Heinrich's Local Rationality: Shouldn't 'New View' Thinkers Ask Why Things Made Sense To *Him*?

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Heinrich's Local Rationality: Shouldn't 'New View' Thinkers Ask Why Things Made Sense To *Him*?

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Abstract

Herbert William Heinrich is one of the most influential pioneers within safety. His concepts, originally from the late 1920s, influence safety practice and theory, even today. In recent years, Heinrich's legacy received increasing critique, also from contemporary safety authors that generally are counted among the 'new view'. The objective of this thesis is to explore how 'new view' thinkers/authors discuss Heinrich and whether they apply the approaches they advocate to Heinrich's work.

This thesis starts by offering a biographical study of Heinrich and an overview of his work, which establishes a timeline and the context necessary to put Heinrich's work into perspective. This background analysis also touches on Heinrich's influences, how his work developed and how his work is cited. This part of the thesis meant literally archaeological research, uncovering more of Heinrich's work than has been available/accessible to safety science before and through this it presents a unique collection of resources that give a richer picture of both the person Heinrich, and his work.

The thesis then turns to a characterization of the 'new view' and a selection of authors to work with. It is reviewed how these 'new view' authors discuss Heinrich and his work. It shows that 'new view' authors discussing Heinrich rarely employ 'new view' approaches. Seldom do they seek deep explanations or explore alternatives. Mostly they take a position and discuss things from that point of view. In addition, they bring forward claims and attributions with regard to Heinrich that are not substantiated and are open for questions when studying Heinrich's work properly instead of cherry picking.

The discussion suggests that substantial critique is only one element in the 'new view' discussion of Heinrich's work. The normative and judgemental language also serves as a pedagogical device. In addition, the increasing 'new view' critique of Heinrich can be seen a part of establishing a new movement that needed something to contrast its message to as a tool of persuasion. In the way of classical storytelling, the 'new hero' needed some 'villain' to overcome in order to make the message looking better.

This illustrates that critique of 'old' safety theories and approaches contains substance as well as ethical implications. When we offer critique, we have a choice of what story we want to tell - just as is the case with accident investigations. Critique does not only serve scientific purposes, or to propose better/alternative approaches. The discourse of this critique can also serve other goals, for example ideological purposes, or even be a way to market a product to sell.

As an alternative analysis, the thesis offers an attempt to recreate Heinrich's local rationality regarding three topics and explores why it made sense to him to subtitle his book 'A Scientific Approach', to offer a linear model and focus on direct causes, and to discuss 'real' and 'true' causes. This exercise shows that, just as they give us a better and richer understanding of accidents and organisational events, 'new view' approaches prove to be useful for the analysis of texts. Looking for the local rationality of an author suspends judgement and contributes to a better and deeper understanding.

The thesis concludes by suggesting some areas for further study.

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I think we should all thank Jesse Bird who took the effort to painstakingly document Heinrich's work and life and create a rich - but regrettably unpublished - source of information on one of safety's pioneers. It is sad that Jesse, who passed away in February 2010, cannot witness this, but I am glad that I can present some of Jesse's work to a wider audience.

Paul Swuste and Coen van Gulijk in helping me to get hold of some of Heinrich's and Lateiner's papers and doing some of the groundwork with their series of historical papers on which I could build.

Of course, I also need to thank countless safety professionals (fellow nerds) that have engaged in discussions on Heinrich, which helped to shape and improve my thinking on the subject. I am sure that I will forget some, but let me at least mention Phil La Duke, Todd Conklin, Alan Quilley, Robert Long, Scott Gesinger, Craig Marriott, Nick Gardener, Daniel Hummerdal, Martijn Flinterman, Frank Guldenmund, Jos Villevoye (great quote), Ron Gantt (discussing prediction), J-C Le Coze (models, visuals and much more), Richard Cook (no reports!), Roel van Winsen (discourse and stuff), David van Valkenburg (FRAM and H), Dave Rebbitt (pyramids!), Jean Pariès (more pyramids), Jim Nyce (for introducing me to some other Hartford intellectuals), and Walter Zwaard (I am so sorry that our awesome book on risk is delayed, but doing this thesis was actually worth it).

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Obviously, the other major dedication is to my lovely wife, Annemarije, who has been super supportive and wouldn't even mind that PhD…

L22, February 2019

Foreword

Like many other Safety Professionals, I was raised and educated with many of Heinrich's metaphors and ideas. During my early years at the workshop, I even conducted some incident investigations where I placed causes and events in various stages of the dominos. I never believed that it was a purely linear five-step sequence; it was just a very practical way of thinking about events and ordering elements in some kind of a logical and branching sequence.

Fast forward, about a decade. At some point, I decided that I should work on a proper professional library, and quickly acquired books by people like James Reason (both *Human Error* and *Managing The Risks of Organisational Accidents*), Charles Perrow and a few others. I also decided that I had to own one of the founding texts of the profession and dashed out a decent amount of cash for two different versions (1941 and 1980) of *Industrial Accident Prevention*.

While I read the other books more or less as soon as they arrived, it would take some five years before I finally turned to Heinrich's work. Annoyed by the fact that many safety professionals discussed his work without ever having read it, I decided that I was not going to fall in that trap. In a way, this marked the beginning of my journey as a 'safety mythologist', even though I was not aware of it then. It also sparked my curiosity. Why did Heinrich choose to look at certain things the way he did while they did not make sense to *me*. His 'fixation' on 'direct causes' was one of the things that I would have loved to ask him about.

Working on this thesis now finally provided me with an opportunity to do exactly that. Not asking him in person, of course, but trying to deduce[1] answers from his writings and the historical context. The thesis work proved to be an at times fascinating archaeological quest that evoked a "Yes!!" feeling whenever another small piece of the Heinrich puzzle(s) came to light or I learned surprising things. Who would have thought that Heinrich has written management books besides his safety classic? Or the fascinating archaeology into Heinrich's influences - providing greater insight into the foundations of our profession.

Sometimes, the thesis work also evoked mixed feelings; going from enthusiasm about great insights a long time ago to being appalled by things like the original dominos with ancestry. Also, it makes me sad how much negative impact things like the 88% ratio and unlucky and wrong readings of the triangle have had. This leaves me conflicted in my study of Heinrich. He fascinates me and has done great stuff for the profession, but he has also written some stuff that leaves me sad...

I count myself in the 'new view' camp, and it would probably be a much easier choice to just dismiss this 'old stuff'. However, as I argue later on, I refuse to close my eyes for the positive possibilities of traditional approaches. Partly out of respect, but also because some of these thoughts still have some value, be it in practical work, or as a device to learn from (possibly as an example how *not* to do things).

The conflict works both ways, by the way. Take for example Robert Long's style of discussing Heinrich, which is hardly uplifting. Still, in his uncompromising - and therefore not always constructive - way, he contributes a lot to safety. I admire that as much as I respect Heinrich's earlier contributions.

Any which way, this has been a truly inspiring intellectual challenge that made me think and rethink concepts and ideas several times. I hope that others also learn something from reading this thesis - and enjoy it with at least a fraction of the fun I had writing it.

"In death as in life Heinrich stimulated discussion." (Jesse Bird, 1976)

[1] Or is it rather induce? Sherlock Holmes talks about deduction, so I will leave it here. This is the foreword, after all, and there is less need for scientifically correct terms here!

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1 Introduction

H.W. Heinrich has been of great importance for safety practice and theory. Dwyer pinpoints Heinrich's book, *Industrial Accident Prevention*, as the start of safety as "an academic and a practical discipline" (Dwyer, 1992, p.266). As we will see later in this thesis, this assessment is open for discussion. More correct and reasonable is probably Fred Manuele's statement from his seminal book *On The Practice Of Safety*, "H.W. Heinrich has had more influence on the practice of safety than any other author. Heinrich's premises have been adopted by many as certainty. They permeate the safety literature." (Manuele, 2013, p.57).

In recent years, Heinrich's legacy received increasing critique, also from contemporary safety authors that generally are counted among the 'new view'. However, few authors seem to engage with Heinrich's work properly and systematically. Many authors and safety professionals rather revert to an extreme position by either unquestioning accepting and echoing Heinrich's ideas (or a contemporary derivate) or dismissing them entirely - with rather little middle ground. This thesis aims to rectify some of that, by diving deep into Heinrich's work and viewing it in combination with the more progressive contemporary thinking in safety.

1.1 Thesis question

The objective of this thesis is to explore how 'new view' thinkers/authors discuss Heinrich and whether they apply the approaches they advocate to Heinrich's work. The hypothesis is that 'new view' thinkers actually use 'old view' analyses of Heinrich's work, instead of exploring why things made sense to Heinrich, which is one of the fundamental 'new view' questions.

This led to the following main research questions: *How do 'new view' thinkers discuss Heinrich's work? And, what was Heinrich's local rationality: why did things make sense to him at the time?*

In order to answer this research question, the thesis will explore a number of sub-questions:

- Who was Heinrich, and what did he do?
- How do 'new view' authors discuss Heinrich?
- Why does it make sense to them to do so?
- How did Heinrich discuss subjects?
- Why did it make sense to Heinrich to discuss a number of subjects the way he did?[2]

1.2 A quick guide to this thesis

Chapter 1 introduced the research question with a number of sub-question to explore the subject. Chapter 2 discusses the method used and limitations of this thesis. Chapter 3 introduces Heinrich's life and some of the main themes of his work. This includes a brief review of Heinrich's legacy and how safety literature references Heinrich. Chapter 4 takes us fast forward over half a century and looks into the 'new view', selecting literature to use in the analysis. Chapter 5 takes a closer look at the analysis of Heinrich by 'new view' authors. Chapter 6 selects three topics from Heinrich's legacy and asks the question "why did it make sense to him?". Since we cannot ask Heinrich directly, I will form some hypotheses and try to find the answer within his work. Chapter 7 ties things together in a conclusion and concludes with suggestions for ways forward. Several appendices give insight into the 'raw' material for this thesis.

[2] The premise is, in line with the 'new view', that Heinrich came to work to do a good job and if it did not make sense to him, he most likely would not have written these things. Given some changes over the year, after a while some things apparently did not make sense to him anymore. Which, of course, is what progress are all about.

2 Method

2.1 Research methods

This thesis builds on various literature reviews of:

- Heinrich's work,
- Safety literature that 'defines' the 'new view',
- Selected 'new view' literature,
- Background literature, including other 'old' safety literature, literature on discourse and influence, and the like.

To find as many relevant documents as possible by selected 'new view' authors, various searches were done in databases like Scopus. Search tools were used to find literature referencing Heinrich, or subjects discussed by Heinrich. Part of this was also some bibliographic research to explore how much and in what way safety literature cites Heinrich. Chapter 4.3 describes the selection of 'new view' authors for this study.

Since Heinrich's books have been out of print for many years, and hardly any of his papers are available through the common academic databases, some 'archaeology' was involved in order to collect as much information as possible from various archives, (online) sources and newspapers. This 'archaeology' was partly expanded to finding literature that Heinrich mentions in his bibliographies, and also other 'ancient' safety literature that may have influenced Heinrich's work or can serve as an illustration for the state of the profession during the early twentieth century.

Heinrich's ideas have been around for over eight decades, and one may wonder about reasons for their longevity. I attempted to find some answers for this through studying a limited amount of literature about 'selling' and 'persuasion'.

The available literature was studied critically and systematically, drawing on thematic coding and hermeneutics. While studying Heinrich's work critically, common themes emerged which then were grouped into themes as presented in chapter 3.3. The analysis was also inspired by literature on discourse (Howarth, 2000; Potter & Wetherell, 1987) and literature on studying history (Kjeldstadli, 1999).

Part of the analysis will be conducted using 'new view' principles and methods for investigation. As the title of this thesis indicates, the concept of local rationality will be used as an analytical framework to try to find an answer on why Heinrich wrote about certain subjects the way he did. Local rationality as a concept is explained in the next sub-chapter and will re-appear in Chapters 4 to 6.

In my analysis, I will first present the analysis done by 'new view' authors and judge this by their own concepts, trying to find out whether their analysis of Heinrich's is the 'new' or the 'old' way. The 'new view' references to Heinrich will be reviewed through the analytical lenses of both the 'old' and the 'new view'. Thereafter, I will offer a 'new view' analysis of a few selected topics from Heinrich's work, trying to understand his local rationality.

Attention to context is essential in 'new view' analysis. Therefore, I will present Heinrich's biography in quite some detail, and explore as much of Heinrich's work as possible. To better understand why Heinrich's writings made sense to him, I will review other early 20th Century safety literature. This will enable me to establish a timeline and the context necessary to put Heinrich's work into perspective.

It is important to note that the 'new view' is about *understanding organisational failure* and not necessarily about *understanding safety literature*. I still think it is an interesting exercise to take up some of the work of 'new view' authors and judge it on their standards.

2.2 Local rationality

The concept of 'local rationality' will appear in several chapters throughout the thesis and be used as the main tool of analysis in Chapter 6. As part of the methods-chapter, I will explain some of the backgrounds of 'local rationality'.

The concept draws on Herbert Simon's concept of 'bounded rationality'. Simon (1969) explained that information in situations exceeds by far our ability to process it. We have limited (sensory) means to gather information. We have limited knowledge and memory. Due to our limited resources to process information, we have to make decisions within these limitations. Humans can never be fully rational; at best, their rationality is 'bounded'.

Others have elaborated on these thoughts. Allison's (1971) analysis of the Cuban Missile Crisis shows that a 'rational' perspective is insufficient to understand everything that happened, but by employing different perspectives (in Allison's case he added a bureaucratic and political perspective), one gets a better understanding of the bounded rationality of involved actors.

Turner (1971; 1978) applied the concept to organisations, posing that organisations 'bind' the rationality of the people in them - both individuals and groups, for example by setting boundaries through limiting the acceptable choices for a decision. Groups can form what Turner (1978) calls a "bounded decision zone": a zone with shared bounded rationality defined by a common set of perceptions and decision premises. An organisation can have many different bounded decision zone within its hierarchy.

The school of naturalistic decision making (e.g. Klein, 1999) studied how experts make decisions with limited knowledge, under stressful circumstances, time pressure and with restrained resources. Gigerenzer (2007) discussed how gut feelings, intuitions and heuristics without involvement of formal logic (i.e. 'full rationality') are often a pathway to success. Gladwell's bestseller *Blink* (2005) can be seen as a pop-science version of this work.

In all variations on the concept since Simon coined it, there is an assumption that 'full rationality' exists. It just eludes humans. In his discussion of the evolution of bounded rationality, Dekker (2017c) notes that at some point the term 'local rationality' (Woods et al., 1994) was introduced to explicitly make clear that,

> "The agent not only does not need perfect rationality; it can never achieve it. It locally senses its inputs and notes its outputs (actions), inducing regularities that hold in its environment. What these agents do is locally rational - assessments and actions make sense given the agent's active goals, current knowledge and focus of attention." (Dekker, 2017c, p.556)

One of the best ways of describing local rationality may be a thought attributed to Jens Rasmussen:

> "As Jens Rasmussen is purported to have said "If you don't understand why it made sense for people to do what they did, it is not because they were behaving really strangely, bizarrely, or erroneously, It is because your perspective is wrong." We need to understand what was going on in the world of those involved and see through their eyes at the time of the incident." (Long, I., 2018, p.4)

Local rationality is discussed by various 'new view' authors (e.g. Dekker, 2002; 2014a; 2017c; Woods, et al, 2010). A central assumption for local rationality is that people tend to come to work to do a good job (Dekker, 2003, p.214), not to create an incident or hurt themselves, or others. Dekker says in the *Field Guide* that local rationality is "what people do makes sense to them at the time - given their goals, attentional focus and knowledge - otherwise they wouldn't do it." (Dekker, 2014a, p.6) Often, readers and analysts apply *their* rationality to a situation. This rationality has the benefit of hindsight, full overview of relevant factors, and plenty of time to analyse and reflect. All too often "behaviour is contrasted against the investigator's reality, not the reality surrounding the behaviour in question at the time" (Dekker, 2002, p.377), which we for the purpose of this study can paraphrase to 'statements and texts are contrasted

against the analyst's reality, not the reality surrounding the author who wrote the text in question at the time'.

Taking that 'outside' perspective may present the observer some things that make no sense to *them*. These things will get an entirely different meaning once one tries to take the 'inside' perspective, which includes all the constraints and goals that people in the situation at the time experienced. Normative judgements lose their value with this perspective, because,

> "The point of a New View 'human error' investigation is not to say where people went wrong (that much is easy). The point is to understand why they thought they were doing things right; why it made sense to them at the time" (Dekker, 2014a, p.7)

In Chapter 6, I will try to apply some of these thoughts about local rationality to some topics we find in Heinrich's writings that *we* may perceive as strange, bizarre, or erroneous, but possibly were entirely sensible to *him*. I will do so by exploring questions that inform us about what could have been his local rationality:

- What was his knowledge at the time?
- What were his objectives?
- What outside factors affected him?
- What was the context he acted (wrote) in?

2.3 Limitations

Doing literature-based research, and especially when studying 'ancient' literature, brings a number of implicit limitations that one has to acknowledge. Besides these, in order to keep the scope and material, depth and width within what is appropriate for an MSc-thesis, there have to be some additional limitations, which means that it is partly ETTOing[3] all the way through.

2.3.1 Limitation 1: The lenses of today, part 1

During a recent discussion[4], Jean-Christophe Le Coze remarked, "history is always seen through the lenses of today". This creates challenges when reading literature from past generations. We may encounter archaic language, or not fully understand the implication of certain words and expressions. Words may look familiar to us, but they may have had somewhat different meanings at the time. The text may describe processes and conventions that are unknown to us, and in general, we will lack much of the context (social, cultural, political, economic, technical, etc.)[5]. Also, we risk to assign contemporary meaning and understanding to the words and phrases we read[6].

This means that this thesis sets out for an almost paradoxical quest of evaluating safety related texts critically against what we know these days and the current state of the art while at the same time trying not to judge against today's standards, both scientifically and with regard to the language chosen. Additionally, we should look out with the aim to identify elements that may be relevant even today, or in the future.

Reading with an open mind can be difficult, because I bear with me already a lot of professional (and cultural, social and other) bias, of course. Especially since I have been in numerous pro/contra Heinrich discussions before. It is important to try to read *what he actually did write*, not what I have heard about it, or what I imagine he wrote.

[3] ETTO = Efficiency Thoroughness Trade-Off (Hollnagel, 2009)
[4] 1 May 2018, Learning Lab "A critical View on Safety Culture" at Utrecht.
[5] One good example, relevant for this thesis, is how hard it is to understand for us what role insurance companies played in safety at the time, and how and why they did so. Most have experiences with insurance companies, and seeing them in a (partly) humanitarian role may just be hard to imagine.
[6] See some of the other limitations below, and also in Chapter 6 where we will discuss this to some degree.

2.3.2 Limitation 2: Heinrich's work

In order to limit the workload, this thesis concentrates on Heinrich's work up until the second edition of his book *Industrial Accident Prevention* (1941)[7]. This covers about two and a half decades of his professional life. The period includes what may be regarded as the most interesting period of his work, including his 'formative' years, the creation of many of his main themes, his establishment as an important figure within safety practice and theory, and an interesting change in thinking/writing from the first to the second edition of his best-known book. This limitation does exclude, on the other hand, important other periods of his life and work, like his involvement in the war, and post-war efforts, and a period of his life when he to an even greater degree focused on management.

The depth of the discussion of Heinrich's work will also be limited. This thesis only allows for superficially reviewing his work and main themes (see chapters 3.2 and 3.3), and discusses only some elements in-depth.

