Why-Because Analysis of the Glenbrook, NSW Rail Accident and Comparison with Hopkins's Accimap

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The Glenbrook Accident: Synopsis

A collision occurred on 2 December 1999 at Glenbrook in the Blue Mountains, west of Sydney, Australia, between two passenger trains travelling in the same direction. An inter-urban train from the Blue Mountains to Sydney collided with the rear of an interstate train, the *Indian Pacific*, designated WL2, which had been waiting at Signal 40.8 which was showing "halt", and was starting to move off. The interurban train designated W534 had just passed signal 41.6, some 1.1 km before signal 40.8, after receiving clearance from the signaller to proceed, for it was showing "halt". The interurban train driver accelerated to 50 kph in the block[1], and only saw the rear of the *Indian Pacific* a short distance before the collision.

The two interim reports and the final report into the accident by a Special Commission of Inquiry, chaired by the Honourable Peter Aloysius McInerney, QC, may be found on the National Library of Australia electronic archive, Pandora, at
http://pandora.nla.gov.au/tep/47325

There had been a failure of a power supply to part of the track-circuit system sometime between 08:01 and 08:04, when the *Indian Pacific* interstate train arrived at signal 41.6 at Glenbrook. Both signal 41.6 and its following signal, 40.8, showed "halt" (the fail-safe position, instigated by the track-circuit system failure). The *Indian Pacific* waited at 41.6 for about 7 minutes, first to wait for it to change, and then for the driver to contact the signaller (at Penrith) to obtain permission to proceed through the signal while it still showed "halt". The *Indian Pacific* driver was required to use the track-side telephone to contact the signaller and obtain permission to proceed. The telephone box was, however, locked (unusually) and the driver returned to his cab to get the key, unlocked the box, and received permission from the signaller to proceed. He then proceeded with "extreme caution", as regulations required, through the block to signal 40.8, also showing "halt". He took 7 minutes 45 seconds to proceed through the block, whose length from 41.6 to 40.8 was approximately 1.1 km, and halted at 40.8. His attempts to contact the Penrith signaller using the trackside telephone failed. He waited one minute, as required, and

1 I use "block" to designate the track between adjacent home signals. The Special Commission noted some terminological difficulties in describing such sections of track (First Interim Report, pp26-7).

was beginning to move off through the signal when the IP was hit from the rear by the interurban train.
The interurban train driver had been informed by the Sydney train controller of a possible malfunction of signal 41.6. The driver said he would contact the signaller upon arriving at 41.6. The controller advised him that it was "*only an auto*", meaning an automatic signal to protect a block, and not a manual signal to be set by a signaller, and to "*trip through it*", referring to a procedure to circumvent a technical protection system in case of a malfunction (in fact, there was no such "tripping" device at 41.6; one presumes the terminology was general). Upon reaching 41.6 at Glenbrook, the interurban train driver contacted the signaller, who gave him permission to proceed, and also asked him to report on the condition of the next signal (40.8). The driver took this as an indication that the block ahead was clear of traffic, and the signaller indeed had assumed this was so, although he did not know the exact location of the *Indian Pacific* (Andrew Hopkins, *Safety, Culture and Risk: The Organisational Causes of Disasters*, CCH Australia, Sydney, 2005, p42). The communication was colloquial rather than formal, but Hopkins (*op.cit.*) considers it to have succeeded without relevant misunderstanding.

The interurban train driver proceeded through the signal, and accelerated to about 50 kph. As he was traversing a cutting, he saw the rear of the IP about 100 m ahead and applied emergency brakes. The trains collided and a some passengers in the interurban train lost their lives, with many injured.

The basic principle of fixed-block signalled operations is that at most one train (or part of one train, such as an individual wagon, in case a train loses integrity) is to be in a block at one time during normal operations (cf. Jörn Pachl, *Railway Operation and Control*, VTD Rail Publishing, Mountlake Terrace, WA USA, 2002; or Jörn Pachl, *Systemtechnik des Schienenverkehrs*, B.G. Teubner Verlag, Stuttgart, 2002). Various countries' regulations allow traffic to proceed into an occupied block, but usually under conditions that it can stop within line-of-sight, should the block turn out to be occupied or in case of other anomalies (broken rail; other obstruction). A "Safeworking" Rule 245 governed this circumstance in such a fashion on the Sydney-region railway. Signal 41.6 guarded the block occupied by the
Indian Pacific, at the end of which block lay signal 40.8 at which the *Indian Pacific* had stopped.

Cultural Causes and Their Sources: The Glenbrook Accimap

Andrew Hopkins is a sociologist, and provides a very readable and fascinating 53-page account of the Glenbrook accident in his book (*op.cit.*, pp25-78). Hopkins concentrates on a sociologically-informed exposition of the findings of the Special Commission, and he is especially concerned to identify organisational-cultural factors which contributed to the state of rail operations at the time of the collision. (The report of the Special Commission identifies and considers such factors also, but this document is almost 300 pages long.) Hopkins presents a resumé of his textual arguments in a graph called an Accimap (op.cit. P77), reproduced here in a different layout as Figure 1. The Accimap is visually similar to a WB-Graph, in that important events and states are represented by nodes, and an arrow is placed between nodes should the phenomenon at the tail be a cause or causal factor of the phenomenon at the head of the arrow. The Accimap is more sparse than WB-Graphs usually are, having 19 nodes for Glenbrook. It also separates the factors into three groups, *Specific Causes*, *Cultural Causes*, and *Sources of Culture,* which are not shown in Figure 1. The Accimap representation will be discussed in more detail below.

I do not intend to present the full range of Hopkins's arguments here, simply to indicate what the Accimap terms mean and how he uses them.

Hopkins, partially following the Special Commission's report, identifies a *culture of on-time running*, a *culture of "silos"*, *a culture of rules*, and a r*isk-blind culture* in the involved rail-service providers. The concept "culture" here means a set of (concrete) practices (Hopkins, *op. cit.*, p28) in the organisations involved with rail transport.

Safety measures at the passenger train operator (State Rail Authority, SRA) were based on a complex and voluminous (8 volumes, to be precise) set of rules, some of which, including "Safeworking" Rule 245, governing how and when a train may proceed beyond a signal showing "halt" :

- were complex to understand, when they were understood at all (Rule 245 extended over 8 pages),
- had parts which did not fit with operational reality,
- and which did not necessarily constitute a good guide to safe operations.

For instance, Rule 245 required that a driver proceed with "extreme caution" into the block governed by the signal showing "halt". Witnesses appearing before the Inquiry guessed variously that this meant 3-5 kph, 10 kph, and 18 kph (Hopkins, *op.cit.*, p35). Proceeding at 3-5 kph would take a train 12-20 minutes to reach a signal 1.1 km further along the track, and even at 18 kph would have taken 3 minutes 40 seconds, which conflicts with the heavy pressure towards on-time running: at normal speeds the section would have been traversed in just over a minute.

Hopkins suggests in his Accimap synopsis (*op.cit.*, p77, reproduced in visually-different form as Figure 1 below) that the "*culture of on-time running*" also led to a certain risk-blindness. However, he does not make that argument specifically in his chapter on risk-blindness (*op.cit.*, Chapter 6, pp61-72). That the interurban train driver proceeded at 50 kph into a block guarded by a signal showing "halt" certainly might be taken to suggest that the train driver did not sufficiently appreciate the risks of so doing. On the other hand, the driver had received information from the signaller that the block was clear, and that advice would normally be sufficient for a driver to infer that the block was indeed clear. Hopkins suggests that he could have asked after the whereabouts of the previous train - and then the signaller would have had to say that he didn't know (*op.cit.*, p69). That the signaller was not risk-aware is obvious enough – he communicated to a driver that a block was clear without knowing where the previous train was. That risk-blindness was a general cultural issue rather than just being limited to the persons of driver and signaller is evidenced by the lack of a train indicator board, a board showing the block positions of all trains, in Penrith (Hopkins, *op.cit.*, pp65-6). As the Special Commission notes (*op.cit.*, p9), the rail operations people in Adelaide, half the continent away, did have such a board and could see exactly where the Indian Pacific was. Why not Penrith? And the answer seems to lie in an organisational lack of awareness of risks.

Hopkins considers the question whether the culture was risk-denying rather than merely risk-blind, and opts for risk-blindness (*op.cit.*, pp61-2).

The culture of “silos” refers to the phenomenon that operatives performed their jobs in ignorance of the tasks and goals of other operatives on which they interdepended: drivers from signallers from controllers from stationmasters and so on. In Hopkins's words, “*There was a tendency to ignore problems facing people in other parts of the system and a failure to recognise that these problems might require a system-wide solution. Indeed, there was almost an antagonism between people carrying out different functions in the rail system. The situation was referred to during the inquiry as a “silo mentality”, in which people retreat to their own organisational or occupational niches and deny any broader responsibilities.*” (*op.cit.*, p41) He suggests that this situation partly followed from the breakup of the state rail authority into (at least) three entities, one responsible primarily for infrastructure including track, one for infrastructure and track maintenance, and one for running passenger traffic, and the conflicts of interest between these three entities that led to some dysfunction in certain critical safety areas (*op.cit.*, pp46-9). He terms this splitting up “disaggregation”. Also contributing to the culture of “silos” was the traditional occupational isolation of operatives, sometimes even mutual suspicion amongst interdependent operatives, particularly signallers and drivers (Hopkins refers to the “*compartmentalised and antagonistic thinking which prevailed*”, *op.cit.*, p43), that had developed over the years.

