes, there are alternative causes present: other employer asbestos fibres and the contributions of the six defendants can be considered as concurrent as there is no material difference as to which fibres lodged first, and the experts asserted that the likelihood of the harmful cell mutation happening because of the first or the sixth defendant is equal.
- CQ3 No, the element is not independently sufficient for the outcome.
- CQ4 Yes, the element is part of a set producing the outcome.
- CQ5 Yes, the other employers are individually insufficient for the outcome.

The analysis above allows us to conclude that $Fibres_1$ can be considered a contributory cause in the case. The diagram of the causal structure, representation of the general causal links in the case, and FCAv2 critical questions uncover the underlying logical structure of the individual contributions and support the reasoners in overdetermination cases.

5 CONCLUSIONS

In this paper we have addressed the issues of determining and evaluating causal arguments in multi-party (overdetermination) cases. We have introduced the rules of the FCA allowing to model causal arguments with causal inferences and evidential abduction rules. The framework was applied in the *Heneghan* case study showing positive results in capturing the causal arguments and their relative strengths. We then presented the criteria for causal argument assessment in overdetermination cases by translating the NESS criteria into a set of critical questions (FCAv2). The new criteria supported the analysis of a single employer liability in a multi-party asbestos exposure case by identifying the employer as a necessary element of a sufficient set of causes.

All in all, causal argument analysis holds great potential for future developments in improving legal analysis in negligent tort cases and beyond [9]. Some of the issues to be addressed in future research include the problem case of preemption, the identification of causal reasoning patterns, and discussions of burden of proof with a focus on structure-based causal analysis.

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