2.3.3 Limitation 3: Was Heinrich right?

Many people would surely like a conclusive answer to that question. This thesis is not an appraisal of Heinrich's work as such. The aim of this thesis is not to look into whether certain ideas or theories (like the much-criticized triangle) are right or wrong. Neither is there any intent to defend Heinrich or his work. One of the prime objectives of this study is to look at why things may have made sense to him - based upon the hypotheses and the available material - and present a *second story*[8] (Woods, et al., 2010).

2.3.4 Limitation 4: 'New view' critique

This thesis only allows selection of a few topics instead of doing a full review of *all* 'new view' critique. Although there will be comments on it, in-depth discussions about the triangle are kept outside the scope of this thesis. This subject warrants a wider study worth a thesis of its own. In Chapter 6, three subjects/themes are selected for a discussion of why they may have made sense to Heinrich.

The thesis will discuss critique from non-'new view' authors, as for example Manuele and Petersen, only in passing and not in-depth.

2.3.5 Limitation 5: Post-Heinrich developments

This thesis may mention, but will not discuss in-depth developments of Heinrich's ideas by people like Frank E. Bird (dominos, triangle, and costs), Dan Petersen (axioms), or Tom Krause (SIF - a recent spin-off from the triangle). Neither will there be a study how unnamed trainers, educators and practitioners may have twisted and altered concepts in their communication and practice. It is likely that these developments have affected 'new view' thinkers, but it is hard to assess in what way without a major study - if it is possible at all. This thesis, therefore, takes 'new view' critique and contrasts this to Heinrich's original words, even though we must acknowledge that some distortion in-between will have played a role[9].

[7] With some glimpses from later work, if necessary.

[8] Talking about first and second stories is a way to view accidents and other events. "First stories, biased by knowledge of outcome, are overly simplified accounts of the apparent 'cause' of the undesired outcome." (Woods, et al., 2010, p.24) This thesis is not about understanding organisational events, but about analysing safety texts. We will use the line of thinking of first and second (or multiple) accounts as one guide in our search to understand the texts, because "When you pursue second stories, the system starts to look very different", and "Through these deeper insights learning occurs and he process of improvement begins." (Woods, et al., 2010, p.242)

[9] Some of this distortion is addressed in Chapter 5.

2.3.6 Limitation 6: Standing in Heinrich's shoes

We must also ask ourselves if we actually can determine why things made sense to Heinrich. By trying to get into his shoes, studying his work closely and trying to suspend judgement we may come some way. We must not forget, however, that just as we cannot interview a pilot who became one of the fatal victims of a plane crash, we cannot ask Heinrich in person what he thought when he wrote what he wrote[10]. So, as with the plane, we have to rely on the 'black boxes' left behind and what we can learn from the context - fragmentary and incomplete as this may be, decades after.

I will try to compensate for this limitation as much as possible in an attempt to get a better - or at least less superficial - picture of the man and his work, by reading as much of Heinrich's writings as possible (several times over) and systematically annotating[11] them. And also by reading about him in newspapers and by studying his biography, and some of his influences and contemporaries in the hope that this will give a better picture of him as a person.

2.3.7 Limitation 7: The lenses of today, part 2

A final pitfall is to attribute today's insights to Heinrich. There is a possibility that with my 2018 knowledge and filters, I may construct or read things into Heinrich's writing that Heinrich did not intend or understand in that way at all.

For example, when I read "Individuals have hobbies and pet aversions which often lead them (conscientiously enough, but mistakenly) to emphasize unnecessarily the importance of specific hazards" (Heinrich, 1931a, p.258), I may interpret this as Heinrich talking about risk perception (Slovic, 1987). It seems that he understood the concept, but did not know the term[12].

Another example is, when Heinrich notes "…the use of severity as a measure can accomplish no more than frequency and has the disadvantage of overemphasizing the injury instead of the real objective…" (Heinrich, 1931a, p.260) that he talks about outcome bias, but most likely that term was not even coined at the time.

Several other of these 'insights' can be found throughout Heinrich's work, and we have to be cautious concluding to what this means to us or him.

Now, to quote the man, "…it is time to stop talking, roll up the sleeves, and *go to work*." (Heinrich, 1931a, p.268, emphasis in original)

[10] Even that would be assuming that he were able to answer that question. Maybe all we would get is a mere hindsight rationalisation…

[11] You can find summaries and discussions of each of the papers on https://luce.instructure.com/eportfolios/7/The_Books. In due time they will most likely be transferred to another site and can be found through http://www.mindtherisk.com/component/tags/tag/6-heinrich.

[12] Heinrich hardly ever spoke about risk, and certainly not in this context, but also that is a subject outside the scope of this thesis. Risk only entered occupational safety and health discourse after the Second World War (Swuste et al., 2019) - although DeBlois (1926) already spends a chapter on probability.

3 H.W. Heinrich: Who was he, and what did he do?

Herbert William Heinrich's influence on safety has been enormous (Petersen, 1971; Manuele, 2013), but surprisingly little information about him is around. These days, a first source to check for anyone with a cursory interest might be Wikipedia. There are only a few Wikipedia pages[13] - all with limited information. Only a few safety scholars have written about him as a person, notably Manuele (2002; 2013) and a Dutch team around Swuste and Van Gulijk (2009; 2010; 2013; 2014), even though not extensively so. A lot has been written about his concepts, however, often without paying attention to the backgrounds.

This lack of information[14] has led some to speculate sometimes wildly. De Groot (2005) makes him a psychologist, La Duke (2014) a statistician, and Long (2012) calls him repeatedly an "insurance salesman". Marriott comes close by "insurance industry researcher, who reviewed thousands of workplace accidents in order to determine their likelihood of occurrence to support actuarial calculations" (Marriott, 2018, p.23). Even the well-researched Dutch team of scholars around Van Gulijk and Swuste somewhat miss the point by calling him a "former military working in insurance" (van Gulijk, Swuste, Ale & Zwaard, 2009, p.80)

So, who was Heinrich, and what did he do?

3.1 A short biography

Note: unless otherwise indicated, this section builds on information from the unpublished Heinrich biographies by former Travelers Insurance employees Jesse Bird and William Lischeid (Bird, 1976; Lischeid & Bird, 2008).

Herbert William Heinrich was born 6 October 1886[15] in Pownal, a little town in Bennington County, Vermont, United States. Pownal is located in the utter south-west of the state, bordering both Massachusetts in the south and New York state in the west. Herbert William was the fifth child to woodcarver Rudolph Carl Heinrich and his wife Minna Rosamond Kortum, who emigrated from Germany to the United States in 1879[16].

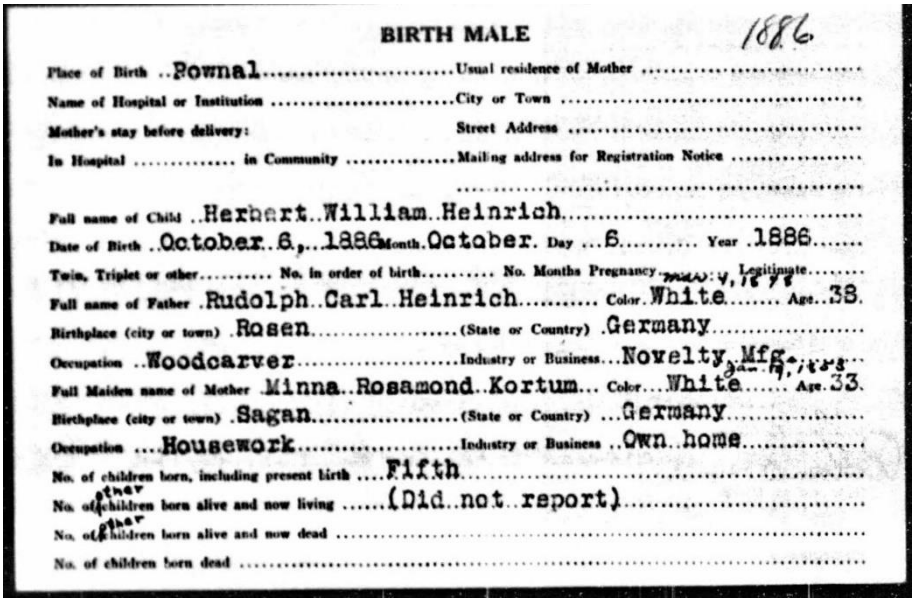
Like all children, young Herbert William went to grammar school, but after completion of the sixth grade, he started working in local quarries and woodworking shops. Heinrich's unofficial biographer Jesse Bird comments on this sparse education:

> "Looking back now from 1976, the six years in school appears quite scant. However, a review of the biographies of the founders of the industrial empires of the 1800s in the United States will reveal that a fourth grade education was adequate for a frugal, risk taking, self-controlled person to become a business tycoon or inventor. Heinrich was burdened with two years of excess education if all he desired was to be a commercial success". (Bird, 1976, p.28)

Heinrich started an apprenticeship in the machinist trade at American Tool & Machine Company in South Boston, MA. By 1901, he was a machinist, learning elements of tool making and design of electrical appliances. Two years later, he went to sea. The first years, in the engineering department of a steamship

[13] I checked 29 April 2019 - there were English, German, Dutch, Italian, Portuguese, Arabic, Korean and Japanese wiki-pages. The Japanese redirected to 'Heinrich's Law' rather than being biographical. For a long time, also the English page was more of a summary of Manuele's 2002 book than a proper page about Heinrich.
[14] And likely lack of effort to research properly, maybe even rhetoric.
[15] There was some confusion on the date of birth when I started this research. Some sources claimed 1886, while others (including Manuele) listed 1881. Heinrich's biographer Jesse Bird insisted on 1881, based on a remark by Heinrich's close associate Edward Granniss that the year of birth in the obituary was wrong and Heinrich was much older. Some research on ancestry.com, however, produced a number of official documents (including the 1900 census) that all list 1886 as the year of birth. My warmest thanks go also to Bill Lischeid who made the effort to take a ride to Fairview Cemetery in Hartford to check Heinrich's headstone, and confirm 1886 as the 'official' date.
[16] According to the 1900 census, found on ancestry.com. The census mentions 'pipefitter' as the father's occupation and two older brothers, Carl R. (* August 1877) and Oscar R. (* December 1883). Nothing on the two other siblings, however.

sailing on the Far East. During this time, he passed the third Assistant Engineer's examination for an Unlimited License - Ocean Steamers in 1904. Most likely, Heinrich acquired during his time at sea knowledge of mechanical engineering and thermodynamic principles, which would be beneficial in his later work.



BIRTH MALE 1886

Place of Birth ..Pownal..... Usual residence of Mother .....
Name of Hospital or Institution ..... City or Town .....
Mother's stay before delivery: Street Address .....
In Hospital ..... in Community ..... Mailing address for Registration Notice .....

Full name of Child ..Herbert..William..Heinrich.....
Date of Birth ..October..6,..1886 Month..October. Day ...6..... Year .1886.....
Twin, Triplet or other..... No. in order of birth..... No. Months Pregnancy..... Legitimate.....
Full name of Father .Rudolph..Carl..Heinrich..... Color..White..... Age..38.
Birthplace (city or town) .Rosen.....(State or Country) .Germany.....
Occupation ..Woodcarver.....Industry or Business...Novelty Mfg.....
Full Maiden name of Mother .Minna..Rosamond..Kortum... Color...White..... Age..33.
Birthplace (city or town) .Sagan.....(State or Country) ...Germany.....
Occupation ....Housework.....Industry or Business ..Own..home.....
No. of children born, including present birth ....Fifth.....
No. of other children born alive and now living .....(Did..not..report).....
No. of other children born alive and now dead .....
No. of children born dead .....

Figure 1: H.W. Heinrich's birth certificate, issued October 1940 by the Town of Pownal, VT. (source: the Vermont, Vital Records, 1720-1908, via ancenstry.com)

In 1906, he worked for the US Navy as a civilian employee as a machinist in the repair, maintenance and inspection of ships and equipment on Mare Island, California. He would stick to this job for a couple of years with assignments in Manila in the Philippines and in Honolulu[17].

After this, he worked briefly for General Electric Co., in West Lynn, MA and then moving to Hartford, CT to work as a machinist for Arrow Electric Co. Here he met George E. Peterson, who was the assistant superintendent of the plant. In 1912, Heinrich moved briefly to Jersey City for a job at the Manhattan Electric Supply Co. only to return to Arrow Electric shortly after.

Peterson left Arrow in 1911 to start working for The Travelers Insurance in the Engineering and Inspection Division. He persuaded Heinrich to join The Travelers as well. Heinrich applied and started his first position there as a boiler and industrial plant inspector on 1 January 1913. Incidentally, later the same year another significant event for occupational safety happened. As a consequence of decades of campaigns by organised labour, the United States Department of Labor[18] was established as a Cabinet-level Department by President William Howard Taft. Taft signed the bill on the last day of his presidency, 4 March 1913. William B. Wilson was appointed as the first Secretary of Labor on the next day by new President Woodrow Wilson.

The Travelers Insurance Co. was chartered in 1863. Before they actually started business, their President James G. Batterson verbally insured banker James Bolter in the sum of $5.000 against death if due to an accident occurring while Mr. Bolter walked from the Hartford Post Office to his residence in the same city, for the amount of two cents. This was the first ever accident insurance in the USA. One week later, on 1 April 1864, Travelers Insurance Co. formally opened for business. (Malcolm-Smith, 1964)

The Travelers was one of the major insurance companies when Heinrich joined them. In 1904, they were the first company in the USA to organize a professional corps of safety engineers. By 1915, there were 339

[17] During to the Bedford Stone Club Safety Talk (Heinrich, 1923b), he told an anecdote from the couple of months that he spent in Honolulu, Hawaii, in 1908.
[18] https://www.dol.gov/general/aboutdol/history

people in the Engineering and Inspection Division, of which 203 were field inspectors and 90 were Home Office professional staff.

Figure 2: H.W. Heinrich joins Engineering and Inspection Service (source: Travelers Standard, May 1913)

The Travelers Insurance Co. had a history of publishing safety related books[19], including the works *Grinding Wheels* (1912), *Accident Prevention on the Farm* (1914), *A Treatise on Safety Engineering as Applied to Scaffolds* (1915), *Safe Foundry Practice* (1920), *Safety in Building Construction* (1921 and 1927), *Coal Mining Hazards* (1916), *Airplanes and Safety* (1921), *Motor Vehicles and Safety* (1915), *Safety in Moving Picture Theatres* (1914), *Safety In the Machine Shop* (1920), *First Aid to the Injured* (1927), and booklets directed to foremen and employees as well as one about *Organization in Safety Work*. Besides these books and brochures, they issued regular publications, notably The Travelers Protection and The Travelers Standard. Especially the latter, a monthly publication of the Engineering & Inspection Division for the benefit of policyholders, contained many quality articles on safety.

Heinrich was assigned to the home office staff for six months, mentored by Dr. Allan Risteen. Risteen was a renowned safety scientist and chemist of the time who lectured at universities. He edited the chemistry sections of Century Dictionary and Encyclopaedia Americana, and initiated the Travelers Standard in 1912. During those first six months of training, Heinrich's task was to 'scrutinize' reports. This meant reviewing reports and recommendations of inspectors, adding improvements and writing a letter to the insured.

After several months, Heinrich was transferred to Boston to take the Massachusetts Boiler Inspector examination and to inspect for all lines of insurance. As a bachelor, Heinrich had to travel quite a lot between various offices in New England and New York. In 1917, he was promoted to Senior Inspector and stationed at the Albany office. Meanwhile, World War I had arrived, and also Heinrich was drafted.

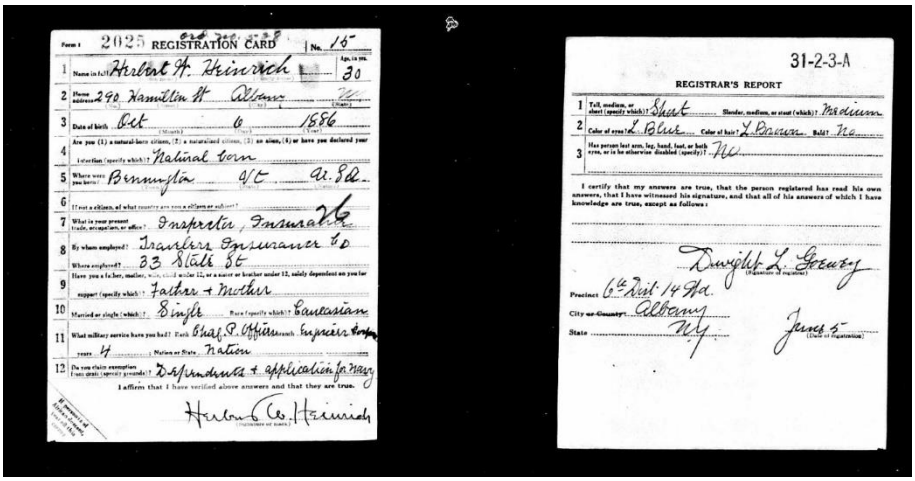


Figure 3: World War I draft registration card (Ancestry.com. U.S., World War I Draft Registration Cards, 1917-1918 [database on-line])

[19] Many of these can be read online via archive.org or catalog.hathitrust.org.

First, he enrolled in the U.S. Naval Reserve as a Junior Lieutenant. It was not before the final months of the War that he was called into active duty. From August 1918 on, he served as engineering officer aboard a ship that transported troops and war supplies. Meanwhile, Heinrich passed the examination for chief engineer on ocean going steam vessels, unlimited tonnage.

Discharge from the Navy came in April 1919 with the rank of Senior Lieutenant. He spent his first month as a civilian in New York City. With several thousand dollars in his pocket, he tried himself on stock market speculation. Successfully, because he made a profit of over 100.000 US Dollar in the first two weeks. This success did not last, however, and in the course of the next month all profits along with most of his original capital was lost.

Heinrich re-joined The Travelers in June 1919. He was promoted to take charge of the newly formed Indemnity Section of the Engineering & Inspection Division. As part of his work, Heinrich prepared and edited numerous articles for Protection and The Standard[20]. He also wrote speeches and started speaking at association and chamber of commerce meetings and courses. Also in not quite job-related matters, Heinrich was an avid speaker. Jesse Bird mentions that Heinrich loved to tell ghost stories at the employee club of The Travelers.

In early 1923, Heinrich presented a speech at the Welding Conference in New York City. This speech appeared as a paper, *Welded Joints in Unfired Pressure Vessels* (Heinrich, 1923a), in The Travelers Standard. This paper is probably the first published work by Heinrich. It is interesting to note that Heinrich would return to these engineering roots after his retirement when he worked with the Uniform Boiler & Pressure Vessel Society.

Later that year, in November, Heinrich presented a safety talk[21] at the Bedford Stone Club (Heinrich, 1923b). This speech contained the first ever mention by Heinrich of one of his main themes, namely the 'indirect' or 'hidden' costs of accidents.

Around this time, Heinrich married Viola V. King, born 29 June 1901 in Philadelphia[22]. The couple lived in East Hartford and on 27 January 1924, their first and only child, Virginia Ruth, was born.