The Accimap: Nodes and Layers

Accimaps originate with Jens Rasmussen (Hopkins, *personal communication*, October 2005). Hopkins's Accimap of the Glenbrook accident is intended as a visual synopsis of the causes of the accident as argued in the text. It is intended to summarise the text, and not to substitute for it (Hopkins, *personal communication cit.*). As a result, one would not necessarily expect that it contain information at the level of detail which normally occurs in a WB-Graph, and we shall see below that this is so. However, the intuitive semantics of the arrows in an Accimap is the same counterfactual interpretation which underlies the formal semantics of an arrow in a WB-Graph (I call it the *Counterfactual Test*; Hopkins the “*but-for*” test.)

Given that the Accimap is a resumé, and not meant to be an autonomous visual argument, its semantics and detail refer back to the text: issues such as ambiguity of node labels or uncertainty in causal-factor attribution should be resolved through considering the textual argument.

One feature of the Glenbrook Accimap not displayed in the WB-Toolset reconstruction (Figure 1) is the layering of types of causes. Hopkins distinguishes between *Specific Causes*, *Cultural Causes*, and *Sources of Culture*. The *Sources of Culture* nodes lie at the top of the Accimap graph; the *Cultural Causes* in the middle, with the *Specific Causes* occupying the lowest layer. The nodes belong to these three groups as follows (the numbering scheme serves as identification, but its ordering has no purpose):

Specific Causes:

1 *Crash*
2 *Failure to drive with extreme caution*
3 *Driver's belief that track clear*
11 *Inadequacy of Rule 245*
4 *Signaller's mistake*
0 *Delays to the Indian Pacific*
10 *Lack of train (indicator) board*
9 *Absence of risk awareness by signaller*
5 *Archaic phone technology*
6 *Signal failure*
8 *Controller focus on OTR*
7 *Indian Pacific failure to use modern radio*

Cultural Causes:
12 *Culture of OTR* (on-time running)
13 *Culture of silos*
14 *Risk-blind culture*
15 *Culture of rules*

Sources of Culture
16 *Public Pressures*
17 *Disaggregation*
18 *Occupational Isolation*

Graphical Representation

Accimap representations as drawn by Hopkins are relatively sparse: the three in his books contain 19 nodes and 24 edges (Glenbrook), 28 nodes and 37 edges (RAAF F-111 occupational health problem), and 29 nodes, 37 edges (Longford accident, in Hopkins, *Lessons from Longford: The Esso Gas plant Explosion*, CCH Australia, Sydney, 2000, p122). Occasionally some arrows pass behind other nodes on their way from source to target, which I found could lead me to misread some of the edges in the Accimaps. Also, the Accimaps with around 30 nodes do not cluster in the way in which WB-Graphs with similar numbers of nodes tend to cluster. We shall see this below. I find this makes it harder to read Accimaps with around 30 nodes and mentally retain a picture of their shape, as I can with the automatically laid-out WB-Graphs with similar numbers of nodes created using the WB-Toolset. However, the WB-Toolset does not (yet, as of December 2005) support layering.

The WB-Toolset representation of the Glenbrook Accimap does, in fact, almost layer the nodes. The *GraphViz* engine which performs the layout layers nodes on the page algorithmically, according to their connections, with all arrows pointing upwards. Since all pf Hopkins's *Sources of Culture* nodes are causal precursors of *Cultural Causes* nodes, which are in turn causal precursors of *Specific Causes*, the *GraphViz* engine places *Sources of Culture* nodes at the lowest level, the *Cultural Causes* nodes generally at the next lowest level, and the *Specific Causes* above these. The one exception is *Risk-blind culture*, which occurs on a layer with two *Specific Causes*. It is easy to see why this is so. The *Risk-blind culture* is according to Hopkins itself a *but-for* consequence of the other three cultures, the *Culture of OTR*, the *Culture of silos* and the *Culture of rules*, and

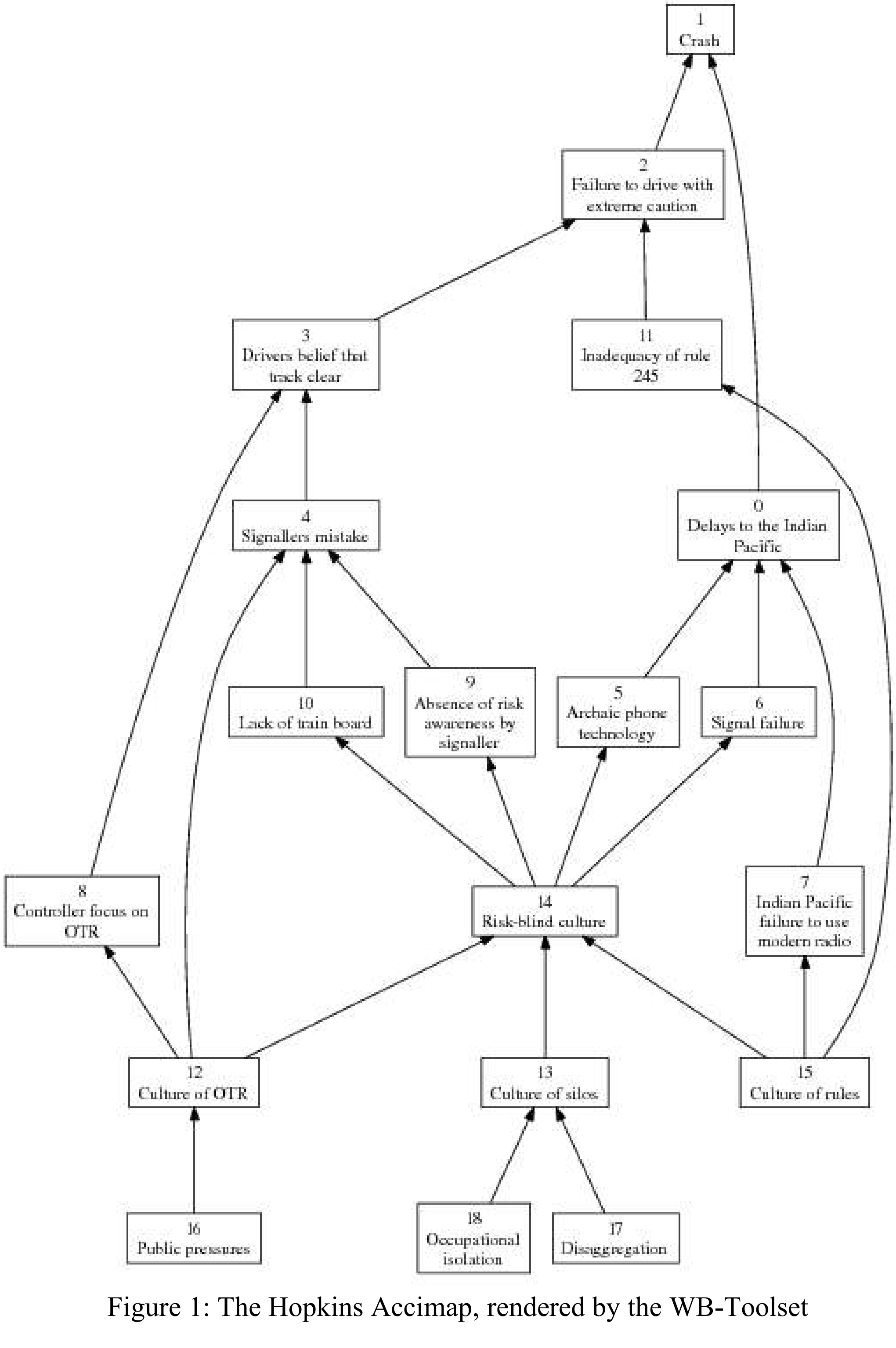

Figure 1: The Hopkins Accimap, rendered by the WB-Toolset

it intermediates between those cultures and every significant causal path on the graph

(either as cultural cause alone, or as co-cause with one other cultural node). The WB-Toolset layout illustrates this clearly, and automatically.
I find the WB-Toolset representations easier to “grok” than the Hopkins originals. This may be a matter of individual taste: I can visually pick up key nodes, such as *Risk-blind culture*, more easily from the WB-Toolset representation.

Some Questions About Hopkins's Accimap

There are a number of points at which I query Hopkins's Accimap.

1. The node
   - *Failure to drive with extreme caution* (by which Hopkins refers to the interurban train driver's passage beyond signal 41.6)
   has as necessary causal factors:
   - *Inadequacy of Rule 245* and
   - *Driver's belief that track clear*.

   It seems to me clear that the interurban train driver's acceleration up to 50 kph was (partially?) due to his belief that the block was clear, but the relation of this acceleration to Rule 245 is far from obvious. The Rule was there; the driver didn't follow it, and may not have been aware of it in detail, partly indeed because it was too complicated (*op.cit.*, p34-6). But the Special Commission also identified the culture of on-time running as dominant over safety (e.g., Special Commission, *op.cit.*, p12). It seems to me plausible that a concern to catch up the couple of minutes he had lost may have encouraged the driver to drive without Rule-245-extreme-caution. Yet there is no arrow in the Accimap from *Culture of OTR* to *Failure to drive with extreme caution*, as this influence would require.

2. The node
   - *Driver's belief that track clear*
   has as causal factors:
   - *Controller focus on OTR* and
   - *Signaller's mistake*.

   I do not see, and Hopkins doesn't explain, how the controller and his focus on OTR may have influenced the driver's belief. It seems to me that when the signaller told the driver to proceed through 41.6 and indicated (albeit informally) that the block was clear, that is reason enough by itself for the driver to take it that the block was indeed clear.

3. There is no component in the Accimap of *Interurban train driver's lack of risk-awareness*. Yet Hopkins argues, correctly in my opinion, that the driver's acceleration to 50 kph shows a lack of awareness of the risks involved in passing a signal at halt, even if the signal is known to be defective (see especially *op.cit.*, p39). So it seems to me that, if there is an arrow from node *Risk-blind culture* to *Absence of risk-awareness by signaller*, which there is, then there should also be an arrow from *Risk-blind culture* to a node *Absence of risk-awareness by interurban train driver*, and thence another to *Failure to drive with extreme caution.* Alternatively, one could

delete the words *by signaller* from the node *Absence of risk awareness by signaller* to render this node as *Absence of risk awareness*, which applies to both signaller and interurban train-driver as argued above, and connect it with an arrow to *Failure to drive with extreme caution,* as well as other suitable nodes.