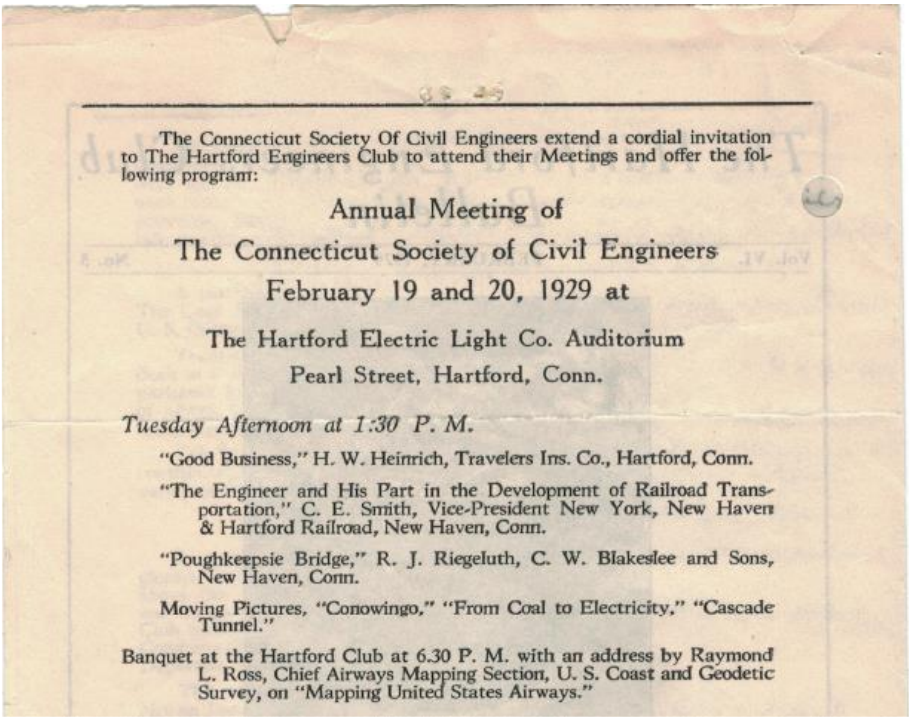
Heinrich was promoted to Assistant Superintendent of the Engineering and Inspection Division in 1925. At the end of that year, during the New York State Safety Congress at Syracuse, N.Y. on 2 December 1925, he for the first time mentions research into hidden costs of accidents and an approximate 1:4 ratio. The 'hidden cost' principle was to become an important driver for safety[23] - and a recurring theme in many of Heinrich's writings. The research continued and was presented more fully in a number of papers about the "Incidental Cost of Accidents" (Heinrich, 1926; 1927a; 1927b; 1927c).

The hidden cost idea - although not particularly new because others had written about it before - gained quite some interest 1928. The magazine Popular Science Monthly (September 1928, p.56[24]) had an item on it, and news items in newspapers over the whole country mentioned Heinrich and his work. According to Aldrich (1997, p.357) the *Incidental Cost* paper was reprinted nine times in 1927 and 1928.

[20] So far, none of these has been located, and maybe they never will. Most articles in Protection were not credited to their authors.
[21] The first safety speech in the available material.
[22] Little information is available about Heinrich's wife (not even their date of marriage!) without engaging in some extensive genealogical research. Her name appears as both Viola V. and Virginia, which gives rise to the assumption that Virginia may have been her middle name which was passed on to the couple's daughter. Her year of birth appears as both 1900 and 1901. Most sources from ancestry.com agree on 1901.
[23] Maybe most popular in the saying "If you think safety is expensive, try an accident" of which Heinrich actually does a variation in his 1925 paper.
[24] Popular Science Monthly (1928) Most Mishaps Avoidable. *Popular Science Monthly*, September 1928, 113 (3), p.56.

Meanwhile, Heinrich led another project by Travelers engineers to study the causes of 75.000 accidents[25]. The first results of this were presented in the *The Origin of Accidents* paper in March 1928 which for the first time presented the (in)famous 88:10:2 ratio[26]. This group of numbers has created many arguments. Jesse Bird notes that they are "poorly understood"[27].

Heinrich's work was highly regarded. The Travelers' Year Book praised the work done by Heinrich and his team - to some dismay of other managers[28], but The Travelers President, Louis Fatio Butler, backed Heinrich's work.



The Connecticut Society Of Civil Engineers extend a cordial invitation to The Hartford Engineers Club to attend their Meetings and offer the following program:

Annual Meeting of
The Connecticut Society of Civil Engineers
February 19 and 20, 1929 at
The Hartford Electric Light Co. Auditorium
Pearl Street, Hartford, Conn.

Tuesday Afternoon at 1:30 P. M.

"Good Business," H. W. Heinrich, Travelers Ins. Co., Hartford, Conn.

"The Engineer and His Part in the Development of Railroad Transportation," C. E. Smith, Vice-President New York, New Haven & Hartford Railroad, New Haven, Conn.

"Poughkeepsie Bridge," R. J. Riegeluth, C. W. Blakeslee and Sons, New Haven, Conn.

Moving Pictures, "Conowingo," "From Coal to Electricity," "Cascade Tunnel."

Banquet at the Hartford Club at 6.30 P. M. with an address by Raymond L. Ross, Chief Airways Mapping Section, U. S. Coast and Geodetic Survey, on "Mapping United States Airways."

Figure 4: Invitation to the Annual Meeting of the Connecticut Society of Civil Engineers in 1929. This is one of many Heinrich-speeches of which no documentation is left. Heinrich spoke on "Good Business" - safety and cost was among his first main themes.

Later in 1929, Heinrich presented another of his main ideas to the world. This continued to build on some of the findings that already had been presented in *The Origin of Accidents*. Titled, *The Foundation of a Major Injury*, the 1:29:300 ratio[29] (a.k.a. the triangle) was presented to the world in Heinrich's presentation before the 12th New York Industrial Safety Congress in Syracuse on 6 December 1928, and papers the month after.

The material from these three papers, *Incidental Cost*, *Origin of Accidents* and *Foundation of a Major Injury* formed an important part of the core for Heinrich's first book, *Industrial Accident Prevention, A Scientific*

[25] Sources do not mention why this project was started. One might speculate that the research into the indirect costs of accidents was so successful that one wanted to continue the approach with something similar. Neither do sources tell whether there is an overlap between the datasets of respectively 5.000 (Heinrich 1926, 1927a, 1927b), 10.000 (Heinrich, 1927c) and 75.000 (e.g. Heinrich, 1928a, 1928b) cases studied by Travelers Engineers.

[26] This ratio postulates that the ratio of direct causes of accidents are - in the words of the 1941 edition of *Industrial Accident Prevention* - 88% attributable to "unsafe acts", 10% "unsafe conditions" and 2% unpreventable (often labelled, 'acts of God'. See also Chapter 3.3.4.

[27] Bird does not elaborate why. Most likely because they tend to be taken at face value without looking further what Heinrich said on the matter.

[28] Ironically, it seems partly over an issue of safety promotion versus getting business…

[29] This ratio tells us that there are many more no-injury accidents than accidents with minor injuries and major injuries. The work of Travelers safety engineers found an average ratio of 300 to 29 to 1. More about this in Chapter 3.3.5.

Approach that was published through McGraw-Hill in 1931[30]. He dedicated the book to the late Butler who had been extremely supportive, but never saw the book since had passed away in October 1929. Jesse Bird suggests that while Heinrich is credited as the sole author, it was very much a collaboration with the academically educated Edward Granniss, who worked with Heinrich at The Travelers from 1925 to 1935. Granniss did supply, and is credited for, the first two appendices of the 1941 edition of *Industrial Accident Prevention*, and he would be credited as co-author for the fourth edition (1959).

There was a heavy speech schedule. Apparently, Heinrich had become some kind of a celebrity within safety circles. On 2 November 1932, he spoke at Maine's Fifth Annual Industrial Safety Conference in the House of Representatives, State Capitol Building in Augusta, Maine. The Industrial Safety Bulletin of the Maine Department of Labor and Industry spoke in glowing terms:

> "The famous H.W. Heinrich, Asst. Supt., Travelers Insurance Company, next offered his paper 'Mastery of the Machine', an exposition many had travelled a hundred miles to hear." (Maine Department of Labor and Industry, 1932a, p.4)

None of the other speakers, not even the very governor of Maine who opened the conference, was spoken about in such superlatives. One wonders whether Heinrich's presence even was one reason for a 30% increased attendance compared to the year before - despite depression times.

When J.L. Thompson, the Superintendent of the Engineering and Inspection Division retired in 1932, Vice President R.J. Sullivan took over direct control of the Engineering Division and all its activities. Heinrich requested to become Superintendent the next year, but Sullivan refused, finding Heinrich not suitable for the job. Instead, James A. Burbank was appointed Superintendent in 1934.

Heinrich realised he was 'frozen' in his position for the remainder of his work career at The Travelers. This sense of being 'frozen' in his position must have irked, especially given his 'celebrity status' outside his own organisation. This may be one partial reason for Heinrich being even more prolific from that point on. He was not the only one that was dissatisfied. Some personnel with top qualifications resigned, including Edward Granniss, who became an industrial staff engineer for the National Safety Council and in 1939 the Director of the Industrial Engineering Division of the Association of Casualty and Surety Companies, and Ralph Crosby, who went to Marsh & McLennan and became a lecturer at New York University.

In December 1933, Heinrich was appointed to direct the safety work in Connecticut State as the Safety Director of CWA, the program to put unemployed to work. The Travelers had loaned services out to CWA[31]. Somewhere in this period, the Heinrich family moved from 827 Burnside Avenue in East Hartford to 24 Castlewood Road in West Hartford where Heinrich would live until his death.

Later in 1934, The Travelers published the six-page accident sequence brochure, for the first time presenting one of Heinrich's most iconic ideas: the domino model. The brochure was based on a speech presented before the Down River Section of the Detroit Safety Council, 30 November 1934. Heinrich went on tour to present the domino accident sequence to the entire Engineering & Inspection Division field staff.

Heinrich was elected chairman of the subcommittee of the The American Society of Mechanical Engineers (ASME) to study and prepare an improved accident cause code. The result, baptized the 'Heinrich cause code' was published in 1937:

> "The underlying philosophy of this method of analysis is that industrial accidents are due to unsafe conditions and unsafe practices, which, if eliminated, would prevent a repetition of the same or similar type of accident. The effort therefore is to enable the statistician to identify and select the

[30] Interestingly, there had been a book titled *Industrial Accident Prevention* before, written by David Beyer and published in 1916. We will discuss this briefly in Chapter 6.
[31] Hartford Courant, 31 December 1933.

> unsafe factors and then present the data to safety engineers for guidance in accident prevention." (Kossoris, 1939, p.526)

Aldrich notes that the cause code "proved cumbersome" (Aldrich, 1997, p.152[32]), but Kossoris was quite positive after a year of use:

> "In this way statistics and statistical analysis are not merely compilations of questionable historical value, but vital tools towards a socially and economically desirable end-the prevention of accidents in industry." (Kossoris, 1939, p.532)

Much of Heinrich's time was filled visiting field offices to ensure the quality of inspectors and instruct them. Around this time, Heinrich joined his former colleagues Crosby and Granniss as lecturer at New York State University, teaching safety to post and undergraduate students for many years to come. He also taught at e.g. John Hopkins and spoke on occasions such as the Congress of the National Safety Council.

War preparations had started and industrial activity increased. The government realised the importance of safety to ensure efficient productivity and called upon 'big names' in safety, including Heinrich, Granniss and Crosby. The importance of safe and efficient work necessary for war preparations was reflected in Heinrich's publications from this period.

In 1941, the updated second edition of *Industrial Accident Prevention* was published, for the first time presenting the dominos, axioms of safety and the 1:29:300 presented in a proper triangle shape. The book became a textbook on various universities across the country[33], and abroad.

When the United States entered the war against Germany and Japan in late 1941, Heinrich came in even higher demand. Edward Granniss had been placed in charge of all safety activities of the U.S. Army with the rank of Colonel. Granniss went directly to the President of Travelers Insurance and asked for Heinrich's services. This was granted. In a letter to Jesse Bird[34], Granniss comments that the Travelers gave Heinrich a premium-free insurance policy for covering him while he was in Granniss' service: "There were a couple of times while we were in the European theater I thought Virginia might appreciate it".

In World War II, Heinrich took up several positions, including Chairman of the Safety Advisory Committee to the War Department and Chairman of the War Department Safety Council. He also visited several U.S. Army installations together with Granniss.

Foremen were a point of focus for the Department of Labor. They were regarded as 'key men' and thus important for the war efforts. Safety was elementary, and foremen were given courses. Heinrich did a series of speeches and papers on the role of the foreman. He had already paid much attention to the role of management in safety work, and from the early 1940s on, this became his main field of interest. In late 1942, he started working on a book dedicated to first line managers, *Basics Of Supervision*, which was published the next year through the Alfred H. Best Company.

When the war came to an end, Heinrich served on a special committee formed by the Secretary of War to control accident fatalities in Europe. With Granniss, he travelled to Germany for several weeks to assist in the organisation of a program aimed to control risks of booby-traps and mines[35].

After the war, Heinrich stuck to the subject of the role of management and supervisory (safety) education. According to Jesse Bird, he would do this by means of long, detailed and technical talks in which he tried to cover all of his two books.

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[32] Aldrich does not explain why the cause code was "cumbersome", however. Most likely because it brought a greater 'administrative' burden, necessary to get better knowledge about causation, circumstances and other information of statistical and preventive value than previous methods.
[33] Hartford Courant, 2 May 1941.
[34] 7 November 1975
[35] Heinrich would describe his experiences in Europe in an article in the July/August 1945 issue of The Travelers Beacon, and do several presentations about his experiences in the Hartford area.

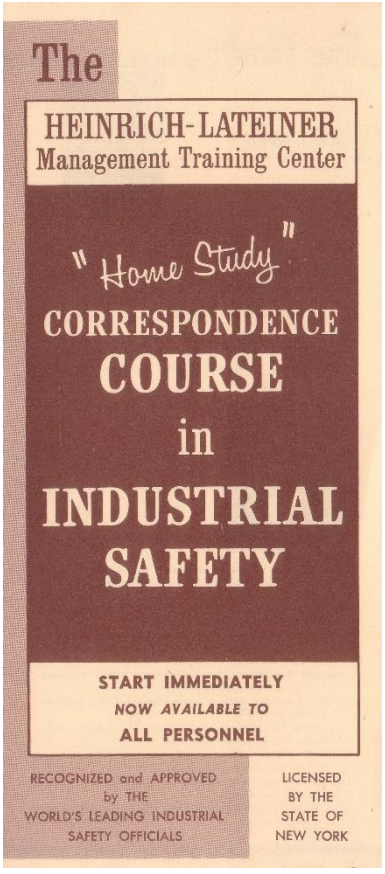
Heinrich and Granniss, who had meanwhile had become manager of the Engineering Department of Eagle Royal, continued to work together. Both were on the Safety Committee of the American Society of Mechanical Engineers that a prepared an ASME standard for the self-evaluation of industrial plants which saw the light of day in 1947. (ASME, 1947)

Since there was a large turnover in the Engineering and Loss Control Division after the war, Heinrich spent much time hiring and training new engineers. Meanwhile he worked on his second management book, *Formula For Supervision*, published by the National Foremen's Institute in 1949. The year after the third, reworked version of *Industrial Accident Prevention* saw the light of day. In addition, Heinrich did a lot of committee work for the American Standards Association (ASA - later renamed to ANSI).

Heinrich kept working on his personal development. In 1951, he took up a one-year night class in French, preparing himself for an assignment for an U.S. airport in French Morocco. He became quite fluent in the language. He also studied a successful preacher in the way he made sermons and presentations. Heinrich learned a great deal from this and from that time on, he did short and concise talks with a limited number of ideas within a 20 minutes timeframe[36].

On a 'negative' note[37], it seems that Heinrich was a heavy consumer of cigarettes. Jesse Bird says:

> "A hallmark of the Heinrich office was the lighted cigarette burning in the ashtray. This continued whether he was in or out of the office for short periods. He admitted to smoking one and a half packs of cigarettes a day and just burning another pack or two. Only two fires occurred in his office[38]. Both were in the old straw waste baskets." (Bird, 1976, p.29)



In 1952, Heinrich visited the construction work in Morocco. That year, he received the Arthur Williams Memorial Medical from the American Museum of Safety in New York, one of the nation's oldest safety organizations, in recognition of "his many and valuable contributions to the cause of safety over a long period of years"[39]. He also received the Medal of the Conservatoire Nationale des Arts et Métiers in Paris. In his speech, Dr. Andre Samont mentioned that Heinrich received the award for his many basic contributions to the science of preventing loss of life and property, and because of the value of the material in his book, that was a standard text in France.

Heinrich led a project on *Effective Work in Accident Prevention*, intended to stimulate engineers to find out how management talks about plant costs, and how engineers can relate accident costs to plant costs that management would understand. All the while, he kept up the routine of doing presentations and visiting field offices.

Heinrich retired from The Travelers on 27 April 1956. Retirement brought a return to his engineering roots when Heinrich became chairman and president of the Uniform Boiler and Pressure Vessel Laws Society[40]. Here he led the compilation of a book during 1957. Besides, he gave lectures on safety-related topics at New York University, which he did until his death.

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[36] Sounds like a proto-TED-talk!
[37] From today's - and my personal - point of view. I admit to slip into a judgemental tone here.
[38] This anecdote arguably supports the triangle…
[39] Hartford Courant, 18 September 1952.
[40] An organization founded in 1915 to promote the uniformity of laws governing the safe construction, installation and operations of steam boilers and pressure vessels in the United States and Canada.

Together with Granniss, Heinrich worked on a revised version of *Industrial Accident Prevention*. Besides he would still regularly appear on conferences for safety speeches. In 1959, the fourth edition of *Industrial Accident Prevention* was published with Granniss credited as co-author. Apparently, the book remained in print for over a decade[41]. In 1980 a fifth edition came out. This was an entirely revised version that was authored by Dan Petersen and Nestor Roos, but still mentioned Heinrich as first author, even though most of the text was not by his hand anymore.

Figure 5: Flyer for the Heinrich - Lateiner correspondence course

During the 1950s and 1960s, Heinrich collaborated with safety consultant Alfred R. Lateiner. Lateiner made some trips to Europe because Heinrich's age did not allow these travels any more. There, Lateiner taught the 'Lateiner Method', which was heavily influenced by Heinrich's work. Heinrich and Lateiner also launched a correspondence course under the umbrella of The Heinrich-Lateiner Management Training Center during the early 1960s, and started working on a book together. Heinrich managed to finish his part for about 80% before he passed away. Lateiner finished and edited the manuscript for the 1969 publication of *Management and Controlling Employee Performance*. This was actually a combination of two books, *Management* by Lateiner and *Controlling Employee Performance* by Heinrich.

In 1961, Heinrich received the ASSE Fellow designation from the American Society of Safety Engineers[42]. He had been a member of the society since 1924[43].

Heinrich resigned his position with the Uniform Boiler and Pressure Vessel Laws Society on 1 June 1962. Occassionally, he played golf. Henry Elliott, one of Heinrich's golf companions, told Jesse Bird "Heinrich did very well at 70", playing at the 100+ level.

On 22 June 1962, Heinrich died at age 75. He was buried on Fairview Cemetery in lot 443 where he rests with his in-laws, James E. King and Minnie P. Keller who both passed away in 1961. Virginia does not rest with her husband.

Heinrich was awarded several posthumous honours. In 1979, he was induced into the Insurance Hall of Fame[44], and in 1993, Heinrich was the first safety engineer to be included in the Safety and Health Hall of Fame International[45].

Figure 6: Heinrich's headstone at Fairview Cemetery (picture by Bill Lischeid)

[41] Judging from a note in the colophon of my copy that Viola renewed the copyright in 1969.
[42] Recently renamed to ASSP - American Society of Safety Professionals.
[43] According to the foreword of National Safety News, May 1956, which features the Heinrich/Blake debate.
[44] http://www.insurancehalloffame.org/laureateprofile.php?laureate=68
[45] https://www.vetsofsafety.org/shhofi/

3.2 Heinrich's work

3.2.1 A general overview

Heinrich was productive during his five decades of active work within safety. Best known is his classic book, *Industrial Accident Prevention*, which saw four different editions during his lifetime (1931, 1941, 1950 and 1959) and a posthumous update (1980). The book was translated and printed in Japanese, French, and Spanish and is among the most influential books in safety (Li & Hale, 2014).

It is much less known that Heinrich also wrote and published two management books, aimed at supervisors, *Basics of Supervision* (1944) and *Formula for Supervision: Outlining the Application of Supervisory Control to Secure, Safe, Efficient Work Performance* (1949). Posthumously, Alfred Lateiner finished and published a management book that Heinrich had working on before he died. This appeared in 1969 as *Management and Controlling Employee Performance*.

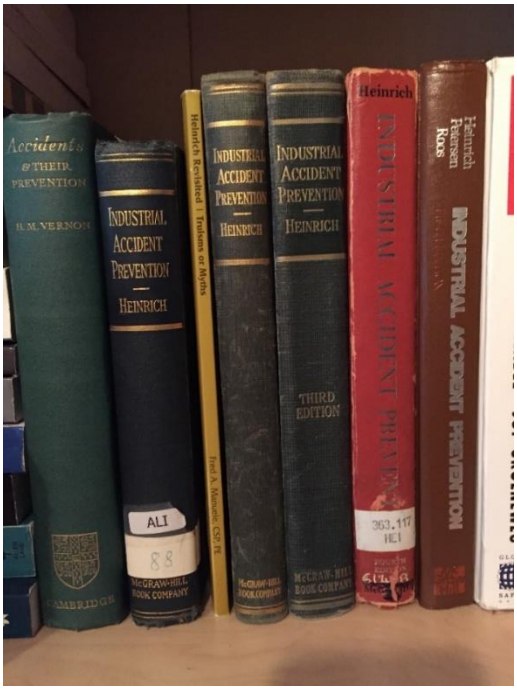

Figure 7: All five editions of Industrial Accident Prevention

He was a member or chairman of various committees, delivering among others the so-called 'Heinrich Cause Code' (1937), the *ASME Standard Form for Use in Self Appraisal of Industrial Plants* (1947), and the book of the Uniform Boiler and Pressure Vessels Laws Society (1957).

Besides this, he wrote over 50 papers[46]. Most of these are very hard to get hold of, so most likely there is more undiscovered Heinrich material somewhere in the archives. Some of his papers are very much alike, and republished in slightly different form in another publication, see the list of references and Appendix 2 to get an impression. Furthermore, he has done hundreds, possibly thousands of safety speeches and lectures at various occasions, including university courses. Only a few of those are still available today in one form or another.

Heinrich's field of work concentrated mostly on industrial (occupational) safety. However, he did not restrict himself to this safety domain[47]. One could mention side steps into what we today would call process safety (gas manufacturing, maintenance, and of course his background was from steam boilers), into traffic and transport safety (after the war, he was chairman of the Traffic and Transportation Committee of the Hartford Chamber of Commerce[48]), and his books contain cases from (occupational) health. Furthermore, one must not forget the fact that he was very much a management consultant and many of his writings and speeches deal with management.

As told in his biography, Heinrich was an avid speaker with a wide area of interests. He also proved to be socially engaged, as is evidenced by newspaper items about Heinrich's ideas about creating work after the Depression[49] and a letter to the editor on the Berlin crisis[50].

[46] Ca. 35 from the period this thesis focuses on.
[47] Neither is the application of some of Heinrich's concepts restricted to occupational safety, see for example Hopkins' (2008) discussion of triangles for occupational and process safety.
[48] Hartford Courant, 9 August 1946.
[49] Hartford Courant, 23 November 1932.
[50] Hartford Courant, 11 July 1948.

3.2.2 Developments and changes

When studying Heinrich's work, one is able to see how several ideas develop through his speeches and papers before they end up in his books where they are presented to a wider audience. These developments concern things as (seemingly) simple as wording. Heinrich varies several times between "incidental costs", "hidden costs" and "indirect costs" to mention just one example (e.g. Heinrich, 1926; 1927a; 1930c; 1931a). Also, subjects and themes get a more or less prominent place in the various versions of the book. For example, the sections about cost or accident proneness are moved around from version to version.

Besides these more 'cosmetic' or 'editorial' changes, Heinrich also alters the contents, description, presentation and explanation of some of his themes. Sometimes significantly. As an example, one could take the 'origin of accidents' chart (see Figure 9, in chapter 3.3.4). This changes significantly from its initial conception (Heinrich, 1928a/b) to the 1941 edition of *Industrial Accident Prevention*, and after. One of the changes that stands out is that Heinrich initially attributes 88% of accidents to causes of a "supervisory nature" (e.g. Heinrich, 1928b, p.124), while these 88% have changed to "unsafe acts of persons" a decade later (Heinrich, 1941, p.19).

Another significant example is how the triangle evolved from the early 'blocky' figure (Heinrich, 1929a/b; 1931a) to the much slicker drawing in later versions of the book (see Figure 10). More importantly, however, the descriptions around the triangle change between versions of *Industrial Accident Prevention* (Manuele, 2002). This also applies to how principles and axioms change through Heinrich's work.

It should not be surprising that subjects and themes change over four versions of a book with about a decade in-between versions. After all, the world changes, knowledge evolves, and insights are rejected and new ones gained. As Manuele points out, however, Heinrich does not offer explanations for these changes (Manuele, 2002).

One of the most striking changes in Heinrich's work is probably from the 1931 to the 1941 version of *Industrial Accident Prevention*. The second version of the book appears to have a greater focus on the human, as stressed by the domino sequence[51] and the changed wording in the 'origin of accidents' figure. As mentioned above, in the 1931 version of *Industrial Accident Prevention*, Heinrich attributes 88% of accidents to causes of a supervisory nature; in 1941, they are due to "unsafe acts of persons".

Heinrich states in the introduction that no fundamental changes are made to fundamental items. He says,

> "Changes have been made in the revised text for the purpose of achieving greater consistency, clarity, and improved arrangement… In no way however, has there been any alteration of the fundamentals on which the original publication was conceived." (Heinrich, 1941, p.v/vi)

One can of course debate what is "fundamental". Moving from "supervisory" to "man failure" may feel like a rather fundamental thing. It is important to realise that also in the 1941 version of *Industrial Accident Prevention* there still is a strong stress on the role and responsibility of management, and the importance of other actions than supervision and enforcement. However, the message remembered by most is the focus on the human at the sharp end, because of the renewed 88:10:2 ratio, which now distinguishes between unsafe acts and unsafe conditions, and the dominos, which in Heinrich's version are very much about the human.

However, in the text of the 1931 version, Heinrich already talked much about "man failure". Many of the 'causes' mentioned in the 'origin of accidents' figure were after all rather attributable to 'man' than directly to supervisory. Therefore, it is likely that Heinrich thought it was best to streamline this and rather present only direct or proximate causes. Supervisory causes would be of a more underlying nature, after all. This

[51] Regarding developments, the dominos is bit of an outlier. One sees a development of the accident sequence through a number of papers in the early 1930s, until the metaphor and description appear all of a sudden in a final form in 1934. Then Heinrich does not make a single mention until the 1941 book where the dominos feature most prominently and will not change until Alfred Lateiner's and Frank E. Bird's dominos in the 1950s and 1960s.

may be what he means by "greater consistency". In addition, we can draw on some of the papers written in-between the two versions of the book. This is not the place to explore this change between versions for full, but the contents of several papers can help to partly explain the differences. Notably *Mastery of Machine* (Heinrich, 1933c), in which he stresses that machines are not at fault, it is the people who make and use them, appears to be one of the key-papers in his work that suggests reasons for changes in direction.

Many other changes between versions of the book are harder to explain, however. Still, it may be understandable that Heinrich (or his editors) chose not to do extensive explanations in the new versions of the book. With a decade between the versions, chances are that this would only be confusing for 'new' readers and rather distract than contribute.

3.2.3 'Best of' or original work?

Heinrich is often credited for the ideas that he presented in his books. Looking into the safety literature of the early twentieth century, however, reveals that most of the ideas that Heinrich presented were in fact already there and discussed by other authors. Stone's review of the first edition of the book notes this:

> "Students familiar with the best current literature and practice in the field will find little that is new in this treatise. It does, however, bring together in convenient, manual form the best current thought on the subject" (Stone, 1931, p.324)[52]

This thesis does not allow for an in-depth study of Heinrich's influences, but as examples of safety thinking that probably has influenced his thinking and writing, one could mention the work on costs by Hubbard (1921), and Lange's discussion of "intangible" costs of accidents (Lange, 1926, p.8)[53]. The idea that most accidents are caused by men was quite common. Cowee (1916) for example suggests that 60% of all accidents can be prevented by education. Another influence are the thoughts on phases of an accident that appeared previously in DeBlois' (1926) work. Heinrich would develop this further in both the triangle and the dominos. DeBlois (1926) also stresses management responsibility as an essential factor, suggests indirect cost of accidents being much greater than direct costs, and advocates "appropriate technique of accident prevention based on sound principles" (DeBlois, 1926, p.32).

Other examples, however, are much more uncertain, and may be sheer coincidence. For example, we can see some parallels between Richardson's brief article on minor accidents and near misses in the September 1916 issue of *Safety Engineering* and Heinrich's writings on the triangle.

It is also important to note that Heinrich's speeches and papers of the 1920s and 1930s clearly indicate that the work was conducted by engineers of The Travelers Engineering and Inspection Division (under his supervision and leadership), and that many of the ideas already appeared in Travelers publications from the 1920s. Heinrich thus collected work done by Travelers engineers and presented it to a much larger audience through his books.

The conclusion that it was not all Heinrich's original thought is not a surprising one. We should not try to find ideas in the minds of people, but study discursive regularities (Howarth, 2000). Taking the perspective that ideas emerge rather than pop up like the well-known cartoon lightbulb, it makes sense to regard *Industrial Accident Prevention* mostly as a 'best of' compilation of safety theory and practice of that moment.

While the ideas often may have been around for a while, before Heinrich gathered them and wrote them down, he did make some very important contributions. Firstly, as one can see through the various papers, he managed to present them in language adjusted to his audience. Secondly, he coupled the ideas to some

[52] Also Aldrich says that Heinrich "summarizes much early work and was the most influential of the early writers" (Aldrich, 1997, p.395). Ironically, apart from the odd academic and safety historian, hardly anyone today has heard of Lange, Van Schaak, Vernon or DeBlois, although their books are quite insightful. Almost everyone in safety has heard about Heinrich, however. This suggests that Stigler's Law of Eponymy has some truth in it.
[53] Even Beyer (1916) already discusses "incidental costs".

highly memorable metaphors, visual representations, models, and ratios (Aldrich, 1997; van Gulijk et al., 2009); "…because of their simplicity, metaphors have strong persuasive power…" (Swuste, et al., 2014, p.16) Thirdly, he illustrated and explained the ideas with lots of analogies and examples, which enhanced understanding and anchoring of the message. Fourth, as Stone noted above, he combined the various elements in a framework that was manageable. Petersen agreed with this view many years later:

> "Perhaps it was because Heinrich proposed a philosophy for safety that his work was so important. Before the publication of his book, safety had no organized framework of thinking. It had been a hodgepodge of ideas. Heinrich brought them all together and defined some excellent principles out of previous uncertain practices." (Petersen, 1971, p.11)

Finally, Heinrich was an optimist. He was convinced that with knowledge of causes and will to act, it would be possible to prevent accidents. His optimism shines even more through the continuous tone of encouraging "this is simple" and "you can do this" statements that one can find through his work, mostly directed towards managers: "…the fundamentals of successful accident prevention are simple. They are readily and inexpensively applied." (Heinrich, 1932a, p.28). Also, Heinrich put great trust in technology. Much progress had been made, he argued, but "Still greater accomplishments will be forthcoming, moreover, because the surface of practical possibilities has merely been scratched". (1931a, p.249; 1941, p.267). In 1934, he even wrote a paper titled *Safety Wins a Place in the Sun* in which he discussed "progress of startling significance" (Heinrich, 1934, p.112), and he was optimistic for the future of safety: "…there is progress and a constantly broadening vision" (Heinrich, 1940, p.118).

3.3 Main themes

Heinrich's work deals with a wide range of topics related to safety management and accident prevention. Reading his work, one can however identify some recurring subjects and ideas, which one may consider main themes in Heinrich's work. For the purpose of this thesis, I will use the following criteria to identify them. Heinrich's main themes are subjects or ideas that:

- stand out when reading his work,
- return frequently throughout his writing,
- are subjects he considers important (as indicated by the way he stresses or repeats them),
- have had (major) influence on safety science and practice.

This thesis is not the first to look at Heinrich's work this way. For example, Swuste, Van Gulijk and Zwaard (2013) suggest six main themes, which they label 'Models and Metaphors':

1. Hidden costs of accidents,
2. Accident cause analysis, including the 88:10:2 ratio,
3. Foundation of major injuries, including the triangle,
4. Accident process in dominos,
5. The foreman, and
6. Scientific underpinning.

This list feels somewhat incomplete. Some themes are missing; others are presented narrower than they should. For example, Heinrich discusses the role of management much broader than merely the foreman - notwithstanding the key role that Heinrich assigns to these people. Also, 'hidden cost' is merely one - yet the most memorable and frequently communicated - subject related to the economic side of safety.

Based on thorough study of the available material[54], I will use an extended list of the following nine main themes:

[54] See Appendix 2 for a detailed overview of how these themes appear in the various sources up to 1941.

1. Scientific approach
2. Cost and efficiency
3. Causation and accident sequence
4. The role of workers[55]
5. Triangle and reacting on weak signals
6. Role of management
7. Axioms of safety
8. Professionalization of safety
9. Practical accident prevention

Note that this categorization is not a strict taxonomy, but rather a practical division into themes. These sometimes can be somewhat overlapping and related. One example for this overlap is the 'origin of accidents' chart that contains a number of ideas, including the division into the duality of unsafe acts and unsafe conditions (using the terminology from the 1941 book), and the 88:10:2 ratio. While both are about causes, the former is mostly related to causation and the accident sequence (and actually a part of it). The latter is mostly about the predominance of man failure and therefore connected to the 'role of workers' theme.

Below I will briefly discuss the nine main themes.

3.3.1 Main theme 1: Scientific approach

Not a single paper has 'science' as the main topic, but the sub-title of *Industrial Accident Prevention*, and the frequent mentioning of 'scientific'/fact-based principles warrant an inclusion in the list of main themes. Often the scientific approach is connected to either the role of management or the professionalization of safety (main themes 6 and 8, respectively), or both. For example when stressing the need for a fact-based approach, improved knowledge or arguing in favour of better statistics and better use of statistics.

We will look more in-depth into this 'scientific approach' in Chapter 6.1.

3.3.2 Main theme 2: Cost and efficiency

This subject features prominently in Heinrich's early work (mentioned as early as 1923 and in all of the early papers/speeches) and opens the 1931 book with an entire chapter dedicated to the subject. As other main themes develop and gain prominence, costs move a bit to the back (compare the place in the 1931 and 1941 versions of the book), but never fully disappear.

Best known in this main theme is probably the 1:4 ratio of direct to incidental/indirect/hidden[56] costs. By this, he meant secondary, non-insurable losses, in addition to direct liability claims and medical costs: "the costs of accidents, other than as represented by compensation, liability, and medical payments, is by far the greater expense." (Heinrich, 1926, p.245) Importantly, however, the theme also includes the argument that accident prevention is "good business" (Heinrich, 1931a, p.16), and that safety and efficiency go together.

To Heinrich the monetary approach to safety was an additional, powerful incentive for employers (and the State) to engage in safety work, in addition to humanitarian aspects: "a powerful stimulus to preventive action" (Heinrich, 1931a, p.17). It seems that this economic angle has had an important impact on safety work and the acceptance of safety by many managers as something to prioritize.

[55] Naming this theme appropriately proved quite a struggle. Large part is about 'man failure' and 'unsafe acts', but naming it so would be too limiting because it envelops much more than that. Labelling the theme 'human factor' would cover the subject quite nicely, but would use a term that Heinrich probably would not use or recognise. In the end, 'role of the workers' seems to fit with most of the elements and contrasts and complements well the 'role of management' theme.

[56] As said above, Heinrich experimented with the term.

3.3.3 Main theme 3: Causation and accident sequence

Heinrich was convinced that knowledge of causes is central in order to find effective actions: "it is the cause of the accident that we must know in order to effect a remedy". (Heinrich, 1928b, p.122) In many of his earlier papers, one finds critique of the assignment of 'causes' at the time. He stressed the importance of seeing the different stages in an accident. To separate between causes, the accident and the consequences (injury).

> "Above all, however, if we assume (as it seems proper to do) that the chief purpose of analysis is to furnish a clue to accident prevention, it is vital to know the *cause* of the *accident* itself as distinguished from the cause of the *injury*…" (Heinrich, 1928b, p.122/123, emphasis in original)

The early sequence of cause(s), accident and injury (e.g. Heinrich, 1928b) was developed over a number of papers gradually expanding to a sequence of events of which the unsafe acts and unsafe conditions ("mechanical or physical hazards") were essential elements. In 1934, this sequence became the dominos[57].

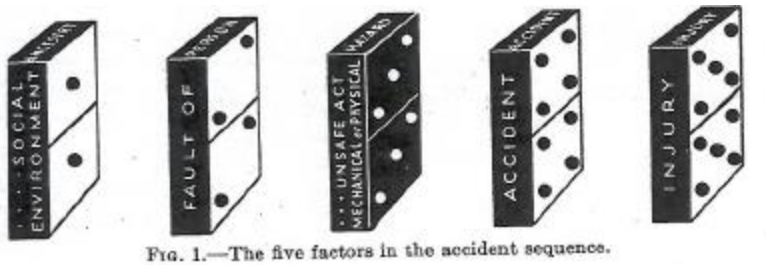

FIG. 1.—The five factors in the accident sequence.

Figure 8: The domino sequence (Heinrich, 1941, p.13)

Heinrich's focus was on proximate and direct causes. That does not mean that he advocated single causation, even though the language and phrasing may suggest this at times. He acknowledges underlying causes (e.g. Heinrich, 1941, p.109), but as we will discuss in Chapter 6.2, he saw no need to always go in-depth.

Heinrich spends much space in his books on explaining better ways to do "accident cause analysis" (1931a, Chapter III) and "fact finding" (1941, Chapter IV) and he suggests improved cause categories.

3.3.4 Main theme 4: The role of workers

One of the things Heinrich is most widely known for is his attribution of the majority of accidents to man failure. Often forgotten (or not known, or ignored) is that this attribution in the first place relates to *direct* or *proximate* causes - the thing that 'happened' right before an accident.

The 'role of workers' theme envelopes many elements, including the idea that most accidents are attributable to 'unsafe acts' or 'man failure' (in particular Heinrich's domino sequence is very much focused on the person). In addition, we find subjects like accident-proneness, safety psychology, fatigue (in the 1941 book) and the influence of age on accidents. Best known within this theme is the 'origin of accidents' chart pictured below, and even more the accompanying 88:10:2 ratio of direct and proximate causes.

[57] While the domino metaphor is a powerful one, and helpful to explain simple linear causation; one point of critique is that the early sequence of phases in an accident is more or less universal, while the dominos appear to be much more specific in their claims about causation and thereby lose much of their general applicability.