4. The node
   - *Signaller's mistake*
   has as causal factors
   - *Lack of train board*
   - *Absence of risk awareness by signaller*
   - *Culture of OTR*

   This set of causal factors cannot suffice, for purely formal reasons. That the signaller made a mistake is an event. The three causal factors are, however, all states. An event cannot be caused only by states (except possibly in some interpretation of quantum mechanics, which is here not relevant). There must be at least one event in the causal-factor list of an event. One can see this here intuitively as follows. The states were all constantly present: there was a pervasive culture of on-time-running, the signaller was continuously risk-unaware, and there had never been a train board. If these three had sufficed causally to engender a signaller's mistake, then the signaller would constantly and continually be making mistakes, without interruption and without end – which is an absurd situation to contemplate.

   I shall take the resolution of this formal dilemma to be as follows. One of the signaller's mistakes was to advise the interurban train driver that the block ahead, guarded by signal 41.6, was clear, when it was not. He made this mistake when prompted for action by *a communication by the interurban train driver*, which phenomenon is an event. So the event of the *signaller's making a mistake* has as causal factor *communication by the interurban train driver* as well as the other named causes. We can interpret the description *Signaller's mistake*, then, as *Signaller's mistake upon prompt from interurban train driver*, which includes a triggering event for the mistake in the description itself. I shall use this interpretation in both the Accimap and in my WB-Graph below.

Combining the Accimap Insights with a WBA

As noted, the Accimap is a visual resumé of the textual arguments. It thus depends for its accuracy and helpfulness on the intellectual acuity of the analyst. I am interested in devising a quasi-algorithmic method by which the causal information in the Accimap may be derived and rendered, as well as checked for accuracy and pertinence, by a line engineer. I first constructed a *List of Facts* as usual in WBA from the raw facts of the accident gleaned from Hopkins's commentary, using a narrow stopping rule which stops at factors specific to the immediate participants, without inquiring into organisational character or adducing any other of Hopkins's general cultural factors. I put the node labels in SAOIndO form (for events) and S-Pred form (for states), performed the Counterfactual Test, and obtained the following WB-Graph.
Figure 2 is a WBA with stopping rule at factors specific to the participants, and not to the organisations in which they worked; also containing no evaluative judgements on how

things should have worked and whether this was a good idea.

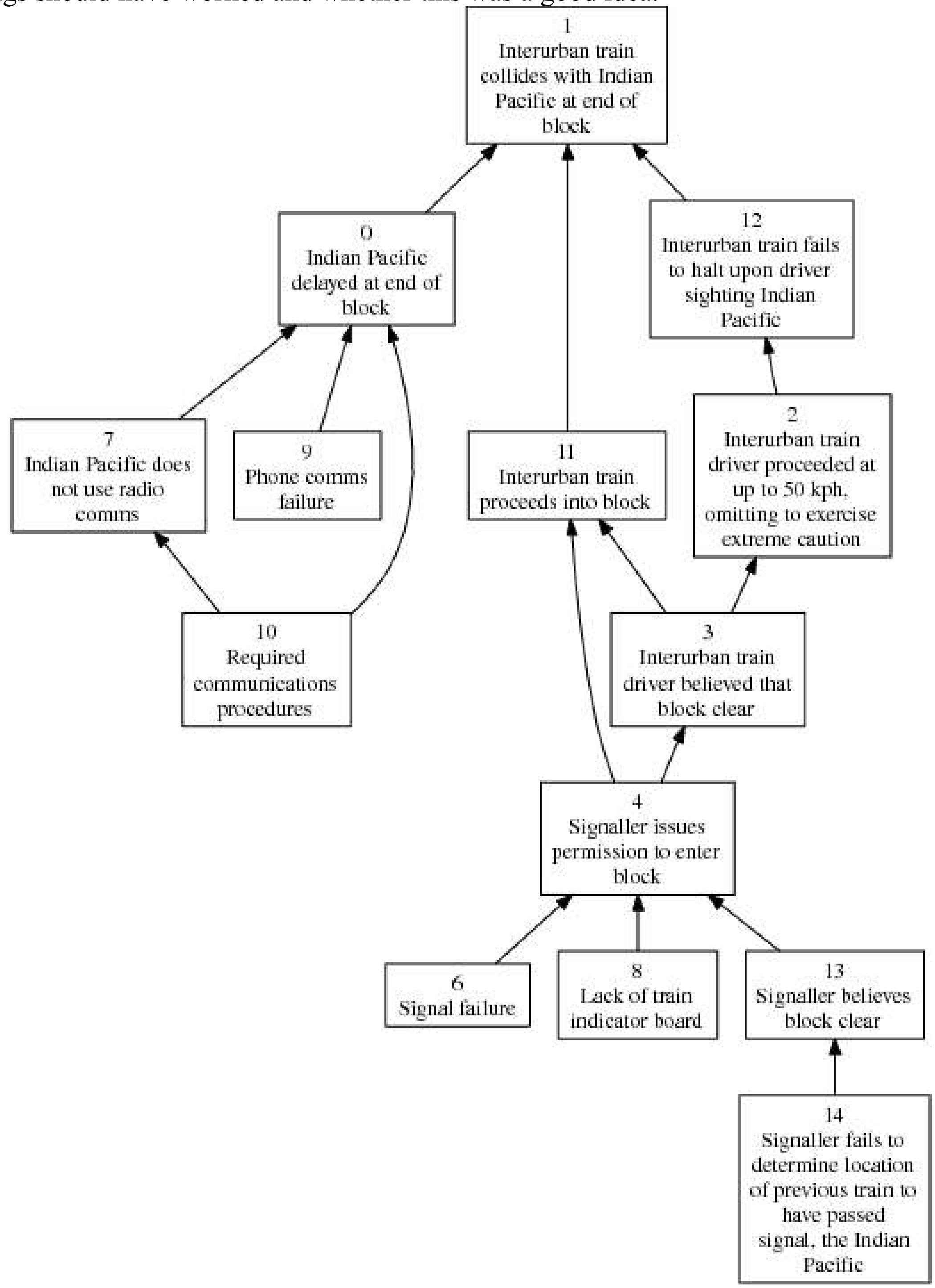

Figure 2: WBG with the Narrow Stopping Rule (WBG-NSR)

Let us call this Why-Because graph the WBG with the *narrrow stopping rule*, WBG-NSR. It has as *ListOf Facts:*

- *Indian Pacific delayed at end of block*

- *Interurban train collides with Indian Pacific at end of block*
- *Interurban train driver proceeded at up to 50 kph, omitting to exercise extreme caution*
- *Interurban train driver believed that block clear*
- *Signaller issues permission to enter block*
- *Signal failure*
- *Indian Pacific does not use radio comms*
- *Lack of train indicator board*
- *Phone comms failure*
- *Required communications procedures*
- *Interurban train proceeds into block*
- *Interurban train fails to halt upon driver sighting Indian Pacific*
- *Signaller believes block clear*
- *Signaller fails to determine location of previous train to have passed signal, the Indian Pacific*

This *ListOfFacts* requires some commentary. The appearance of non-events and non-actions in a WBG must be justified through existence of a procedure that requires that they happen. There are two non-events adduced in the WBG. They are justified as follows:

- The adverbial phrase attached to the 50 kph speed observation, that the train driver omitted to exercise extreme caution, is justified as a non-event (that he *omitted* to do something) by the explicit requirement in Rule 245 that he exercise extreme caution. I presume that proceeding at 50 kph does not constitute proceeding with extreme caution: although witnesses differed as to what this meant, the range was 3-18 kph, very much slower.
- The non-event *Signaller fails to determine location [of Indian Pacific]* must similarly be justified by a procedural rule that entails that an action must take place. In this case, I presume that there is a rule that signallers are required to determine that a block is clear before giving permission to enter. There is such a requirement on most railway systems. Technically, though, this remains a presumption: Hopkins does not say explicitly that such a rule exists.

The WBG-NSR represents the causal factor relations amongst all those things which were indisputably there – which, one might say, little green visitors from Mars would also agree occurred or were present. There are some controversial facts, namely those concerning what the interurban train driver and the signaller believed (also the controller, come to that, but he is not in the story yet). Our green Martian visitors would equally be unable to determine what the truth was. That was part of the mandate of the Special Commission, however, and we take those question to have been settled according to the Commission's ruling, as Hopkins does and as we could imagine our Martian visitors might do also. We may now compare the nodes in the WBG-NSR with those in the Accimap. The following nodes are present in both:

- *Indian Pacific delayed at end of block*
- *Interurban train collides with Indian Pacific at end of block*
- *Interurban train driver proceeded at up to 50 kph, omitting to exercise extreme caution*

- *Interurban train driver believed that block clear*
- *Signaller issues permission to enter block*
- *Signal failure*
- *Indian Pacific does not use radio comms*
- *Lack of train indicator board*
- *Phone comms failure*
- *Required communications procedures*
- *Interurban train proceeds into block*
- *Interurban train fails to halt upon driver sighting Indian Pacific*
- *Signaller believes block clear*
- *Signaller fails to determine location of previous train to have passed signal, the Indian Pacific*

The following nodes from the WBG-NSR are *not* present in the Accimap:

- *Phone comms failure*
- *Required communications procedures*
- *Interurban train proceeds into block*
- *Interurban train fails to halt upon driver sighting Indian Pacific*

I note also that there are three nodes in the WBG-NSR which I take to be represented by one node in Hopkins's Accimap, namely:

- *Signaller issues permission to enter block*
- *Signaller believes block clear*
- *Signaller fails to determine location of previous train to have passed signal, the Indian Pacific*

The corresponding one node in Hopkins's Accimap is

- *Signaller's mistake*

That is, I consider the signaller to have made three specific mistakes. The question arises, then, as to why these nodes are not in the Accimap, since they appear to be "*specific causes*". They became identified through the systematic approach of WBA to identifying, discerning and discriminating necessary causal factors.

The following nodes in the Accimap *Specific Causes* are not present in the WBG-NSR:

- *Inadequacy of Rule 245*
- *Absence of risk-awareness by signaller*
- *Archaic phone technology*
- *Controller focus on OTR*

Let us consider them individually to discern why they do not occur in the WBG-NSR.

1. Three of them are value judgements

1. That *Rule 245 is inadequate*. This seems to be well established by the Special Commission, and Hopkins goes to some length to explain it. It is a complex rule of 8pp, in a rule book of 8 volumes that was known not to be kept up to date by drivers, and obviously not memorised. Hopkins shows that Rule 245 was inadequate in various ways as a practical guide to operations when proceeding past a signal at "halt", as well as suggesting that the interurban train driver was understandably not necessarily familiar with the details of the rule and did not necessarily consider it to guide his on-the-job behavior (*op.cit.*, pp34-6). However, our Martian friends, good at memorising volumes of rules and applying them appropriately, might not agree (as, presumably, the SRA did not agree). I take it as established, though, by the Special Commission that the driver was unable to apply Rule 245 correctly, and that the greater proportion of the reasons for this lay in the formulation of the rule, and in the general rule basis for operations. To satisfy the WBA non-event inclusion criterion while phrasing the factor as *Rule 245 is inadequate*, one would need to identify a procedure or regulation which specifies that the Rule should be adequate; and there is no obvious candidate. Thus I shall rephrase the factor as *Rule 245 did not guide operations as intended*. The negative formulation of the factor is substantiated through the observation that it should have guided operations; this fits the WBA criterion for non-event inclusion.

2. That the *phone technology is archaic* means a number of things. The phone communications were time-consuming. Had the Indian Pacific not spent 7+ minutes following the communications protocol at signal 41.6, but had otherwise done exactly what he did do, he would have moved off some 7 minutes before and been well out of the way, no matter what signaller and interurban train driver thought. So that it was time-comsuming in that particular way is a necessary causal factor of the accident. And our Martian friends could see that too. The phones and/or the communication protocols were also not necessarily reliable – recall that the *Indian Pacific* driver phoning from signal 40.8 did not reach the signaller. But even if he had reached the signaller, the question arises whether the signaller could then have reached the interurban train driver in time to warn him of the stationary train in his block. Probably – they had direct radio communications. Whether it would have been enough to avoid, or only enough to mitigate the severity of the accident can remain undecided here. Our Martian friends could judge this as a causal factor in the accident (if severity is counted as part of the accident, as it usually is in risk analysis).

3. *Absence of risk-awareness by signaller*. Although this is counted as a factor, the question arises as to its status. Was it proven that the signaller was not risk-aware in general? Or is is only proven that the signaller did not happen to pay attention to the specific risks of his specific action/belief/non-action tripleton that specific morning? The answer does not follow from Hopkins's discussion. That does not mean that it is undecided: there might well be evidence for one or the other in the Special Commission report.

The fourth node, *Controller focus on OTR*, is indisputably factual. Hopkins goes to some lengths to demonstrate it (*op.cit.*, pp52-3 and p55). However, it is not clear what direct causal role it played in the accident. Recall that it was not present in the WBG-NSR.

Hopkins does not argue that controllers were able to intimidate drivers; neither does he argue that drivers' pressure to run on time and to catch up time even at the expense of safe operations was caused by the controllers – rather, he argues that discipline was applied by the organisation at higher levels of the hierarchy - inspectors, maybe senior managers, the issuance of warnings by management personnel (op.cit., pp52-54). I do not see that it is established by any of the arguments presented that *focus of the controller on on-time running* in this instance was a causal factor in the accident.

Thus we can build the Rule-245-factor and the phone-comms-factors into the WBG-NSR to generate the WBG with Specific Causes, WBG-SC, Figure 3.

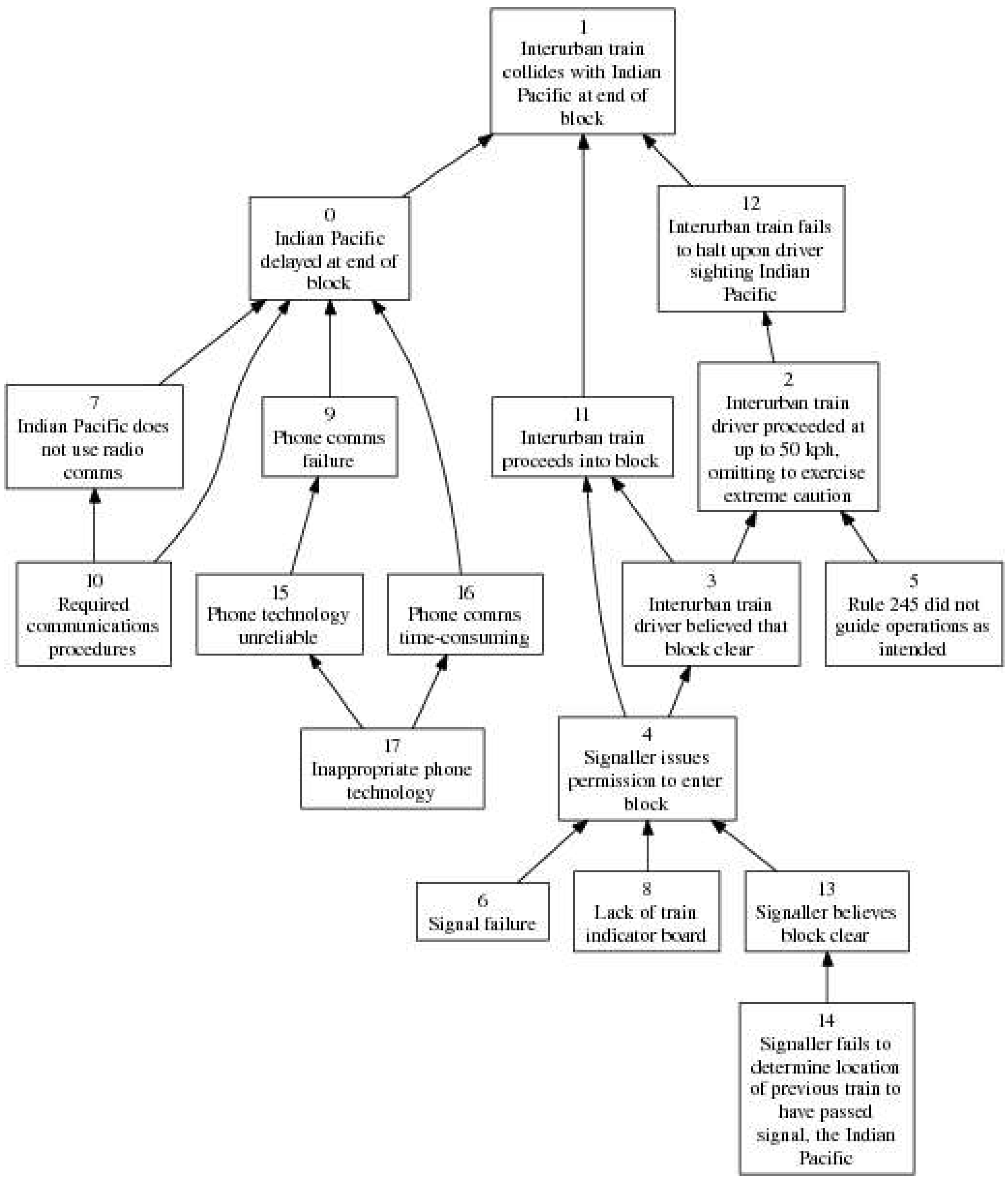

Figure 3: WB-Graph with all Specific Causes (WBG-SC)

Note that I have made precise exactly what it was about the phone technology that caused problems. I take the view that it doesn't matter whether the kit was archaic or not. What mattered was whether the kit worked, along with its communications protocols, and it did not in this case – and foreseeably in lots of others as well.

Note that I argued above that both the unreliability of the phone comms, and the failure of the kit, were necessary causal factors **of the accident**, not just of the delay to the *Indian Pacific*. So why are there not arrows from these nodes to the top node? I use here an informal short cut which we shall use more formally below, which is that one may omit the direct edge in the case in which

- a node B may be reached by following a short chain X from node A, and
- A is a necessary causal factor of B as established by the Counterfactual Test, and
- the reasons why A is a necessary causal factor of B all lie on the chain X

(For "chain X" here, one may read also a set of paths from A to B.)

Lewis defines a *cause* as

- *A is a cause of B* just in case a node B may be reached by a chain X of necessary causal factors from node B

Thus we may say without fudging that WBG-SC is a *causal graph*. The representational point is that this graph is *almost* a WBG, and the reason why we leave off certain edges is to maintain easy readability. It is becoming standard practice amongst WB-analysts to do so.

From Specific to Cultural Causes

We may now consider adding the nodes from the Accimap *Cultural Causes* layer. I find Hopkins's arguments for their existence and their causal influence compelling. The question I address here is how they are connected to the specific causes we have identified. Let us consider the four cultural causes one by one.