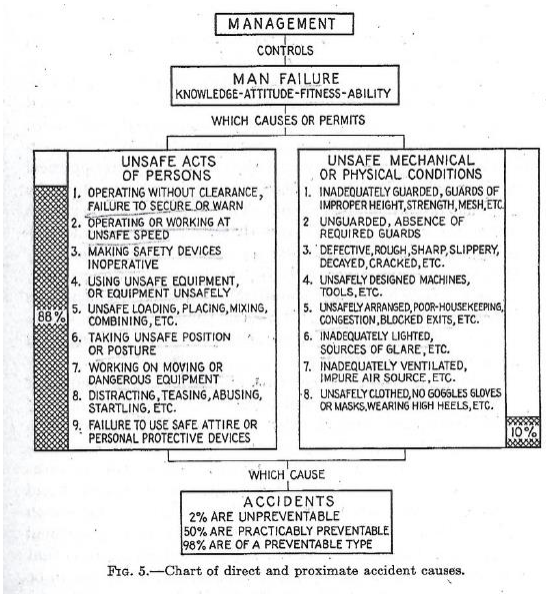

FIG. 5.—Chart of direct and proximate accident causes.

Figure 9: The 'origin of accidents' chart from the second edition of Industrial Accident Prevention (Heinrich, 1941, p.19)

Safety psychology is a subject with dedicated (but short) chapters in the first and second edition of *Industrial Accident Prevention*, but Heinrich does not define clearly what he means by 'safety psychology'. He lends great importance to the subject, however: "Psychology lies at the root of the sequence of accident causes" (Heinrich, 1931a, p.127). The text presents an underlying assumption that there is 'something' inside the human that can be explained and fixed. This 'something' is beyond our reach right now, but may be accessible in the future.

Interestingly, while Heinrich is known for his attribution of accidents to "unsafe acts of persons", and he indeed frequently discusses humans as careless and error-producing beings, he also acknowledges them as an essential positive factor and advises to draw on their strengths:

> "…in many cases safety may be promoted by employing the ingenuity and mechanical genius of workmen in the average plant, in the revision of process and procedure." (Heinrich, 1931a, p.246)

In the opening paragraph of the *Unsafe Habits of Men* paper, he even prefers "…capable, and experienced men who work under unsafe conditions" (Heinrich, 1940, p.112) over "…incapable, and inexperienced men who work under safe conditions" (Heinrich, 1940, p.112). This is almost prototypically 'new view' thinking: resilient people who have the capability to handle variations in uncertain environments.

In contrary to a common belief that connects Heinrich to behaviourist approaches (e.g. Dekker, 2017a), Heinrich did not advocate purely behaviourist actions, aimed at correcting the "unsafe acts". "Guarding and other action of an 'engineering-revision' nature often provide a remedy even for accidents caused chiefly by man-failure…" (Heinrich, 1940, p.112; 1941, p.35) and therefore, "…it is unwise to depend automatically and invariably on educational or supervisory methods…" (Heinrich, 1940, p.112).

3.3.5 Main theme 5: The triangle and reacting on weak signals

One of Heinrich's most iconic - and enduring - metaphors is the safety triangle (alternatively labelled 'pyramid' or 'iceberg', in this thesis I will mostly use 'triangle') which proposes that for any accident with major consequences there is a larger number of accidents with minor consequences and an even larger number of accidents without any consequence at all. He illustrated this with the (in)famous 1:29:300 ratio.

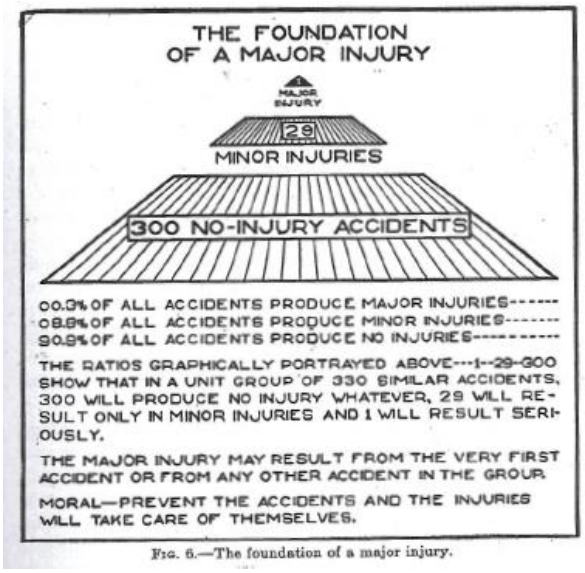

Figure 10: The 1941 version of the triangle (Heinrich, 1941, p.27)

Heinrich relates this clearly to the distinction of causes, accident and consequences that we already saw in the accident sequence. In his view, one should not wait for the accidents with serious consequences, but instead react on what we today would call 'weak signals' (Weick & Sutcliffe, 2001). He said that "we are often misdirecting our efforts and ignoring valuable data" (Heinrich, 1929b, p.9) when we wait for the 'big thing' to happen and only then take action. This thinking also echoes the concept of risk, without using that word: "The importance of any individual accident in prevention work lies in the *potential power* to create injury and not in the fact that it actually does or does not so result". (Heinrich, 1929b, p.10, emphasis added)

This theme shares the following insights:

1. Paying attention to 'small things' increases your knowledge base (frequency may be more important than severity).
2. Potential is more important than actual consequence (a risk based approach).
3. You may prevent serious consequences from happening by reacting on events and conditions with no or minor consequences (a more proactive approach).
4. For the purpose of accident prevention, all events are regarded equally important, regardless their consequences[58].

Heinrich's main message with the triangle is one of *opportunity* and proactivity: handle things while they are still small, do not wait for the (rarer) big ones to act upon. According to him, the triangle is "a splendid opportunity to discover and correct accident-producing conditions long before an injury actually happens" (Heinrich, 1929b, p.10). The critics who focus on the numbers, the research behind it or the confounded applications generally forget this positive and more proactive approach.

3.3.6 Main theme 6: The role of management

Heinrich is widely known for his focus on workers' behaviour, but (top) managers were actually his primary audience (Heinrich, 1931a; 1941)[59]. When people acknowledge that Heinrich 'also' paid attention to management, it is often stressed that he focussed on the foreman/supervisor (Swuste et al., 2013).

[58] Heinrich discusses unwanted events, and calls them all 'accident', regardless their actual outcome. One could take this one step further and view it as a limited, yet prototypical 'new view' argument that success and failure stem from the same source and one should look at things that go right just as much as at things that go wrong. (Hollnagel, 2014b).

[59] A critic may comment that this makes perfect sense. After all, managers will love to hear that the worker's behaviour should change, but that would be ignoring a major part of Heinrich's arguments.

Indeed, these middle/low managers had a lot of his attention, and were the subject of two books and several papers (e.g. Heinrich, 1929d/e; 1930a; 1938a). To state that this was the only group that Heinrich had attention for means that one grossly underestimates the scope of this theme, which contains at least four elements:

1. The role of foremen and supervisors

These people are in close contact with the day-to-day work and employees and were regarded as being in the best position to anticipate and correct 'unsafe behaviour' and physical hazards. In the 1931 version of *Industrial Accident Prevention*, Heinrich attributes 88% of accidents to causes of a supervisory nature, meaning that in his view foremen and supervisors could control most of the accidents.

2. The role of executives and the employer

While workers and foremen may make mistakes and disregard instructions; "*the responsibility lies, first of all with the employer*" (Heinrich, 1931b, p.11, emphasis in original).

> "…it is true that the employee is responsible to a certain extent. The employer, however, must accept the lion's share, because in the final analysis it is he who creates the working conditions, offers employment, selects and assigns workers, and initiates the entire series of events included in industrial operations. Any disclaimer, by management, of responsibility for accident occurrence is specious. It also retards business recover, inasmuch as it leaves and unnecessary expense problem unsolved." (Heinrich, 1933b, p.54/55)

3. Safety (accident prevention) as part of everyday business

In many of his papers, Heinrich stresses that management, production, efficiency, quality assurance and safety build on the same principles and go perfectly together. Methods of most value in accident prevention are analogous with the methods required for the control of the quality, cost, and quantity of production: "it is therefore not only possible to prevent the great majority of accidents, but also to do it by *the exercise of the very methods* that make for *economy, greater production and greater profits*." (Heinrich, 1928b, p.130, emphasis in original)

4. Responsibility (especially of management)

Responsibility is a recurring subject in many publications. "Acceptance of responsibility is a vital factor in industrial leadership" (Heinrich, 1929e, p.23), he wrote in the *Message to the Foremen* papers, which primarily deal with taking responsibility anyway. Also in his books he speaks regularly of "placing responsibility" (Heinrich, 1931a, p.78) and notably the 1941 edition of *Industrial Accident Prevention* contains a complete section in Chapter II, dealing with the responsibilities of various 'players'. Heinrich stresses here the responsibility of management over that of safety engineers and employees.

After the second edition of *Industrial Accident Prevention*, Heinrich would concentrate on management with a series of papers and two books, mostly aimed at supervisors. According to his biographer, Jesse Bird, management was Heinrich's favourite subject (Bird, 1976, p.16).

3.3.7 Main theme 7: Axioms of Safety

The Axioms are 'self-evident truths', statements that need no further explanation and are the basis of something. "The actual work of accident prevention depends, first of all, upon the recognition and knowledge of the fundamental truths involved…" (Heinrich, 1926, p.257). Heinrich's Axioms of Safety do not appear as such until the second edition of *Industrial Accident Prevention*[60]. Still they do deserve to be featured in this list of main themes because they are a central part of Heinrich's work and they provide the

[60] Therefore, one might argue that this main theme is rather under-represented in the literature reviewed for this thesis.

framework for the 1941 book, and later editions. Several authors would later suggest alternate axioms (e.g. Petersen, 2001) or comment on them.

In Heinrich's earlier work, we find the 'principles of scientific accident-prevention' that can be regarded as predecessors of the Axioms. These principles change somewhat between papers, but by and large they can be described as:

1. Executive interest, support and action.
2. Knowledge of accident facts
3. Appropriate and effective action based on these facts.

Already the Bedford Stone Club Safety Talk (Heinrich, 1923b) contains ten "fundamental principles" for successful safety organisation, some of which can be linked to the future axioms while others are more oriented on practical safety management.

The First Axiom, "The occurrence of an injury invariably results from a completed sequence of factors - one factor being the accident itself" (Heinrich, 1941, p.12), is frequently cited in the literature studied for this thesis, often in connection to the dominos.

3.3.8 Main theme 8: Professionalization of safety

"The prevention of accidents is a science, but it is not recognized nor is it treated scientifically today" (Heinrich, 1928b, p.121), Heinrich noted early in his career. Despite the safety movement from the first decades of the century (Aldrich, 1997), and the fact that companies like The Travelers had impressive staffs with safety engineers, in Heinrich's time, safety was in general not seen as a science or as "a separate domain" (Swuste & Sillem, 2018, p.27).

Through his entire career, Heinrich has tried to improve this situation. In most early work, professionalization of safety is more of a side-theme (with some exceptions, like Heinrich, 1932c), but throughout much of his writing, he hinted on it, by suggesting improved use of statistics, knowledge of basic principles, definitions, proper causal analysis and the like. Swuste et al. (2010) note that the publication of reference books like DeBlois's and Heinrich's were a clear contribution to and a sign of professionalization of safety.

In later papers and speeches, Heinrich would be even clearer about the need for the professionalization of safety. In the early/mid-1940s he did speeches and a paper *What makes a Safety Engineer* (Heinrich, 1945), in 1947 he prepared a paper for ASME about *Integrating Safety Engineering in College Curricular*[61], and his final paper for the National Safety Council in October 1956 dealt with *Recognition of Safety as a Profession* (Heinrich, 1956).

3.3.9 Main theme 9: Practical accident prevention

This is a bit of a 'miscellany' category, but an important one, not in the least when one looks at the number of pages spent. For example roughly one quarter of the pages of both the first and second edition of *Industrial Accident Prevention* are dedicated to machine guarding, illustrated with many pictures. Another example is the detailed discussion of illumination in both editions of that book.

Besides concrete safety actions at the sharp end, Heinrich's work also contains many other subjects related to the organisation of safety (management), safety education, process and procedure revision. In the second edition of *Industrial Accident Prevention* this was further widened by adding chapters on for example fatigue, occupational disease and first aid[62]. Through his work, one can even find early suggestions for a hierarchy of controls - preferring for example machine guarding and procedure revision over behavioural controls.

[61] Regrettably, this paper has not yet surfaced.
[62] See Appendix 1 to get an idea of some subjects in a glance.

It is also noteworthy that Heinrich did several sector specific papers, where he adjusted his general message to the specific challenges of sectors like construction (Heinrich, 1925; 1938b), gas manufacturing (Heinrich, 1931d) and small plants (Heinrich, 1932a).

3.4 Heinrich's influence and longevity

Heinrich's work has been extremely influential on safety theory and practice, and its influences last until today. Aldrich attributes the 'success' to "easily remembered ratios" and the fact that there was "something for nearly everyone" (Aldrich, 1997, p.152) in his work, from managers to safety engineers and employees.

> "Heinrich's ideas were a departure from the safety thinking of the time. What he said, however, made sense to people in the field of safety, and his ideas were accepted. They were accepted so completely that even today we largely work within his framework. His work set the stage, in effect, for all safety work since 1931." (Petersen, 1971, p.11)

One reason for Heinrich's lasting influence, contrary to other early safety thinkers/authors, is that he remained active also after World War 2 (van Gulijk, et al., 2009), thereby bringing his thoughts and writings into a new era. Also, he updated some of his work, e.g. by adding a framework for Safety Management. (Heinrich, 1950)

Two of the most iconic metaphors in safety - the dominos and the triangle - are part of his legacy. In terms of recognisability, probably only the Swiss Cheese Model (Reason, 1990; 1997) is in the same league. Heinrich's ratios, models, (visual) metaphors and methods have become part of the 'mainstream' safety curriculum and established safety wisdom/beliefs - not necessarily in the form that Heinrich conceived them or wrote them down because other authors, and practitioners, have adapted and changed them[63]. At this point, we will only briefly mention a few that have been significant.

One of the first to take Heinrich's ideas further, seems to have been Alfred Lateiner who contributed to popularizing Heinrich's models in Europe during the 1950s (Swuste et al., 2010). He changed the descriptions of the dominos somewhat, and it appears he was among the first to call the triangle an iceberg (Van Gulijk et al, 2009).

> "The accident problem is like an iceberg with only one eleventh of its mass visible. The invisible base - made up of no-injury accidents - is ten times greater. We ordinarily look at an accident critically only when it produces an injury. In brief, for every accident we report, investigate, analyse, and record there are 10 that we usually ignore." (Lateiner, 1958, p.14)

Frank E. Bird jr. did a major study during the late 1960s into over 1.500.000 accidents and came up with a new accident ratio of 1:10:30:600, including property damage as the third level of the triangle[64] and making this the central driver for safety work (Bird & Germain, 1966; Bird & Loftus, 1976). Bird - in cooperation with others, notably Germain - updated also Heinrich's other metaphors, drawing the hidden cost ratio as an iceberg, and updating the dominos with more politically correct attributions in the first domino (Bird & Germain, 1992). Given the fact that Bird basically continues with Heinrich's ideas, he does not credit Heinrich as much as he might reasonably be expected to. Bird's work in loss control had major impact on industry and safety thinking, helped by the fact that DNV acquired and used his work.

Another renowned and influential American safety scholar, Dan Petersen, drew much on Heinrich's work. He was of course involved in the 1980 revision and update of Heinrich's *Industrial Accident Prevention*. In his own work, Petersen would both draw on, and critique Heinrich. Petersen a.o. suggested an update of Heinrich's axioms (Petersen, 1996; 2001).

[63] We will return to this thought in chapter 5.4.7.
[64] Bird also drew the triangle in a '3D' pyramid shape.

Some state that behavioural approaches to safety have contributed to the continued popularity of Heinrich's teachings (Swuste et al., 2016), but that is probably only one part of its continued popularity. It cannot be denied, however, that the Behaviour Based Safety (BBS) movement draws heavily on some of Heinrich's ideas (and misinterprets them at least partly) with their focus on identifying and changing unsafe worker behaviours, for example through the observation of 'unsafe acts' and 'unsafe conditions'.

More recently, following accidents like Texas City and Deep Water Horizon, some proponents of BBS started to 'untangle' the safety triangle. Leading up to these accidents, the application of the safety triangle led to a focus on occupational safety, which distracted attention from process safety. This was seriously critiqued (e.g. Hopkins, 2008). The 'untangling' led to the SIF (Serious Injuries & Fatalities) movement, which focuses on the 'high potential' part of the triangle instead of minor, low potential events like slips trips and falls. (Martin & Black, 2015)

One can wonder about the longevity of Heinrich's ideas - over eight decades by now. The Heath brothers list a number of characteristics of ideas that 'stick'. (Heath & Heath, 2007) These characteristics can help to explain Heinrich's endurance. His work lives up to most of the characteristics identified by the Heaths. Metaphors like the dominos fill all or most of these simultaneously, being simple, concrete, credible, appealing to emotion and illustrated through examples (stories).

Le Coze (2013) suggests another set of criteria for successful and persuasive (safety) models. They should be simple to understand, normative, generic and therefore useable in different contexts, and have visual appeal[65]. Seemingly, Heinrich had a knack for ticking all the boxes, as Le Coze confirms explaining the success of the triangle[66] (and Swiss Cheese Model):

> "First is their capacity to be generic, whether in the chemical industry, in aviation or in the railways, both models adapt fairly well (1) and normative because they provide principle for assessing specific situations (2). They also have the ability to mobilise appealing metaphors (3), to be inscriptions (4) and to become boundary objects (5) with a performative dimension (6)." (Le Coze, 2018, p.88)

3.5 Citing Heinrich in safety literature

Before we continue to discuss the 'new view', and their analyses of Heinrich, let us see how safety science references Heinrich in its publications. It has been argued in the previous sections that Heinrich's work has been influential for safety theory and practice for many decades. Still, reviewing the academic attention for his work shows some surprising results. A simple search in Scopus showing the number of publications citing *Industrial Accident Prevention*[67], indicates a continuously increasing number of publications citing Heinrich's book. More than eight decades after the publication of the first edition, and almost four decades after the publication of the last version, and with the book being out of print for a long time, 'common sense'[68] might suggest a picture of declining interest as new theories and new authors enter the field. Figure 11 seems to paint another picture, however.

[65] Outside the scope of this thesis, but noteworthy with regard to visually appealing models, is the introduction of a 'safety ladder', as a five-step visual representation of a basic safety management system in the third (1950) edition of *Industrial Accident Prevention*. One could view this as a further development of his principles of 'scientific' accident prevention.

[66] Noteworthy, along with the success thanks to visual strength comes also the danger of misinterpretation: "visual properties are specifically at the heart of their heuristic value and power to explain, to make sense and to perform (note also that their downside is that they are ways of not seeing, they lock users in certain interpretations)" (Le Coze, 2018, p.90)

[67] Conducted 20 April 2018. Note that the search returns all five editions of the book.

[68] No such thing of course.