1. *Risk-blind culture*. As I noted earlier, this is by far causally the richest of the cultural nodes. Hopkins argues well that it was causal in the lack of risk awareness of the signaller of clearing a train into a block, and indicating that the block was free, without knowing definitively where the previous train in that block was (*op.cit., ????*). He also argues well that the choice of the interurban train driver to proceed at up to 50 kph was partially due to a lack of awareness on his part of the risky possibilities (that there still might be an obstruction, or a broken rail or some other fault in the block, even though the signal had already been identified as previously faulty) (*op.cit., ????*) And he argues that both were due to a general risk-blind organisational culture (*op.cit., ????*). So we may join the cultural node *Risk-blind culture* not only to its Cultural-Cause and Sources-of-Culture predecessors as in Hopkins's Accimap, and to the Specific Causes with which it has been identified in the WBG-SC, but we may also add two more specific nodes *Lack of risk-awareness of signaller* and *Lack of risk-awareness of interurban train driver* for which it is a necessary causal factor, and connect these nodes appropriately.

   Hopkins claims in the Accimap that the *Risk-blind culture* also led causally to signal failure, but I see a more plausible explanation that does not relate to risk-blindness. In his text, Hopkins argues that recent disaggregation of the State Rail Authority into three different entities resulted in a lack of effort by the disaggregated entities to consider the impact of their behavior on the system as a whole. He says "t*he rail track owner, which also owned the signals, did not recognise that signal failure might contribute to accidents and that it was therefore incumbent on the infrastructure owner to drive the failure rate of signals down as close to zero as possible. Its view was that, provided drivers compied scrupulously with rule 245, signal failure was not a risky event*." (*op.cit.????*) I think the view is defensible that if one has a back-up such as (some acceptable version of) Rule 245, then proceeding through signals at "halt" with "extreme caution" is acceptably non-risky.

Most rail operators in the world have such a regulation about when one may proceed through and how. The question here is whether Rule 245 was adequate. If the rail operator believed Rule 245 was adequate, then it had reason to consider signal failure as acceptably risky. Further, an operator adjusts operations to the rate of signal failure one actually has; it may not matter as much for safe operations whether that rate is close to zero, or somewhat above that; only that it does not vary much from the customary rate.

There is another factor possibly contributing to the signal failure which is not noted by Hopkins in this regard. The people maintaining the signals and the people using the signals (passenger trains) were two different entities, and a higher-than-acceptable rate of signal failure might well ensue as a result of disaggregation: it is a well-known phenomenon that, when the costs of a feature fall on one organisation while the benefits accrue to another, the feature is prone to degrade. Hence we might well be prepared to consider an unusually high rate of signal failure, or a lack of attention to signal system maintenance, to be a direct result of disaggregation. We shall consider this possibility again when we consider *Sources of Culture*. For now, I choose not to consider *Risk-blind culture* as a causal factor of the *Signal failure*.

2. *Culture of OTR*. I have argued that the culture of on-time running may have contributed to the interurban train driver's nonchalance at accepting clearances from the signaller (and also the controller, but I have argued that I do not see that as specifically causal to this accident), as well as a decision to proceed at speed into the block.

3. *Culture of Rules*. I agree with Hopkins that the culture of rules was directly causally responsible for the inadequacy of Rule 245, as well as for the failure of the Indian Pacific to use the radio to contact the signaller, as well as contributing causally to the culture of risk-blindness.

4. *Culture of silos*. I agree with Hopkins that the culture of silos contributed causally to the pervasive risk-blindness. A question arises that, if we consider that disaggregation was partially causally reponsible for the signal failure, we might consider that causality being mediated through "silo" culture. I judge not; the meaning of the "silo" culture for Hopkins is the individual isolation of groups of workers, and this is a phenomenon independent of the phenomenon of cost-benefit asymmetry which I

adduced as possibly partially responsible for the signal failure.
We include the Cultural Causes and the Sources of Culture, as indicated above, in the WBG-SC to obtain the WBG-SC-CC, as in Figure 4.

Factoring the WBG-SC-CC

The WBG-SC-CC has 27 nodes, a factor of 50% increase over that of Hopkins's Accimap. There is a causal connection between *Disaggregation* and *Signal failure*, and not between *Risk-blind culture* and *Signal failure*, as discussed above; otherwise the connections are substantially as indicated in the Accimap. However, the WBG-SC-CC is visually unwieldy. Part of this may be due to the number of nodes (I have already remarked that the 30-node Accimaps seem to be more difficult visually to comprehend), and part due to the particular structure of an Accimap (see below). It is time to consider a modified representation, so that we may preserve the visual comprehensibility of WBG-SC while retaining the important cultural information of the Accimap cultural causes.

I suggest a factorisation of the WBG-SC-CC based on the following observation. The WBG-SC exhibited a visually clear structure, starting at the root node (the collision) and largely spreading out downwards from the root, with some accumulation. The cultural causes are a small group of four nodes that causally influence many nodes throughout the WBG-SC structure. So the cultural causes structurally spread upwards to meet the spread of specific causes tending downwards. We can factor the graphs along the direction of structural spread. I reduce the WBG-SC-CC paths which lie entirely in WBG-SC to their lowest node and topmost node (the collision). Thus I indicate the specific-causes part of the WBG only through path heads and tail. It is a *causal graph* in the sense defined above, in which arrows now denote causes, not necessarily causal factors. I call the result the *Cultural-Causal Graph*, CCG. See Figure 5.

In the CCG, the cultural-causal nodes are

- *Risk-blind culture*, with its two consequences
    - L*ack of risk awareness by signaller*
    - *Lack of risk awareness by interurban train driver*
- *Culture of rules*
- *Culture of OTR*
- *Culture of silos*

The *Sources of Culture* are, as in the Accimap:

- *Occupational isolation*
- *Disaggregation*
- *Public pressures*

and the *Disaggregation* node is connected to the *Signal failure*, as suggested above.

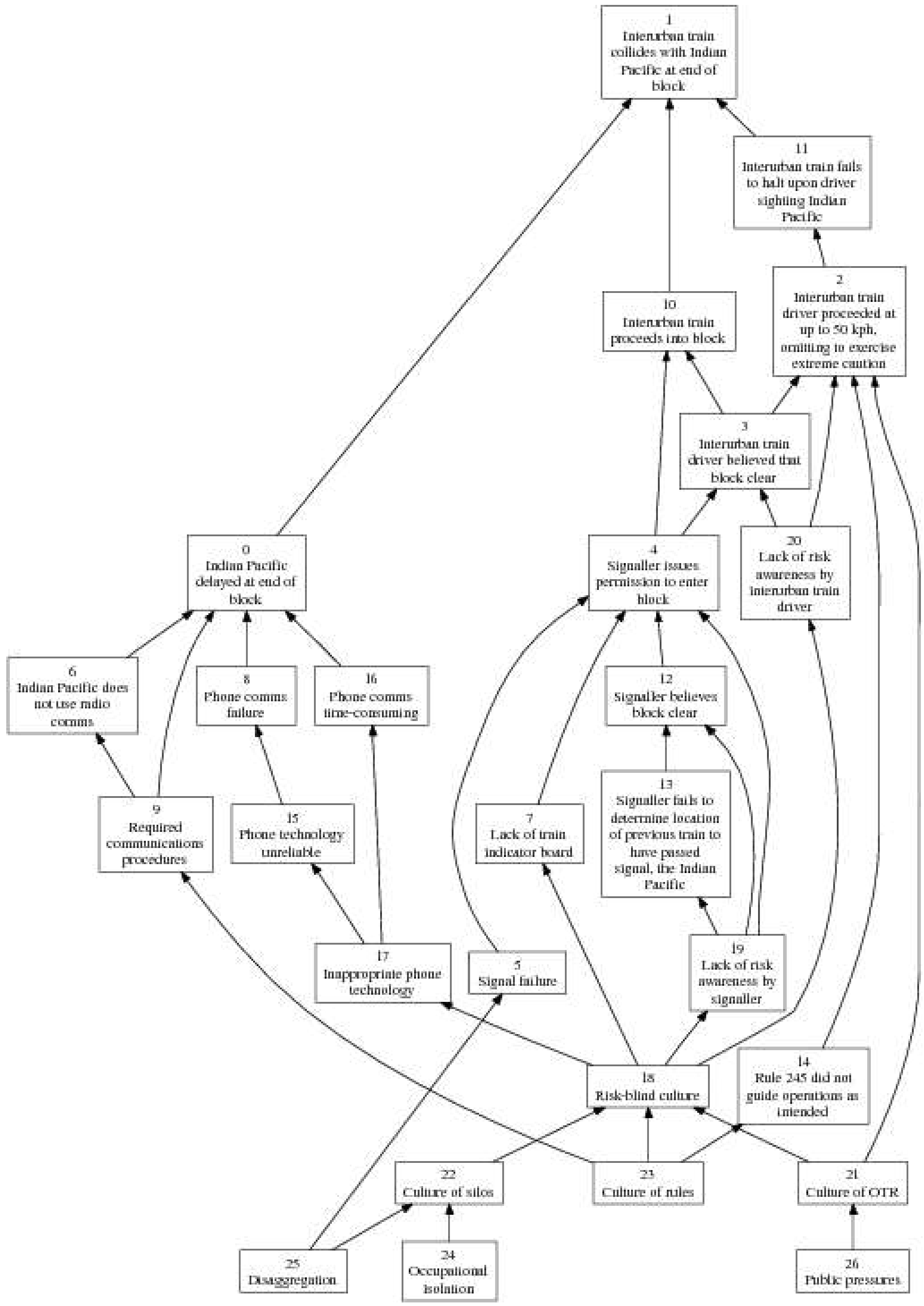

Figure 4: Glenbrook WBG with Specific and Cultural Causes and their Sources (WBG-SC-CC)

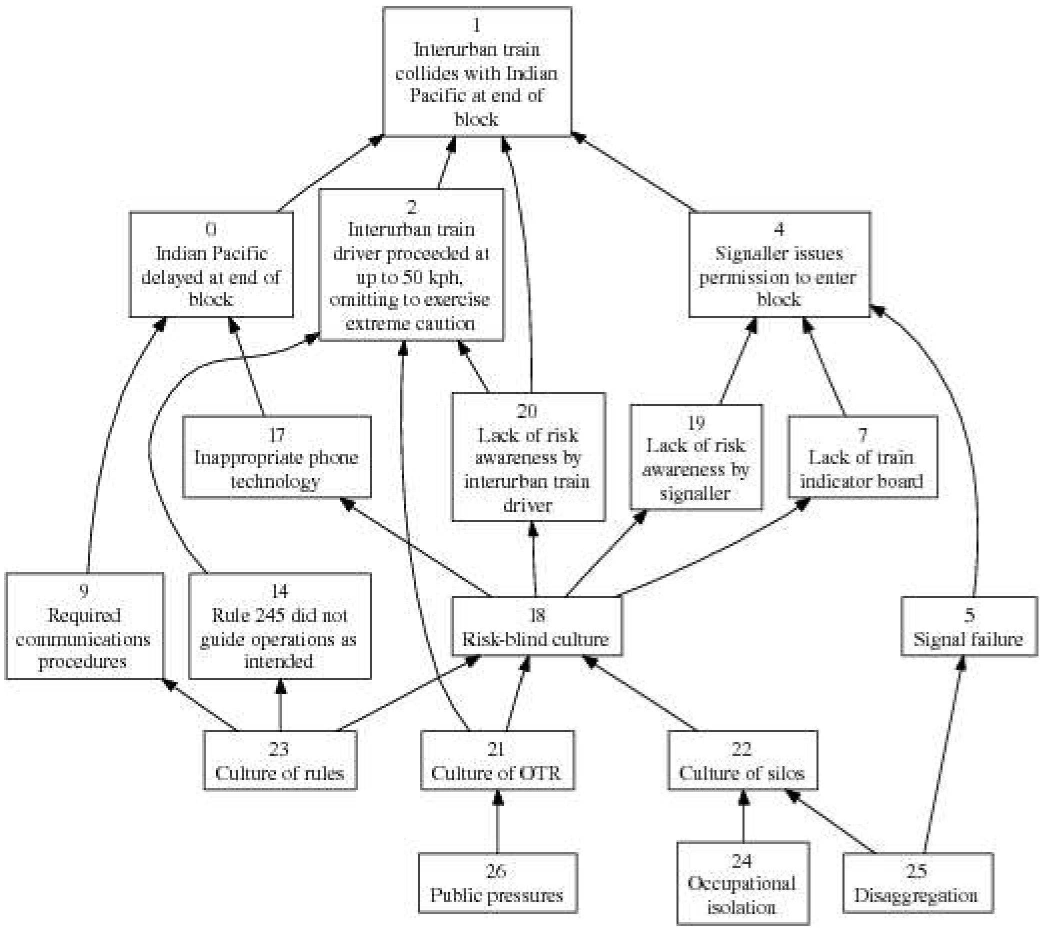

Figure 5: The Cultural-Causal Graph (CCG)

Comparison of the WBG-SC-CC with Hopkins's Accimap

I use the following methods of comparing the two causal graphs:

- Comparing nodes: those that are the same and those that are different
- Comparing edges after reduction to the common node set

Nodes

There are 18 nodes in the common node set of the WBG-SC-CC and the Accimap, compared with an original count of 19 for the Accimap and 27 for the WBG-SC-CC. The Accimap is, then, essentially a subset of the WBG-SC-CC. The only node it has which does not appear in the WBG-SC-CC is:

- *Controller focus on OTR*

which we have already discussed, and concluded did not play a causal role.

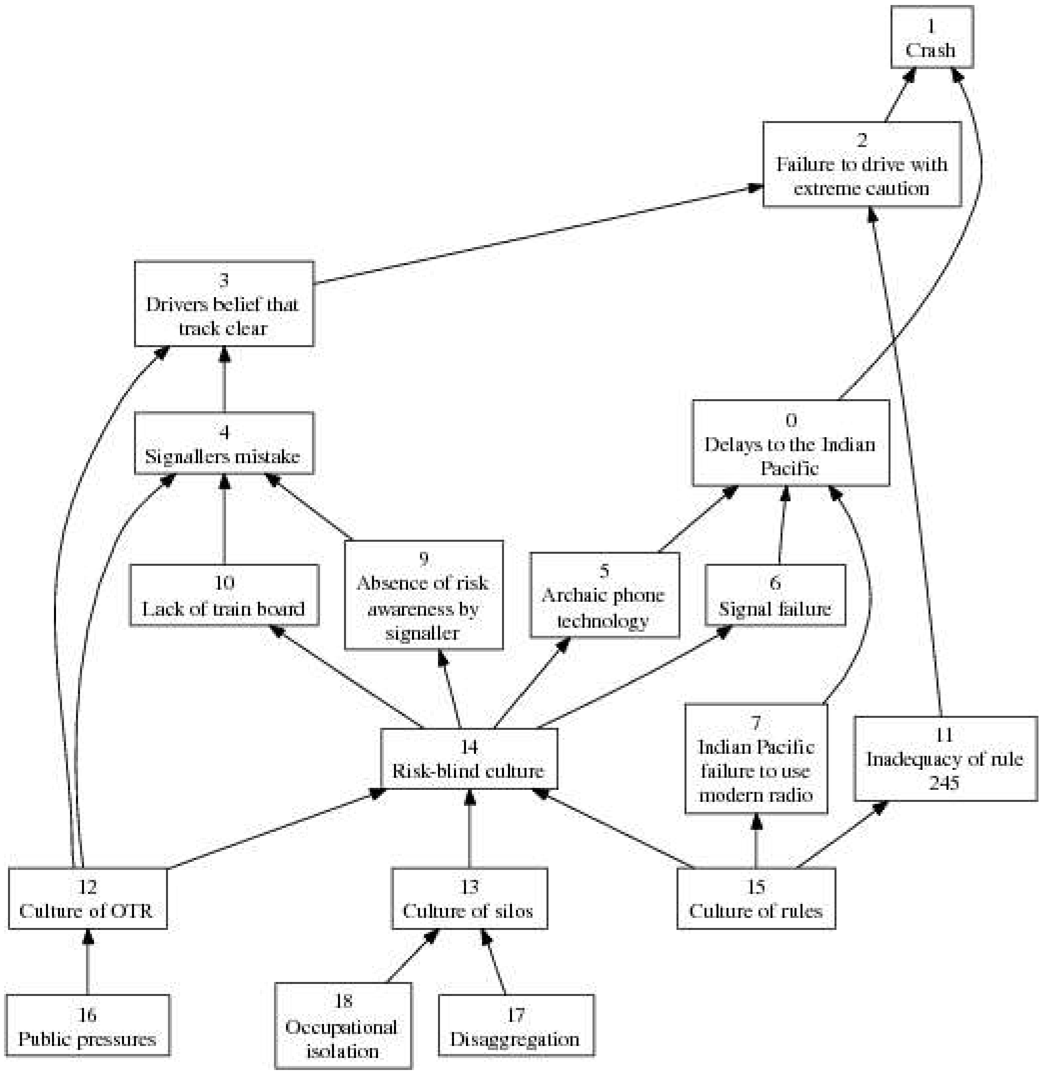

Figure 6: The Accimap Reduced to the Common Node Set

Let us call the Accimap reduced to the common node set the *Reduced Accimap* (Figure 6) and the WBG-SC-CC reduced to the common node set the *Reduced WBG-SC-CC* (Figure 7). When we reduce, we perform the following operations:

- Retain in each graph only nodes common to both
- Retain the paths between nodes that were present in the original.
    - So, if A → B → ... → C are in a graph, and all nodes between A and C disappear, but A and C remain, then we add an edge A → C in the reduced graph