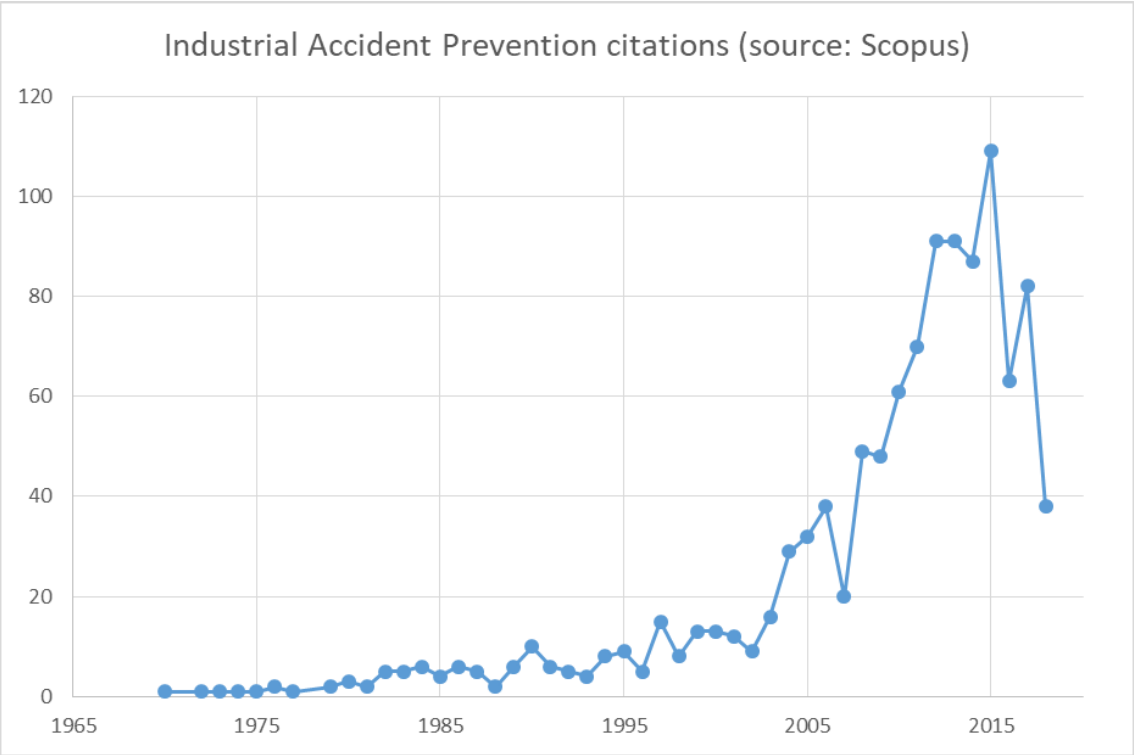

Figure 11: Citations of Industrial Accident Prevention per year (source: Scopus)

From the first citation in 1970, the diagram shows a slow increase until the early 2000s. The average number of citations per year from 1970 to 2003 is below 5,5. Some years see no citation of *Industrial Accident Prevention* at all. In 2003, the number of citations suddenly starts a steep climb, peaking in 2015 (109 times referenced) and declining somewhat thereafter, while staying well above the pre-2000 level.

It is important to note that the vast amount of safety literature is rather *practical* than *academic*. Much of safety literature aimed at practitioners can be found in professional magazines (e.g. from associations like ASSE, NSC, IOSH or NVVK), books, course materials, guidance documents and websites[69]. These are rarely found in academic databases like Scopus and attempting some form of systematic bibliographic research in 'practical' literature encounters serious difficulties. As an example, one might mention Frank E. Bird's work. This was strongly influenced by Heinrich, continuing many of Heinrich's core concepts like hidden costs, the dominos and the triangle, and was very influential for safety practice from the late 1960s until the 1990s. However, Bird's work is not found in the above Scopus search of publications citing Heinrich[70].

Another limitation of the search is that it returns mainly papers published in academic journals and hardly any books. A cursory check shows that also books by for example Dan Petersen (multiple works from the 1970s to early 2000s), Dekker, Townsend, Conklin, Marriott or Gesinger are not found[71]. Also two of Fred Manuele's notable works, *On The Practice Of Safety* and *Heinrich Revisted: Truisms or Myths*, dealing (partly) with Heinrich's work, are missing, and neither are my books included. Interestingly, several of Hollnagel's books *are* included - but not all of them.

The search and diagram above are thus a rather crude way of looking at the matter, but it may nevertheless suggest a direction and indicate a growing number of academic authors citing Heinrich. Whether this is due to an increased interest in his work, or rather that people cite him because they feel

[69] Another factor is that much professional literature is written in the language of the country it is published in, which may limit its inclusion in academic databases and its international use.
[70] Oddly, Bird's work *is* cited by for example Fragola (2005) which is part of the search results.
[71] Although this is not surprising since Gesinger's and Marriott's books are fairly new, and Conklin practices a notoriously 'sloppy' or non-existing use of references in his books, which are aimed at practitioners.

they should do so as part of the "academic name dropping" (Hopkins, 2014, p.8)[72], we cannot conclude without diving deeply into the material.

The table below shows the six journals with the largest number of citations in the search presented in Figure 11. *Safety Science* takes roughly 10% of the total number of citations. Even more when one considers that *Journal of Occupational Accidents* transformed into *Safety Science* in the early 1990s.

Table 1: Top 6 journals with citations of Industrial Accident Prevention (source: Scopus)

Publication	**Number of citations**
Safety Science	101
Accident Analysis And Prevention	33
Journal Of Construction Engineering And Management	30
Journal Of Safety Research	29
Journal Of Occupational Accidents	24
Journal Of Loss Prevention In The Process Industries	18
Other journals/sources have less than 15 citings	

Taking a closer look at the rate of publishing of these six journals[73], the diagram in Figure 12 below pictures *all* publications of these journals within a year. We see that all journals, with the exception[74] of *Journal of Safety Research*, show a steep increase of the number of publications from the early 2000s on. While it stays under 100 publications per year, even *Journal of Safety Research* more than doubled its number of publications in the period after 2002. Assuming that other journals follow a similar pattern, this suggests that significantly more academic safety literature is published in the 2000s than in the decades before.

It makes one wonder why this is. Reasons may include establishing safety as an academic discipline[75], a general increase in academic publications of all disciplines[76], and increasing globalisation. For this thesis I will not explore the reasons for this increase of published safety papers further and just take it as a given.

[72] Hopkins discusses this in the context of Perrow's Normal Accident Theory. The wonderful full quote:
"I suspect the fact is that while people continue to make reference to the theory, this is no more than lip service. We are dealing here with one of the more unfortunate aspects of academic practice. People refer to the works of others not necessarily because that work supports their arguments or are in any other way relevant to what is being said, but simply to establish that they are aware of the relevant literature. Such citations amount to little more than academic name dropping. I have myself been cited by people who seem unaware that my point is quite the reverse of theirs and that my work undermines their own conclusion, rather than supporting it. I suspect that this process of catch-all citation is part of the reason the theory of normal accidents continues to be cited." (Hopkins, 2014, p.8)

[73] Searched 22 April 2018.

[74] And obviously except *Journal Of Occupational Accidents* which turned into *Safety Science*.

[75] Which probably would please Heinrich, given his Main Theme 8 - although his interest was practical rather than academic.

[76] Several authors point out how the introduction of metrics to measure and express academic productivity and impact has led, or at least contributed, to an inflation in academic publications. Quantity rather than quality seems to be the tendency of the past decades. (e.g. Muller, 2018)

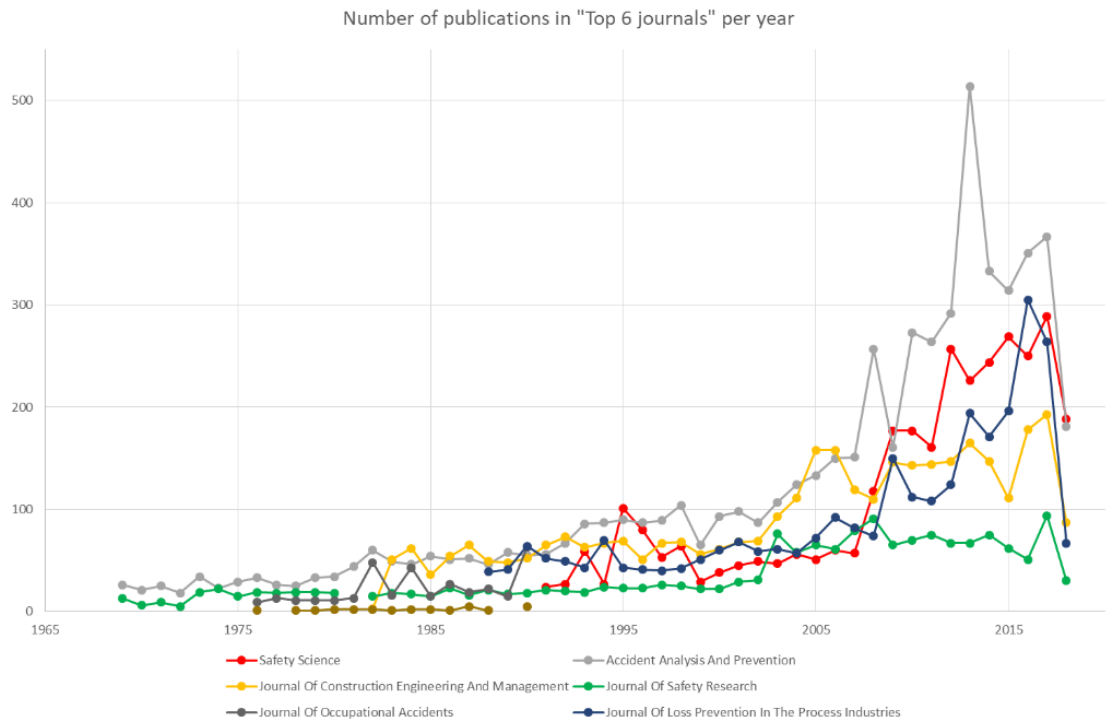

Figure 12: Number of all publications in "Top 6 journals" per year

When we search for the number of publications that mention 'Heinrich'[77] in these six journals, Figure 13 shows a pattern that is roughly comparable to that of all publications in these journals. There are a few 'peaks' in 1987, 1990 and 1997, but the absolute numbers are so low that this variability is not unexpected.

It is worth noting that we observe an increase in *absolute* numbers of references to Heinrich in recent years. When we look at a *relative* measure, for example the number of publications mentioning Heinrich divided by the total number of papers published that year, instead of an increase, we would rather see a somewhat randomly fluctuating line.

[77] Note that this search is different from the search opening this section, pictured in Figure 11. This search is somewhat wider and opens for the possibility that a mere mention of 'Heinrich's triangle' is included (referenced from a non-Heinrich source), but at the same time allows for some 'false hits', for example when other persons named Heinrich are mentioned.

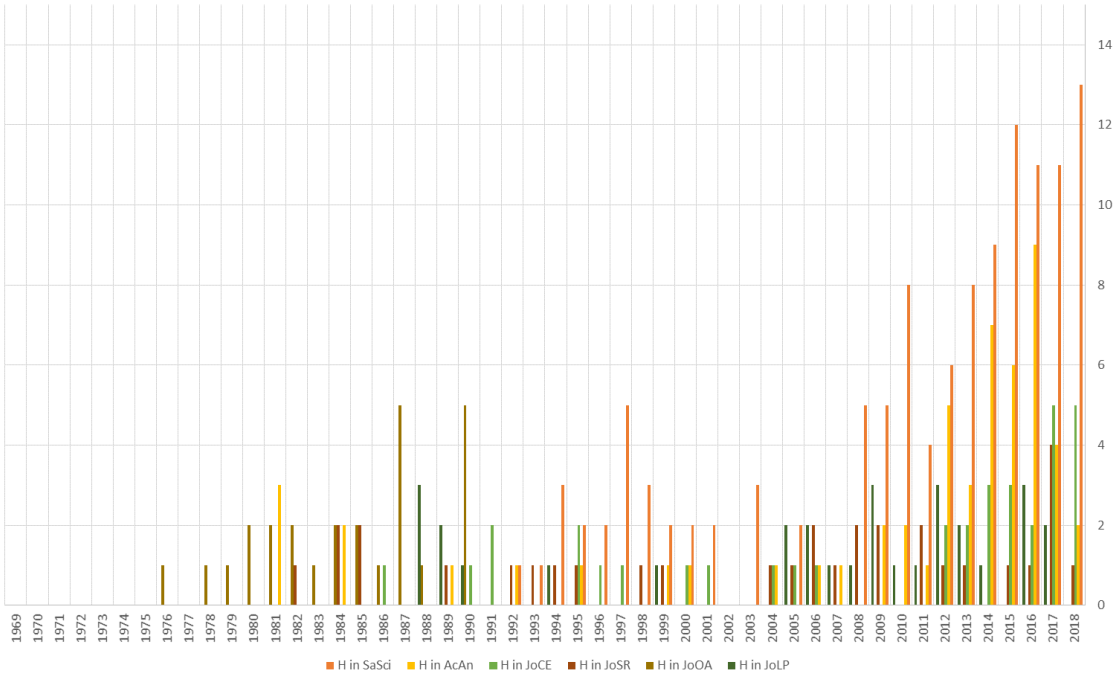

Figure 13: Heinrich mentioned in the "Top 6 journals" per year

Having provided an overview, context, background and a timeline for Heinrich's life and work, as well as some baseline for his appearance in safety literature, I will now go fast forward over half a century and look into the 'new view' of safety in the next two chapters.

4 A 'new view'

This chapter makes a leap to some developments in safety science and practice of the past couple of decades[78], which are often labelled the 'new view'. Of course, safety science and practice have been evolving and developing in the decades between the end of Heinrich's work in the late 1950s/early 1960s and the dawn of the new millennium[79]. However, even though new developments often presented themselves as 'different', these developments did rarely question some of the basic premises of traditional safety thinking and position themselves squarely against them (including Heinrich's teachings). The 'new view' does exactly that and therefore it is interesting to investigate how it discusses Heinrich.

4.1 What is this 'new view'?

Looking objectively, one might comment that the 'new view' is not that new anymore, since the term as we understand it at this point in time was coined almost two decades ago (see e.g. Dekker, 2002), and notions of it appeared much earlier, for example in the writings of Rasmussen who discusses complexity (Rasmussen & Lind, 1981) and problems with 'human error' as a cause (Rasmussen, 1990).

Only recently, the 'new view' has gained wider traction with the emergence of related terms like Resilience Engineering (Hollnagel, Woods & Leveson, 2007); Safety-II (Hollnagel, 2014b), 'safety differently' (Hummerdal, 2014[80]) or Human & Organizational Performance (HOP) (Conklin, 2012) and these thoughts seem to be crossing over increasingly into the mainstream safety thinking[81], and some of the terms are even starting to become buzzwords and proponents of traditional safety approaches are trying to present their approaches by latching on to new approaches (e.g. Williams & Roberts, 2018).

The approaches mentioned above argue that there is a need for new ways to work with safety, because "…workplaces and systems become increasingly interactive, more tightly coupled, subject to a fast pace of technological change and tremendous economic pressures to be innovative and cutting-edge." (Safety Differently, n.d.) Therefore, traditional, linear approaches which attempt to control risks through compliance and technical measures are not sufficient anymore.

Often, we take the term 'new view' just as a given, as if it were an objective indication. It is not, it is merely a practical shorthand that many seem to understand, especially when they consider themselves part of the movement. We should keep in mind that 'new' is not an absolute term, but a relative one. Let us not forget, Heinrich was part of another 'new view' back in his days. Petersen states this in the quote we already encountered in Chapter 3.2.4, "Heinrich's ideas were a departure from the safety thinking of the time." (Petersen, 1971, p.11) Aldrich agrees when he discusses how safety pioneers of the 1920s and 1930s introduced a view that saw accidents as events that were caused and could (and should) be prevented (Aldrich, 1997, p.114). Heinrich himself speaks even of "a change in trend of thought" (Heinrich, 1931a, p.260), discussing the growing recognition that previous cause attributions were not really about causes.

Therefore, when we now have another movement that we call 'new view', we should ask ourselves, 'new' compared to what? It is helpful to contrast this 'newness' to something else. This also takes us back to the origins of the term. Some of the earliest descriptions, we can find in Dekker's early papers (Dekker, 2002; 2003). Here he describes 'old' and 'new' views regarding human error and therefore this may be a good point to start. According to Dekker, in the 'old view':

---

[78] Pinpointing the start of the 'new view' is hard, if not impossible. Some of the thinking has been around for a very long time. In this thesis, I choose to place it somewhat arbitrarily around the early 2000s with Dekker's early papers.
[79] A few developments were mentioned in Chapter 3.4, but this did not even scratch the surface.
[80] The term 'safety differently' was inspired by a Brisbane discussion group that talked about new ways in safety. Hummerdal started the website safetydifferently.com in 2012 and Dekker published a book of the title in 2015. In a 2018 blog, Dekker describes how he coined the term and discusses its philosophy. (Dekker, 2018c)
[81] Indicated by for example an increasing number of HOP/Safety Differently/Safety-II conferences and workshops, the BBS-HOP debate at the ASSE congresses, and the *Safety Differently* movie.

- Human error is regarded as a, and often the main, cause of accidents.
- Systems are inherently safe when they are designed and constructed.
- This inherent safety is undone by the unpredictable and unreliable behaviour of humans in the system.
- Safety is created and improved by striving to reduce the influence of the 'erring' human. Methods include selection, training, rules, compliance and technical interventions.

Heinrich fits very well into this description of the 'old view'. After all, he attributes most accidents to 'man failure' or 'unsafe acts'[82] (e.g. Heinrich, 1928a; 1928b; 1931a; 1941), he believed that the work systems were getting increasingly safer[83] (Heinrich, 1928b, p.126: "It has been known for a number of years that physical hazards are becoming less and less a real factor in safety") which left 'man failure' as the main cause for accidents and he suggested a wide arrange of interventions, including that an employer were to "train, instruct and supervise his employees properly" and "guard his machines and correct unsafe methods or practices" (Heinrich, 1928b, p.127).

In contrast, the 'new view' of safety does not see human error as an explanation for the occurrence of accidents, but rather as a consequence of things elsewhere in the system. Human error is a symptom that needs to be explained. (Reason, 1997) Dekker (2003) characterizes the 'new view' by the following:

- Human error is not a cause of accident, but a symptom of failures deeper inside or higher up in the system. Human error is not a conclusion, but a starting point for analysis.
- Systems are not inherently safe. They are imperfect, have limitations, contain latent failures (Reason, 1997) and conflicting goals.
- People create safety during their day-to-day interaction with the system, often by compensating for, and adapting to, the system's imperfections.
- Human error is a consequence of factors in people's context. Understanding and influencing these factors and the connections between them contributes to creating safety.

Hollnagel uses the terms Safety-I and Safety-II to indicate the traditional approaches to safety and new ways, respectively. He describes Safety-I as "reactive" because it reacts on unacceptable risks or unwanted events and focuses on having as few as possible negative consequences. Safety-II is about making sure that as much as possible goes right, focusing on the positive side, proactively trying to anticipate developments and adapt to them. Safety-I assumes different causes for success and failure. Failure causes accidents and investigations try to 'discover' these causes. Safety-II states that failure and success spring from the same source. Investigations try to understand how things usually go right, and sometimes wrong. Where Safety-I tries to suppress variability, Safety-II recognizes that it is inevitable and useful. (Hollnagel, 2014b)

4.2 What characterizes the 'new view'?

While it is hard to provide a clear-cut definition for the 'new view', below I will describe a number of traits that characterize, and are commonly attributed to, the 'new view'.

Today's technology and work systems are complex, dynamic and there is constant and rapid change. Because of these characteristics, traditional approaches are not sufficient anymore and new approaches to investigation, modelling and controlling safety are necessary. Contemporary 'new view' authors stress the importance of understanding and embracing complexity (e.g. Hollnagel, 2009; Woods, et al., 2010; Dekker, 2010; 2014a). Because the 'new view' embraces complexity, safety, success and accidents are seen as emergent phenomena. (Leveson, 2002; Dekker, 2003; Hollnagel, 2014b). Complexity also means that variability is inevitable and even necessary for systems to function and thrive (Dekker, 2011).

[82] Heinrich rarely used the term 'human error' himself and only in his later work.
[83] Note that this is not entirely the same as "systems are inherently safe", but it shows a tendency in that direction.