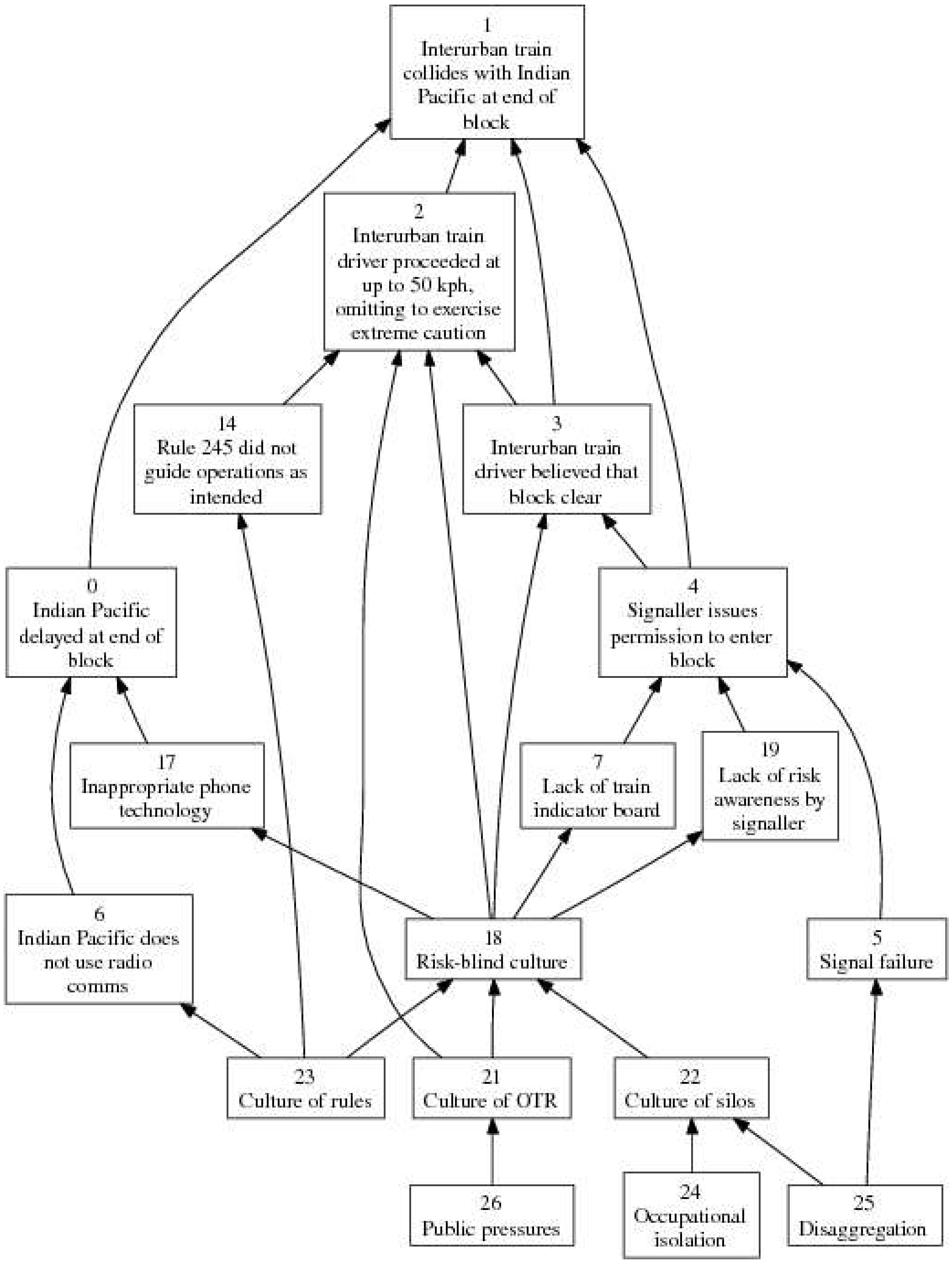

Figure 7: The Reduced WBG-SC-CC

There are 18 nodes in the reduced graphs; 24 edges in the Reduced Accimap and 27 edges in the Reduced WBG-SC-CC. There are 11 edge-differences: 7 edges in the Reduced WBG-SC-CC that are not in the Reduced Accimap, and 4 edges in the Reduced Accimap that are not in the Reduced WBG-SC-CC. There are 20 edges wich occur in both graphs. I enumerate the edge-differences in the graphs:

- *Interurban train collides with Indian Pacific at end of block* has causes
  - *Interurban train driver believes block clear*
    - *Present* in Reduced WBG-SC-CC; *absent* in Reduced Accimap
  - *Signaller issues permission to enter block*
    - *Present* in Reduced WBG-SC-CC; *absent* in Reduced Accimap

- *Interurban train driver proceeded...omitting to exercise extreme caution* has causes
  - *Culture of OTR*
    - *Present* in Reduced WBG-SC-CC; *absent* in Reduced Accimap
  - *Risk-blind culture*
    - *Present* in Reduced WBG-SC-CC; *absent* in Reduced Accimap

- *Interurban train driver believed that block clear* has causes
  - *Culture of OTR*
    - *Absent* in Reduced WBG-SC-CC; *present* in Reduced Accimap
  - *Risk-blind culture*
    - *Present* in Reduced WBG-SC-CC; *absent* in Reduced Accimap

- *Signaller issues permission to enter block* has causes
  - *Signal failure*
    - *Present* in Reduced WBG-SC-CC; *absent* in Reduced Accimap
  - *Culture of OTR*
    - *Absent* in Reduced WBG-SC-CC; *present* in Reduced Accimap

- *Indian Pacific delayed at end of block* has cause
  - *Signal failure*
    - *Absent* in Reduced WBG-SC-CC; *present* in Reduced Accimap

- *Signal failure* has cause
  - *Disaggregation*
    - *Present* in Reduced WBG-SC-CC; *absent* in Reduced Accimap
  - *Risk-blind culture*
    - *Absent* in Reduced WBG-SC-CC; *present* in Reduced Accimap

All of these 11 differences except for the causality of the collision node involve differing causal roles attached to the three nodes
- *Signal failure*
- *Culture of OTR*
- *Risk-blind culture*

I have discussed these nodes and their causal roles explicitly. In particular, I commented specifically when initially discussing the Accimap on the two causal connections:

- *Interurban train driver proceeded...omitting to exercise extreme caution* has cause
  - *Culture of OTR*
    - *Present* in Reduced WBG-SC-CC; *absent* in Reduced Accimap

- *Interurban train driver believed that block clear* has causes
    - *Culture of OTR*
        - *Absent* in Reduced WBG-SC-CC; *present* in Reduced Accimap

so one may reasonable propose that only 9 edge differences in the reduced graphs arise from the differences between the WBA and the Accimap generation, and that two arise from differences in judgement concerning the Accimap.

I leave it to the reader to choose between the accounts I offer above and the judgements Hopkins offers. It seems to me that they represent differences in judgements about the subject matter, not simply causal mistakes. The two reduced graphs, then, have 74% (20 out of 27) to 83% (20 out of 24) of their edges in common. I have concentrated on discussing differences. It is thus appropriate here to point out that nevertheless the reduced graphs have much in common.

They are similar, which shows to my mind that they are objective representations of the causality of the accident. But against that similarity, one should also consider the differences significant. For the differences in causality attribution can lead to differences in formulation of countermeasures, prophylaxa, and these prophylaxa will be more or less effective depending on the accuracy of the attributions of causality in the WBG from which they are derived.

Reduced Causal Graphs, Version 2

Suppose we modify the Hopkins Accimap according to my original critique. That would mean we had an Accimap differing from the Hopkins Accimap in three aspects:

- It would contain a node
    - *Absence of risk awarenes by interurban train driver*
      which has as causal factor:
    - *Risk-blind culture*
      and which is a causal factor of
    - *Driver's belief that track clear*
    - *Failure to drive with extreme caution*

- The node *Driver's belief that track clear* would not have as factor
    - *Controller focus on OTR*
      and therefore the node *Controller focus on OTR* would not be present, eliminating also its edge from *Culture of OTR*

- There is a causal connection from
    - *Culture of OTR*
      to
    - *Failure to drive with extreme caution*

The modified Accimap according to this critique is shown in Figure 8.

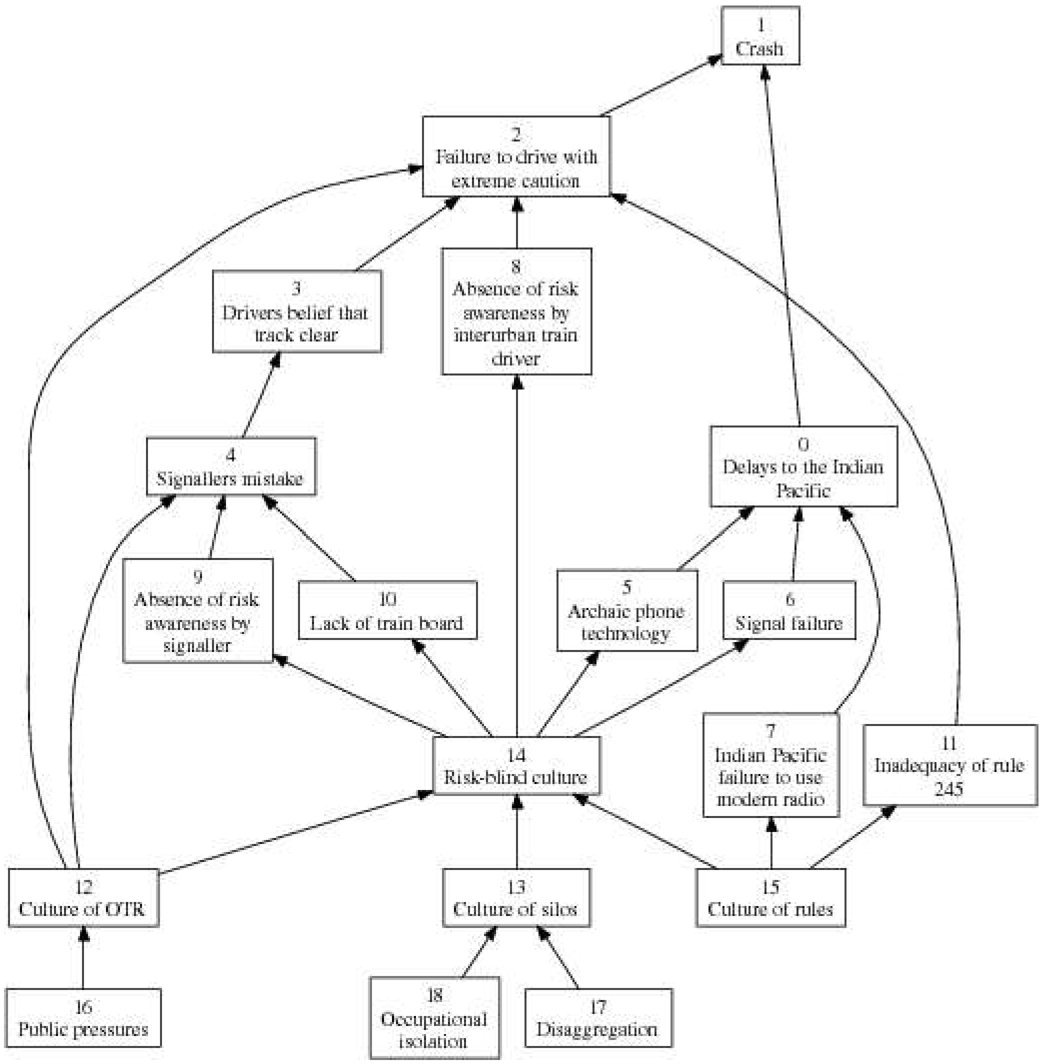

Figure 8: The Glenbrook Accimap According to Ladkin (Ladkin-Accimap)

There are as a consequence of the re-rendered Accimap (which I shall call the *Ladkin-Accimap*) some alterations in the reduction. Since the Ladkin-Accimap has as nodes a subset of the nodes of the WBG-SC-CC, the Reduced Ladkin-Accimap is identical to the Ladkin-Accimap itself: there are no nodes to eliminate and thereby also no further arrows to add to designate paths through eliminated nodes.