One fundamental idea for 'new view' scholars is the urge to adopt to a systems-approach. Rasmussen concluded that we need "a system-oriented approach based on functional abstraction rather than structural decomposition" (1997, p.183). Dekker (2003; 2010; 2011; 2014a) argues against 'reductionism'. Accidents do not necessarily result from 'broken parts', but can come out of normal work and variations in components of the system or by gradual drift into a certain direction (Vaughan, 1996; Snook, 2000; Dekker, 2011; Hollnagel, 2014b).

The 'new view' places great importance on context (Pupulidy, 2015) and circumstances that can lead to accidents. Hollnagel stresses that the "whole is larger than the sum of the parts" (Hollnagel, 2014b) and Hollnagel and Woods (and others) discuss joint cognitive systems instead of separate systems that are combined.

> "Accidents can occur from the unanticipated interaction of non-failing components. Independently benign factors at multiple levels of analysis interact in unanticipated ways over time, often leading to tragedy". (Snook, 2000, p.15) Snook found in his research "normal people, behaving in normal ways, in a normal organisation" (Snook, 2000, p.202)

Just as one cannot reduce a system to its components, it is impossible to separate the various objectives. Safety is merely one among many other goals of the system. There are constant trade-offs. (Rasmussen, 1997; Dekker, 2003; Hollnagel, 2009)

Because complexity never can be captured into one (simple, linear) narrative, the 'new view' invites multiple views, looks at a case from various sides, and wants to hear "second stories" (Woods, et al., 2010).

Human error is not seen as a valid, distinct causal category. It is merely a hindsight attribution or judgement. (Woods, et al., 2010; Dekker, 2003; 2014a; Gantt, 2017) Human error is rather a consequence than a cause. Rasmussen already called it a "stale category" due to the "subjective and context depending aspects." (Rasmussen, 1990, p. 454)

Instead of searching for human failure, the 'new view' looks for human sense making (Snook, 2000; Dekker, 2002). Therefore, the 'new view' places great importance on local rationality (Woods, et al., 2010; Dekker, 2002; 2014a; 2015; Conklin, 2015), and tries to see things from the perspective of the person in the situation, instead of taking the outside view.

> "Acts that are quite rational and important during the search for information and test of hypothesis may appear to be unacceptable mistakes in hindsight, without access to the details of the situation" (Rasmussen, 1990, p.456).

In the 'new view', humans are a strong element in the system. People are not seen as a problem to solve, but rather as a solution, and an asset to cultivate. (Dekker, 2014a) Organisations should harness the expertise and insight of the front-line workers and experts and supports them to respond flexibly to the situations that they face. People adapt constantly to make up for variations in the system, to try to improve the system, to make up for imperfections in the system, or to handle conflicting goals.

> "Often we found that attempts to improve safety of a system from model of local features were compensated by people adapting to the change in an unpredicted way" (Rasmussen, 1997, p.184)

The 'new view' tries to avoid the effects of hindsight. These effect include making complex scenarios linear (e.g. by cherry-picking and regrouping of evidence), counterfactual reasoning about what different actions and decisions could have avoided an accident, and normative judgements about what people should have noticed, known, done or omitted. (Dekker, 2002; Woods, et al., 2010) Because the 'new view' avoids judgement and normative language, it also avoids blaming individuals or groups for things that happened.

One of the catchphrases of the 'new view' is that success and failure spring from the same source. Therefore, we must not only focus on incidents and things that go wrong, but also and especially on things that go well (Hollnagel, 2014b). We should have focus on normal work and things that go right rather than on things that go wrong. The 'new view' focuses on 'work-as-done' instead of on 'work-as-imagined' (Hollnagel, 2014b). Rasmussen already indicated the basis for Safety-II:

> "Explanatory descriptions of accidents are, as mentioned, focused on the unusual events. However, the path can also be broken by changing normal events and functions involved. The decomposition of the flow of events, therefore, should not focus on unusual events, but also include normal activities." (Rasmussen, 1990, p.453)

4.3 A selection of authors

What authors are part of the 'new view' in the above description that we may want to look into more closely for this study? Let us propose the following criteria for a selection:

Firstly, and obviously, the authors have to be positioned in the 'new view' in writings and/or safety management practices. This means that they have to demonstrate clearly and consistently the abovementioned characteristics in their work. Additionally, relevant authors show a critical stance towards traditional approaches to safety. Also authors that are clearly affiliated with 'new view' institutions, like for example the contributors to the Safety Differently website, are taken into consideration.

Secondly, and also obviously, the authors have to discuss Heinrich, or Heinrichian themes[84]. Many authors that can be considered essential 'new view' authors never discuss Heinrich. Examples are Woods[85], Leveson, or Cook. Neither have authors whose work has been highly influential on the emergence of the 'new view' - e.g. Rasmussen[86], Reason[87], Vaughan, or Snook - discussed Heinrich in their work.

Thirdly, we want to avoid the inclusion of mere 'bloggers' and 'opinions' - interesting as they may be - in the study. Preferably, the authors for selection should have at least one academic paper, or a book published (or have contributed with book chapters) in which Heinrich, or Heinrichian themes are discussed. Admittedly, this is a rather superficial way of assuring that the author has put some decent effort in his or her work, either by living up to the standards of academic journals with a peer review process and other quality assurance routines, or by writing and going through the editorial process of a book. Safety books are not necessarily a guarantee for academic rigour[88], because many of them are aimed at practitioners rather than at academics, but we will assume that writing a book takes much more effort and thought than a mere blog[89].

These criteria provide us with some of the better-known - and most prolific - names in the 'new view': Dekker, Hollnagel, and Conklin. All of them have written about Heinrich on several occasions. Through literature searches and private reading these are supplemented by authors like Long, Marriott, Gesinger,

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[84] To count as a 'Heinrichian theme', the subject has to be connected directly to Heinrich, for example by the mention of one of his metaphors (domino, triangle) or ratios. A mere discussion of causation or human error in general does not qualify.

[85] This is to say, *Behind Human Error* (Woods, et al., 2010) does discuss both the dominos and the triangle (the Bird version), but it is not indicated which of the co-authors contributed these particular sections.

[86] Rasmussen's influence on the 'new view' cannot be stressed enough as is well-illustrated by the numerous Rasmussen quotes in this chapter.

[87] Several authors link Heinrich's dominos and Reason's Swiss Cheese Model because of their graphic similarity. Reason, however, makes no mention of dominos or of Heinrich's accident sequence, so the similarities are probably coincidental. Besides, the Swiss Cheese Model, is rather about the *spaces between* the dominos.

[88] The possibility of self-publishing opens for even weaker editorial quality assurance. However, even reputed publishing houses like Routledge and Ashgate have published safety books with quite obvious mistakes, weakening faith in their editorial process.

[89] Phil La Duke is an author that I chose not to include. He published a book in 2018, but this is mainly a collection of blogs. Furthermore, even though he is critical of many contemporary safety practices, his work belongs as much to the 'old' as to the 'new view'.

and Townsend. In this research, I will allow for the inclusion of blogs and podcasts by authors who fill the above mentioned criteria. Additionally, I will not wield the third criterion too strictly in order to have a broader, richer and more colourful source to draw from. While not academic, publications in 'respectable' professional publications are also acceptable, which adds Anand to the selection. Hummerdal does not fill the third criterion (although he has a number of non-Heinrichian academic papers), but has been included nevertheless because of his role in the establishment of the 'new view', as founder of the Safety Differently website. Appendices 3 to 6 present a full overview of the authors selected for this study.

Finally, I consider myself rather 'new view' in my thinking and writing, and I admit to being both puzzled and judgemental when first confronted with terms like 'real cause' and a focus on direct causes in Heinrich's work. I cannot include my own publications, since I am hardly impartial enough to comment on these. However, I will propose one subject for analysis in Chapter 6.

4.4 Heinrich in 'new view' literature

4.4.1 General

The appendices 3 to 6 present the 'new view' literature that was reviewed in order to select relevant publications for this study. These tables include a global overview of whether a publication references Heinrich's work or mentions a Heinrichian theme, and in what manner, including relevant quotes and some primary comments[90].

The 'bigger names', Dekker and Hollnagel (appendix 3 and 4 respectively), both have what appear to be complete overviews of their publications on their websites[91]. These were helpful in locating potentially interesting documents[92]. Some additional bibliographic searches were done to ensure that as much documentation as possible was included. A large selection of their work was browsed and reference lists were checked to find possible discussions of Heinrich, or Heinrichian themes (since the dominos and triangle sometimes are discussed without direct reference to his work). Only the publications that contained direct or indirect references were selected for further study.

While the work for this thesis naturally pays much attention to the 'bigger names', a number of other 'new view' authors have been included in the discussion for further illustration and to be able to draw on broader sources. When starting to collect material, it turned out that Robert Long mentions Heinrich and Heinrichian themes quite frequently. This made it sensible to gather his work in an appendix (5) of its own. For the other 'new view' authors (appendix 6) a somewhat more 'direct' selection was made, mostly based on sources that were known to contain Heinrich, or Heinrichian themes, from earlier reading. A few publications were picked up during literature searches and on the Safety Differently website[93].

I will now discuss the various authors and their discussion of Heinrich in more detail.

4.4.2 Dekker

Appendix 3 shows an overview of all publications by Sidney Dekker browsed for the purpose of identifying relevant publications for this study. Among a total of 59 selected papers and books authored and co-authored from 2000 to 2018, only thirteen[94] qualify directly or indirectly for further study. What strikes immediately is that for the first decade of his published work, Dekker did not touch Heinrich at all.

[90] These comments should be read in a 'note to self' way. Not all these 'notes' will be addressed or answered in this thesis, by the way.
[91] Respectively www.sidneydekker.com and www.erikhollnagel.com.
[92] Triggered by words like 'accident', 'incident', 'model', 'prevention', 'management', 'failure' or 'error'.
[93] Four from this source to be precisely: Townsend, 2013; Hummerdal, 2013; Dekker, 2017a. Also, Dekker discusses the triangle in 2018b.
[94] Plus one that is listed in Provan's section.

Dekker only started discussing Heinrich recently. We find the first direct reference to Heinrich in the third edition (2014a) of *The Field Guide*[95].

Heinrich is introduced in the chapter titled *Understanding Your Accident Model*, which opens with the "chain of events model" (Dekker, 2014a, p.123). One may expect an argument about the limitations of linearity, comparable to Hollnagel's, but it takes a different turn:

> "The idea of the chain of events comes from H.W. Heinrich[96], *whose research into injury causation showed that 88% of accidents were caused by workers themselves (this was based on supervisor reports about those accidents, so no wonder there)*. Heinrich concluded that, "The occurrence of an injury invariably results from a completed sequence of factors - the last one being the accident itself. The accident in turn is invariably caused or permitted by the unsafe act of a person and/or a mechanical or physical hazard"." (Dekker, 2014a, p.123, emphasis added)

Dekker plays a little rhetorical trick in this quote. First, he sets out to discuss a linear accident model, the dominos. Then he inserts the part in italics, which is not related to the accident sequence at all (the 88% ratio came several years before the accident sequence, after all). In the context of Dekker's book, it frames things negatively; suggesting a message of 'Heinrich, the guy who blamed the human, came with this linear accident model, etc…'. This is enhanced by the remark about the source material in parentheses. By association, everything Heinrich said becomes suspect.

After this brief section on the dominos, Dekker does not resume a discussion of this and other accident models. Instead, he gets into a side track ("Heinrich, by the way, …") for a much longer critique of the triangle (Dekker, 2014a, p.124/125) before finding the way back to the chain of events and other models. In this side track, Dekker critiques the use of the triangle: "…the false idea that we can control the risk of a major disaster by counting, recording, tabulating and supressing the small stuff" (Dekker, 2014a, p.125). This sketches a superficial, misguided application that does not correspond with what Heinrich envisioned, and is at odds with Heinrich's notion of seeing 'weak signals' as an opportunity[97]. Interestingly, later in the *Field Guide* Dekker advocates Hollnagel's approach. This approach contains the same message as Heinrich's approach when he discusses the opportunity given by the triangle: "if we want to understand the latter [daily, normal work - cb.], we have to focus on frequent events, not necessarily severe ones." (Dekker, 2014a, p.140)

After having first discussed the triangle in the 2014 version of the *Field Guide*, Dekker follows up on this subject through several publications. One can see it building up from the 2014 *Field Guide* through the *Bureaucratization of Safety* (2014b) and *Examining the Asymptote in Safety Progress* (2015b) papers, with indirect attacks on the triangle via critique of Wright and Van der Schaaf. In his commentary to Zwetsloot et al. (2017b) and 2018's *Safety Anarchist* he turns up the heat with a full frontal attack on the triangle and Heinrich, climaxing in an axiomatic dismissal of the triangle in his 2018 blog:

> "There should be no need to point this out any longer: the so-called safety triangle is of course wrong, as it always was. That much is trivial." (Dekker, 2018b).

In *The Safety Anarchist*, Dekker spends most Heinrich-related effort on the triangle, although he not necessarily addresses Heinrich as such, but rather later, applications, interpretations and beliefs. As such, Dekker phrases it correctly as "prescriptions *inspired* by Heinrich" (Dekker, 2018a, p.94, emphasis added).

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[95] Before that, there is only a mention in passing of the dominos in *Drift Into Failure* (2011) and a discussion of the dominos and (Bird) triangle in *Behind Human Error* (Woods, et al., 2010). Dekker is one of the co-authors of this book, but it is not indicated who wrote these particular sections.

[96] This is not entirely correct. As we saw, DeBlois (1926) already discussed a sequence of events. However, Heinrich's later version is the better-known one.

[97] Besides, Heinrich did not discuss major *disasters*, but *injuries* (no, minor and major injuries). Granted, Heinrich does mention an example where 17 bus passengers died or were severely injured when a gasoline-station attendant smoked while fuelling the bus (Heinrich, 1931a, p.94), but this is an exception.

In this book, Dekker also brings forward a wider scope of Heinrich critique, including of the use of 'human error', 88%, the dominos, the scientific basis, Heinrich's missing data and Taylorism.

One wonders why a critique of Heinrich became a part of the third edition of the *Field Guide* when two previous editions managed without any Heinrich. Why did Dekker start to discuss Heinrich, and why does he so increasingly (for the moment at least)? Upon asking, Dekker commented,

> "I was made increasingly aware of Heinrich because of the incredible penetration that misconceptions (or over-interpretations) of his work have in hard-hat industries. Australia doesn't have a lot of high-tech safety industries, but mostly hard-hat safety issues and people, and I saw so much references to the 'holy Heinrich triangle' that I decided to try to go into the actual data and his method to find out whether there was anything there. The suggestion that we can manage the big stuff by making small stuff go away is misguided."[98]

I will return to these questions in the next chapter.

4.4.3 Hollnagel

Appendix 4 shows an overview of all the publications by Hollnagel browsed for the purpose of identifying relevant papers for this study. Reviewing 40 Hollnagel papers and books from 1983 to 2018 gives 21 'hits' that qualify for further study.

Unlike other 'new view' authors discussed here, Hollnagel started discussing Heinrich quite early[99] - a decade before most others (see Figure 15 in Chapter 5.2). In addition to being early, Hollnagel has also been discussing Heinrich rather consistently over the years. There are a few significant peaks: in 2004 with the *Barriers* book, in 2014 with the *Safety-II* book and to a somewhat lesser degree in his collaborations with Besnard (2012), and with Lundberg and Rollenhagen (2009; 2010).

Coincidentally, Hollnagel's first citation of Heinrich happens around the time that Manuele's *Revisiting Heinrich* (2002) book was published. Most likely this is unrelated, since Hollnagel does not refer to Manuele's critique[100] and more importantly, he discusses Heinrich's work from different angles. Since it deals with the dominos, Hollnagel's first discussion of Heinrich appears not to be inspired by Hale's (2002) critique of the triangle either. Hollnagel would, however, turn to the triangle soon after, relating to Hale's critique in *Barriers And Accident Prevention* (2004) as well as in the *Safety-II* book[101] (2014b).

Hollnagel starts paying attention to Heinrich while developing his classification of accident models - from linear to more complicated and complex - and his critique of root causes (Hollnagel, 2002). He had been working on this for a while (Hollnagel, 2000; 2001). The dominos, often coupled to the First Axiom, are the Heinrichian subject that Hollnagel discusses most frequently. He does so in no less than 19 publications[102], in somewhat varying settings. Hollnagel often refers to the dominos when discussing linear (or sequential) cause-and-effect chains:

> "The approach assumes that adverse outcomes can be explained by linear cause-effect chains, as originally proposed by the Domino metaphor, and later, by Reason's Swiss Cheese model. It also assumes that all adverse outcomes, whether mild or serious, have causes which can be found and fixed, and that these differ from the causes of ordinary, successful care." (Braithwaite, Wears & Hollnagel, 2015, p.418)

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[98] Personal correspondence with the author, 14 December 2018.
[99] Relative to others. Not when looking at Hollnagel's own career, which had been underway for about three decades by the time.
[100] Hollnagel *does* refer to Manuele's 2011 paper in the *Safety-II* book (Hollnagel, 2014b).
[101] Even though the reference there is not quite correct, mixing up several papers.
[102] The other two publications were not accessible for this study, but from the references shown on Scopus, we can assume that also these contain a variation of the linearity/domino/First Axiom/root cause discussion.

It appears that Hollnagel does not intend his discussion explicitly as a critique of Heinrich's model; often he rather presents it as the typical example of linear/sequential models. While Hollnagel is critical of the shortcomings of linear accident models, his tone is never an attack. Often he is rather exploring and sometimes even explaining why Heinrich (or his contemporaries) may have chosen certain approaches. On some occasions Hollnagel *does* in fact explore Heinrich's local rationality. One example:

> "For these situations, Heinrich (1931) proposed that the most proximate cause should be prevented, *following a recommendation from the US department of Labor (1920) suggested* that more distant causes should be pursued for severe accidents, such as train accidents. *Thus, the model proposed* by Heinrich is linear, considering only the immediate surroundings, including line management. Although commitment from higher management levels were seen as vital for success in implementing safety work, Heinrich *did not think it was a fruitful* approach to point to higher management levels as causes. It is noteworthy that two lines of enquiry were considered: The first went through the person or surroundings, looking for causes to actions that in hindsight seemed incorrect, or for causes of problems with equipment or other items in the surroundings. The second line of enquiry went towards the line manager, looking for reasons why the accident was not prevented." (Lundberg, Rollenhagen and Hollnagel, 2009, p. 1298, emphasis added)

While it is the 'favourite' object for many other 'new view' authors, Hollnagel discusses the triangle only in the two above-mentioned books from 2004 and 2014. This is somewhat surprising, given the amount of critique that the triangle tends to get. Hollnagel does not even discuss the triangle in the *Myth* paper with Besnard (2012). In comparison with most others, Hollnagel also does a much more nuanced discussion of the triangle[103], even though his discussion becomes more critical over time when one compares the discussion of the triangle from *Barriers and Accident Prevention* (2004) with that in the 2014 *Safety-II* book. Here he speaks of "A pyramid of problems" and labels some applications of it as "a myth" (Hollnagel, 2014b, p.67).

In comparison with many other authors, some other things stand out. Firstly, Hollnagel hardly ever critiques Heinrich's 'research'. He more or less takes the claims as they are and discusses their substance, rather than the 'research' they are based on. Secondly, he draws on a relatively large repertoire of Heinrich references (in addition to several versions of *Industrial Accident Prevention* he also cites a few papers). Thirdly, on several occasions, Hollnagel uses lengthy Heinrich quotes to illustrate a point he is making (e.g. Hollnagel, 2014b, p.71/72), showing his familiarity with and knowledge of Heinrich's work.

4.4.4 Long

Rob Long is a rather prolific author with so far seven books to his name and many blog posts of which no less than 38[104] mention Heinrich or Heinrichian themes (most frequently the triangle). Appendix 5 shows an overview of the reviewed literature by Long.