The Reduced WBG-SC-CC (which I call the Reduced WBG-SC-CC Version 2) is shown in Figure 9.

The differences in the Reduced Ladkin-Accimap (= Ladkin-Accimap) and the Reduced WBG-SC-CC Version 2 between the causal factors to nodes

- *Interurban train driver proceeded .... omitting... extreme caution*
- *Interurban train driver believed that block was clear*

have been eliminated: the causal connections to these nodes are now identical

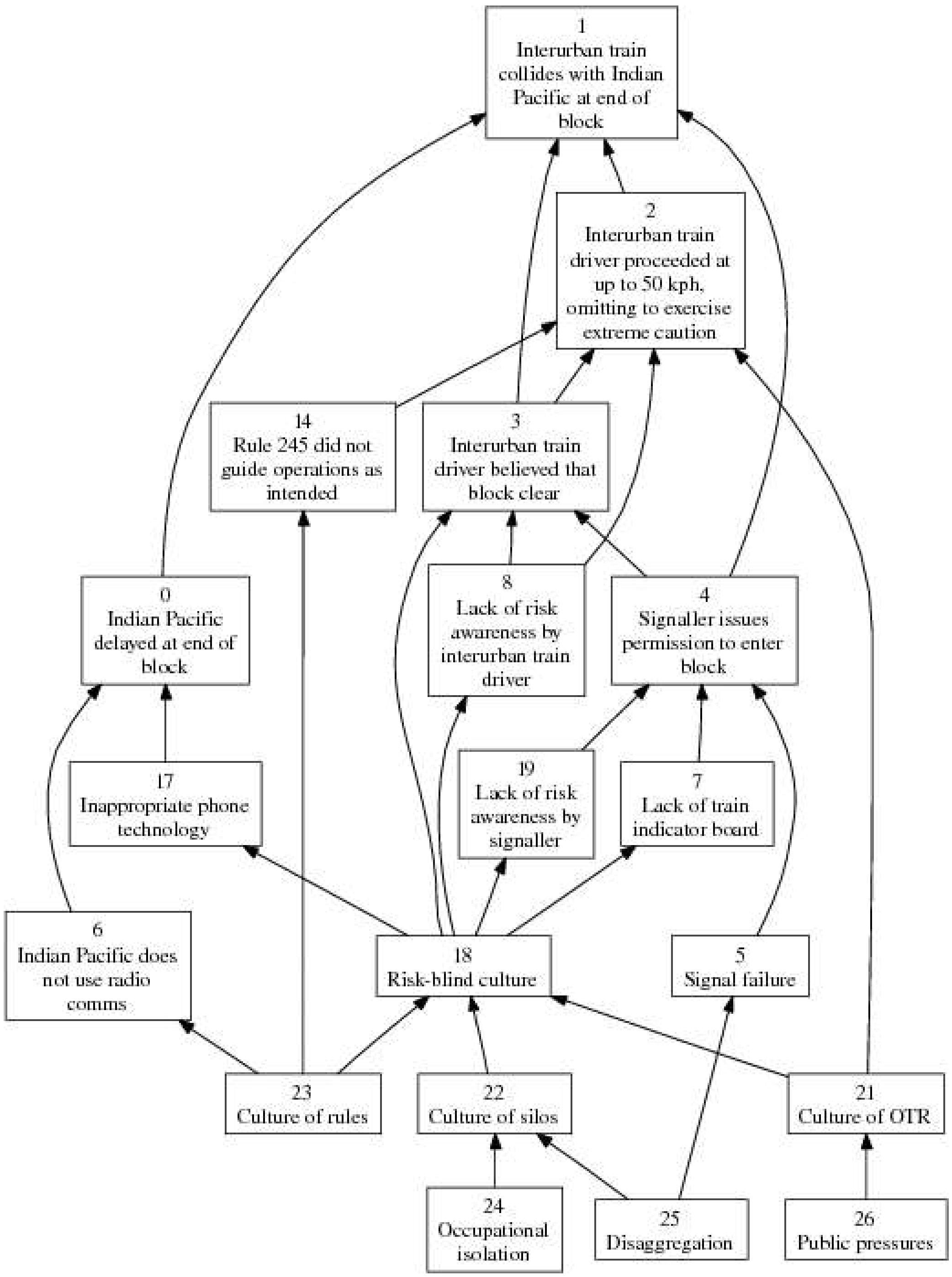

Figure 9: The Reduced WBG-SC-CC Version 2 (to compare with the Ladkin-Accimap)

The differences between the Reduced Ladkin-Accimap and the Reduced WBG-SC-CC Version 2 are:

- *Interurban train collides with Indian Pacific at end of block* has causes
    - *Interurban train driver believes block clear*
        - *Present* in Reduced WBG-SC-CC; *absent* in Reduced Accimap
    - *Signaller issues permission to enter block*
        - *Present* in Reduced WBG-SC-CC; *absent* in Reduced Accimap

- *Signaller issues permission to enter block* has causes
    - *Signal failure*
        - *Present* in Reduced WBG-SC-CC; *absent* in Reduced Accimap
    - *Culture of OTR*
        - *Absent* in Reduced WBG-SC-CC; *present* in Reduced Accimap

- *Indian Pacific delayed at end of block* has cause
    - *Signal failure*
        - *Absent* in Reduced WBG-SC-CC; *present* in Reduced Accimap

- *Signal failure* has cause
    - *Disaggregation*
        - *Present* in Reduced WBG-SC-CC; *absent* in Reduced Accimap
    - *Risk-blind culture*
        - *Absent* in Reduced WBG-SC-CC; *present* in Reduced Accimap

There are 27 edges in the (Reduced =) Ladkin-Accimap and 28 edges in the Reduced WBG-SC-CC Version 2. The graphs are causally very similar. The differences concern judgements of causality of the collision itself, and the causal role of the signal failure.

Summary and Conclusion

We have derived a Why-Because Graph of the Glenbrook accident in a methodical manner, starting with a narrow stopping rule which included personal factors of the operators but left out organisational and cultural factors, and then we added more specific causes to obtain the WBG-SC. The cultural factors and the sources of culture according to the exposition of Hopkins were added to obtain the WBG-SC-CC. I observed that the WBG-SC-CC is visually confused and could profitably be separated into two graphs, the WBG-SC and the Cultural-Causal Graph (CCG) which showed the connections of the cultural causes and their sources with the specific causes, but reduced a path through specific causes to an edge from first specific cause in the path direct to the accident node.

The combination of the WBG-SC and the CCG, along with their methodical derivation, provide the same information provided in the WBG-SC-CC.

We also compared this derivation with the Accimap, using a reduction technique whereby only nodes common to both representations are retained, as well as all paths between retained nodes that were present as paths in the unreduced graphs (this by adding direct edges between retained nodes where there are paths through unretained nodes in the original graph). The original Accimap has 19 nodes; the reduction has 18 nodes. The original Accimap has 25 edges; the Reduced Accimap 24. The WBG-SC-CC has 27 nodes; the reduction of course 18. The WBG-SC-CC has 40 edges; the Reduced WBG-SC-CC has 27.

The reductive comparison eliminated 1 node from the Hopkins Accimap and 9 nodes from the WBG-SC-CC. In the reduced graphs, there were 11 edge differences: 7 edges in the Reduced WBG-SC-CC that there not present in the Reduced Hopkins Accimap, and 4 edges in the Reduced Hopkins Accimap that were not present in the Reduced WBG-SC-CC. The reduced graphs have 20 edges in common: that represents 74% of the edges of the Reduced WBG-SC-CC and 83% of the edges of the Reduced Hopkins Accimap.

However, I had criticised the original Hopkins Accimap in four respects. One of these issues was formal and was resolved through an informal reinterpretation. The other three issues concerned specific causal connections. I redrew the Hopkins Accimap according to this critique to form the Ladkin-Accimap. The Ladkin-Accimap has 19 nodes, and 27 edges.

The Ladkin-Accimap has a node set that is a strict subset of the nodes of the WBG-SC-CC. The Ladkin-Accimap thus remains unchanged during the reductive comparison. The Reduced WBG-SC-CC Version 2 (for comparison with the Ladkin-Accimap) has of course 19 nodes, and 28 edges. There are 7 edge differences between the Ladkin-Accimap and the Reduced WBG-SC-CC Version 2: 4 edges are present in the Reduced WBG-SC-CC Version 2 and absent in the Ladkin-Accimap; 3 edges are present in the Ladkin-Accimap and absent in the Reduced WBG-SC-CC Version 2. These differences stem from two sources:

- The WBG-SC-CC has two necessary causal factors of the collision that the Ladkin-Accimap does not so recognise
- Differences in the causal role of the signal failure

The reduced graphs have 24 edges in common: this represents 86% of the edges of the Reduced WBG-SC-CC Version 2 and 89% of the edges of the Ladkin-Accimap.

I conclude that the methodical construction employed by WBA yields greater precision in determining causal factors by the Counterfactual Test than does the informal approach of the Accimap. They do, however, lead to closely similar results on the causal relations between the factors that they identify in common, when corrected for differing judgements about the facts of the matter (the Ladkin-Accimap), having between 85% and 90% of the causal judgements in common.

One might conclude from this comparison that a causal error rate of 10-15% is to be expected when informal causal comparisons and judgements are made upon the same facts and factors. However, it would be premature to generalise from one example alone.