The main focus of Long's study and writing is the social psychology of risk, which discusses risk from a humanizing approach. As a consequence of this, Long has generally a very critical look on the state of knowledge in safety, and the "mechanistic" (Long, 2014a; 2015a; 2018e) engineering approach that underpins much of the common safety thinking and discourse[105].

Long's work has numerous mentions of Heinrich and one almost gets an impression that he is on some kind of a crusade against Heinrichian topics - especially the triangle - and other traditional safety teachings. Reason's Swiss Cheese Model is another prominent target of Long's critique. It is easy to suspect that Long goes for a wholesale rejection of traditional safety of which Heinrich is a part and flagship.

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[103] Which should be no surprise if he indeed was inspired by Hale's (2002) thorough discussion.
[104] The search was restricted to the safetyrisk.net website where Long frequently posts, up until 19 December 2018.
[105] Interestingly, this includes critique of resilience *engineering*. See some quotes in appendix 5 as an illustration for Long's critical stance.

Usually, Long does not discuss Heinrich in detail, nor does he provide proper critique (and neither does he draw on the critique of others, like Manuele), but he uses Heinrich rather as a symbol of 'traditional safety'. I will discuss this in the next chapter.

While having read Heinrich's work[106], Long makes several attributions that are wide open for debate. These include linking Heinrich and the triangle to 'zero' (Long, 2017b), calling him a Taylorist (Long, 2012; 2013), and attributing the use of lagging indicators to Heinrich (Long, 2014a; 2015a; 2017f). I will discuss these attributions in Chapter 5.4.

Seeing Heinrich as a symbol rather than discussing his specific ideas may be one reason for these attributions and they are probably a rhetorical device. This may also be the case for the clearly incorrect[107] presentation of Heinrich by Long as an "insurance investigator" (2014d) and - more often - as an "insurance salesman" (Long, 2012; 2014a; 2015a; 2017b).

In Long's books and numerous blogs, we find these rhetorics, and statements like "A hard way to learn that both zero and metrics are meaningless! A hard way to learn that Heinrich's pyramid is a concocted cook-up and that Swiss cheese is a reductionist irrelevance!" (Long, 2018d; 2017b) along with plenty of derogative words like "fictional manufacture" (Long, 2014b), "hoax" (Long, 2017c), "delusion" (Long, 2017f), "dumb" (Long, 2017g), "nonsense" (Long, 2017a) and "petty pissy safety" (Long, 2017a). These appear to be tools[108] in Long's attempt to 'hammer home' an alternative - social psychology of risk - way of approaching safety.

4.4.5 Others

Appendix 6 gives an overview of other authors that can be counted among the 'new view' and whose work was selected for inclusion in this study. It must be noted that some of the selected works are more oriented at practitioners (notably the books by Conklin, Gesinger and Marriott) while others are proper academic papers.

Anand

Nippin Anand has a background from operations, academic research, consultancy and certification and regulation in the maritime, oil and gas sector. He is an active contributor to a.o. the Safety Differently website. On his website[109], we find two articles discussing Heinrich. Additionally, there is one mentioning the dominos.

Anand's main interest appears to be the triangle, which he addresses in two articles. Interestingly, the first article is not all dismissive of the concept. It starts with a critique of contemporary applications that mix occupational safety and process safety, mentioning an example of not wearing PPE having no relevance for pressure relief valve problems. Then, however, Anand embraces scenario thinking (without spelling this out), and acknowledges some value in the triangle:

> "But this is not to say that Heinrich's Law does not apply to technical safety. Incident reports such as 'slight leakage in lubricating oil pump', 'small crack in a double bottom tank', 'minor engineering modifications without approval' if unnoticed may lead to serious outcomes. But all this requires seriously questioning and analysing the nature of incidents, rather than just counting the number of reports." (Anand, 2015, p.6)

Also the later article (Anand, 2018) addresses problematic contemporary applications of the triangle (or rather, of bureaucratic near miss reporting systems). Manuele's critique forms most of the backing. I will briefly return to this paper in Chapter 5.5.2.

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[106] Personal communication with the author, 10 December 2017.
[107] Heinrich's books state clearly his occupation, you do not need to look further than the title page.
[108] Rather blunt ones, one could say!
[109] http://nippinanand.com. Visited 15 July 2018.

Conklin

Todd Conklin has a background from the Los Alamos National Laboratory where he worked as a Senior Advisor for Organizational and Safety Culture for 25 years. In recent years, he is rather prolific, having written three books in the *Pre-Accident Investigations* series as well as publishing *The 5 Principles Of Human Performance* in early 2019, doing numerous podcasts[110] and being a wanted speaker. He has been a strong advocate for the HOP-approach, and entered an open debate with BBS luminary Scott Geller at the 2017 ASSE conference[111].

As early as 2007, Conklin wrote a short article on Heinrich and the triangle for the Nuclear Weapons Journal. While meant as a critique of Heinrich, it is interesting to see that Conklin says much of the same as Heinrich did seven decades earlier, but using other words. "Near misses are probably the best data that we receive on the reliability of safety systems. Accidents without consequences are a good thing." (Conklin, 2007, p.18) suggests using the opportunity that no-injury accidents offer (Heinrich, 1929a; 1929b; 1931a). Also, "Contrary to Heinrich's law of averages, any mistake can lead to a severe injury or other disastrous consequence" (Conklin, 2007, p.18) resonates well with Heinrich's statement that "one major injury may result from the very first accident, or from the last, or from any of those that intervene" (e.g. Heinrich, 1931a, p.91).

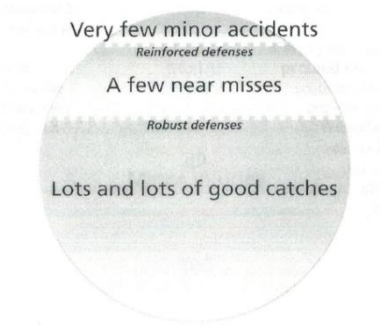

Figure 14: The accident sphere (Conklin, 2007, p.18)

Most interestingly, at the end of the article Conklin proposes an "accident sphere" as an alternative, more positive approach to look for the data one needs to "effectively build and maintain defences within a safety system". (Conklin, 2007, p.18)

After this, Conklin did not write about Heinrich for about a decade. In his two first *Pre-Accident Investigations* books (from 2012 and 2016) he does not discuss Heinrich's work at all. The third book in the series (2017a) then deals rather harshly with Heinrich, especially with regard to the triangle. This critique was quickly followed by a podcast (October 2017) elaborating on the subject.

Given the title of the third book in the *Pre-Accident Investigations* series, Conklin's interest in Heinrich is probably inspired by the SIF-movement (Martin & Black, 2015), and likely also influenced by recent work by Dekker (2014a).

Most of Conklin's critique deals with the triangle (unsurprisingly, given the link to SIF), questioning its value as a tool for prediction. Furthermore, he touches briefly upon the 88% ratio and the scientific foundation of Heinrich's work. In Conklin's view, the triangle makes organisations focus too much on prevention, or rather when things go wrong the failure to prevent. This is the wrong focus according to Conklin; organisations should rather learn how to fail safely.

Like many others, Conklin discusses certain applications of the triangle rather than Heinrich's original intention. Therefore Conklin poses that the "…pyramid is reducing your operational data not increasing operational knowledge." (Conklin, 2017a, p.58) This is quite contrary to what Heinrich intended. However, according to Conklin, "Heinrich was wrong - Admit it - and move on" (Conklin, 2017b).

Gantt

Ron Gantt is a safety consultant and PhD student working on a thesis dealing with practical drift. A few years ago, he took over as the webmaster of the Safety Differently website from Hummerdal. Gantt has one publication that (partly) deals with Heinrich when Gantt discusses the "persistent belief" in unsafe behaviour as a prime cause of accidents (Gantt, 2017).

[110] https://preaccidentpodcast.podbean.com/
[111] Watch it at https://www.youtube.com/watch?v=43u61TQpOxQ.

He does not critique Heinrich directly, but uses him as one of several examples of the widespread belief that most accidents are caused by unsafe acts, and the belief in the dualism of man failure versus technical failure. Gantt's paper is mostly a critique of these beliefs. Noteworthy is that Gantt is careful in his citation, noting that Heinrich discusses *proximate* causes.

Gesinger

Scott Gesinger is a safety engineer who attempts to 'shake up' safety practitioners a bit with his book (2018) that critically addresses beliefs and practices, and offers alternatives. He discusses Heinrich in several chapters of his book. At times, he does so quite humorously. Chapter 10 of his book; for example, is titled *Safety Management System Title Match: Deming versus Heinrich*, describing an imaginary boxing match between these two icons with guest appearances of other significant historical figures. Deming and Heinrich exchange blows with their concepts. (Gesinger, 2018)

Following Manuele's lead, Gesinger acknowledges Heinrich's positive contributions to the safety profession, while also criticizing negative effects:

> "While some of Heinrich's work has inspired safety philosophies that are detrimental to our profession, other aspects of his work have go on to inspire safety philosophies that are based on sound engineering principles. This is why he is in the realm of Ptolemy and Freud instead of Rasputin." (Gesinger, 2018, p.24)

Gesinger does not provide in-depth critique - he admitted in personal conversation[112] that he did not read Heinrich's original texts before writing his book - and follows mainly critique raised by Manuele (whom he references to) and possibly Dekker (who clearly influenced Gesinger, but is not referenced on these points. Dekker also wrote the foreword to Gesinger's book).

Hummerdal

Daniel Hummerdal has a background from aviation and organisational psychology. After several years of consultancy, he started recently as 'innovation advisor' for WorkSafe New Zealand. In 2012, he started the Safety Differently website, which is a platform for many 'new view' authors. His work does not offer proper critique of Heinrich. His sole mentioning of Heinrich is one in passing:

> "13.000 stories about situations in which people either struggled with safety, or had stepped up to save the day!? And this in a company with one of the best accident records in the industry. Numbers fascinating enough to cast serious doubts on Heinrich's accident pyramid." (Hummerdal, 2013)

In the blog, Hummerdal does not explain these "doubts", but they are likely a reflection of how the triangle is often perceived as a simple metric or a fixed ratio, based on post-Heinrichian interpretations and applications of the triangle. After all, Heinrich does mention one to several thousand ratios in his work (e.g. Heinrich, 1929a; 1929b; 1931a).

Marriott

Craig Marriott is an experienced safety professional with a background in nuclear and petro-chemical industry. He is active on international professional forums, and runs his own website SafetyQuo.com with which he aims (as the title of his book suggests) to challenge the status quo within safety.

Marriott is quite generous in acknowledging Heinrich's contributions:

> "This was groundbreaking at the time and a great step forward in thinking, effectively forming the basis for modern leading indicator programmes." (Marriott, 2018, p.24)

[112] Personal communication with the author, 8 December 2017.

He also offers a nuanced discussion of the topics he picks up, showing various sides of the issue. Marriott is one of few authors who stresses that there is not one triangle, but several, "It should be quite apparent that the triangle will be a different shape for different industries" (Marriott, 2018, p.26)[113]

Marriott is the clear exception from the younger generation of 'new view' authors in the way he discusses Heinrich. Critically, yet through a nuanced discussion showing various sides of the issue.

Pariès

Jean Pariès has a background from, and several decades of experience in, aviation (safety). Currently he is president of Dédale, advising on human and organisational aspects of safety in various sectors. He has written a number of papers and contributions to the Resilience Engineering community, but only two are of direct interest in this study. In the first publication (Pariès, 2007), he more or less makes a Hollnagelian statement about linearity when mentioning the dominos.

A decade later, Pariès returned to Heinrich, this time discussing the triangle as an example of underlying beliefs within safety. He mentions known points of critique including examples of studies that do not support the correlation between minor and major accidents, and he suggests that the "assertion of a constant ratio between unsafe behavior, minor injuries, and fatal accidents" (Pariès, 2018, p.142) has been "refuted by many researchers".

Provan

David Provan has become a new name within the Safety Differently community during the past year. He has worked in various safety functions for almost two decades. He is a student of Dekker's, dedicating his PhD thesis to the role of a safety professional. Currently he works as a consultant and is quite active with a series of Safety Differently seminars.

Only one of his papers mentions Heinrich. In this paper, he does not discuss Heinrich directly, but rather comments on the state of safety practice and education with Heinrich and Heinrichian themes as examples.

Shorrock

Steven Shorrock is chartered ergonomist, chartered psychologist and human factors specialist with experience from various sectors. Currently, he works for Eurocontrol where he also is editor-in-chief of the HindSight magazine. He runs a blog, humanisticsystems.com, where he regularly publishes pieces about Safety-II and related subjects. In 2016 he co-edited/wrote the *book Human Factors and Ergonomics in Practice*.

Shorrock hardly mentions Heinrich in his work. He was one of the co-author of the Eurocontrol Safety-II white paper (Hollnagel, et al., 2013), but the mention of dominos and linearity in there is so typical of Hollnagel that there is little doubt about whose contribution this was. The other occasion where Shorrock mentions Heinrich is when he mocks him in the caption of a picture for a 2013 blog (Shorrock, 2013), which is rather untypical for his writing.

Townsend

Andrew Townsend was one of the early contributors to the Safety Differently website. He left the world a book before he passed away in September 2013. He critiques Heinrich's (and Bird's) research done for the triangle. Most of all, however, he directs his critique at the safety community for not recognizing and teaching the limitations of models. Townsend cautions that one cannot blindly take a concept and apply it directly to another context:

[113] It seems that Marriott relates to Hale (2002), Bellamy, et al. (2008) or Busch (2016), but does not reference either of them. This may be a deliberate choice by the author to make his book as accessible as possible for practitioners.

> "…few in safety stand back from their involvement in the here and now to recognise that things are changing. If they did, they might be alarmed. They would see that the original theories of Heinrich and Bird do not match modern standards of research." (Townsend, 2013)

In his discussion, Townsend attributes some things to Heinrich (or Bird) that are not theirs per se, for example the fixed ratios and proportional reduction.

4.4.6 Summing up: what is discussed?

The table below gives a global overview of the Heinrichian subjects discussed by 'new view' authors. The theme that attracts most mentions and critique is the triangle, which almost all 'new view' authors discuss[114], often commenting the assumption of fixed ratios or its use to drive a bureaucratic approach to safety reporting (more about this in Chapter 5).

Table 2: Heinrichian subjects discussed by 'new view' authors (based on appendix 3-6)

	Science	Triangle	Domino linearity	Role of worker	Other subjects
Dekker	x	x	x	x	Axiom Zero Taylorism, bureaucracy
Hollnagel		x	x	x	Axiom Importance Management
Long	x	x	x	x	Taylorism Zero
Anand	x	x	x		
Conklin	x	x		x	Zero
Gantt				x	
Gesinger	x	x		x	Importance Management Practical prevention
Hummerdal		x			
Marriott		x		x	Importance
Pariès		x	x		
Provan		x		x	
Townsend	x	x	(x)		

While the critique of the triangle is relatively homogenous, critique of Heinrich's view on the role of workers is more mixed. Somewhat surprisingly, there is little explicit critique of the 88:10:2 ratio. Here one could have expected much more from a 'movement' that tries to counter the common beliefs in constructs like 'human error', 'unsafe acts' and 'man failure'. As we saw earlier, Gantt provides a thorough critique of the belief in the duality of causes and that most accidents are attributable to 'man failure'. However, often the '88%' is rather mentioned in passing than critiqued, like when Besnard and Hollnagel discuss prevailing beliefs and state that the "concept of a human error became part of the safety lore" with Heinrich (Besnard & Hollnagel, 2012, p.16). When others like Dekker (2014a) and Hollnagel (2014b), or before them Rasmussen (1990), discuss the concept of 'human error', they generally do so without explicitly mentioning Heinrich.

Another subject of Heinrich's mentioned frequently - as we saw especially by Hollnagel - are the dominos, often in combination with the First Axiom. Usually, the dominos are used to describe an evolution in

[114] Only Gantt does not mention the triangle.

accident models, as an example of the 'old view' or traditional safety, and/or as a contrast to new approaches.

Finally, another recurring theme is the acknowledgement of Heinrich's importance for safety theory and practice by several authors (Gesinger, 2018; Marriott, 2018; Hollnagel, 2004; 2014b). However, as we will see in the next chapter, some authors choose to rather stress negative sides of Heinrich's contributions.

4.4.7 Bonus section: Manuele's critique

Having explored some 'new view' characteristics, selected authors to work with, and reviewed what these authors say about Heinrich in their work, the next chapter will show how 'new view' thinkers seem to make an 'old view' analysis of Heinrich. Before that, I want to provide some additional background. Earlier, I excluded a discussion of Manuele's critique of Heinrich from the scope of this thesis. While I do not intend to discuss and evaluate in depth what Manuele says, I think it is wise to give at least a brief overview of his critique, for the benefit of the reader. After all, much of the critique from 'new view' authors is based on the critique by Manuele (who is not to be counted among the 'new view') to some degree[115].

Fred Manuele has delivered two main works delivering extensive critique of Heinrich's work, while acknowledging Heinrich's contribution to safety. The first is the book *Heinrich Revisted: Truisms or Myths* that was published through the National Safety Council in 2002. The second was his paper, *Reviewing Heinrich: Dislodging Two Myths from the Practice of Safety*, for the October 2011 issue of *Professional Safety*, the magazine of the American Society of Safety Engineers (ASSE). In this paper, Manuele more or less revisits some of his earlier critique. The paper was later incorporated in the 2013 (fourth) edition of his book *On The Practice of Safety*. In 2014, Manuele expanded his Heinrich critique in a paper on incident investigation countering Heinrich's premise that supervisors are best qualified to do incident investigations (Manuele, 2014). Here he also repeats most of his 2011 critique.

The 2002 book *Heinrich Revisted: Truisms or Myths* contains extensive critique dealing with a large number of subjects, Manuele sums up his findings in nine points (Manuele, 2002, p.77-81):

1. Heinrich's sources are not available for review.
2. Are the data and ratios from the 1920s still valid in our time?
3. Heinrich placed disproportionate importance on 'psychology'.
4. The 88:10:2 ratio is invalid, and has done great harm.
5. The 1:29:300 ratio is invalid and the changes between versions are not explained.
6. The belief that the predominant causes for accidents with major and minor consequences are the same is not supported.
7. The 1:4 ratio of indirect costs is unsupported and it is not plausible that there is a universal ratio.
8. There is too much emphasis on individual unsafe acts as causal factors and not at other parts of the system.
9. The attribution of 'root causes' in Heinrich's domino sequence (ancestry and social environment) is socially inappropriate in our time.

Manuele's critique is thorough in some ways, notably in his comparison of the various versions of *Industrial Accident Prevention*, among other things in his discussion of unexplained changes between the first four editions[116]. With his critique, he delivers and important and influential contribution to safety science.

[115] Gesinger and Anand lean heavily much on Manuele's work. Others, like Marriott, Dekker and Hollnagel mention Manuele's critique without revealing how strong of an influence he was. Conklin does not reference or mention Manuele, but given his critique, it is hard to believe that he has not heard about it and has not been influenced by it. Gantt and Provan both reference Manuele, but seem not to use his Heinrich critique directly in their work.

[116] Given the fact that he has studied Heinrich's books closely, it is quite remarkable that Manuele does *not* comment the change of causes of a 'supervisory nature' in the 1931 edition to 'man failure' in the 1941 edition of *Industrial Accident Prevention*.

It is not without flaws, however. For example, he does pay a lot of attention to the various ratios, but does not discuss the function they may have (see Chapter 6.1.8). Also, it is remarkable that Manuele only concentrates on the first four versions of *Industrial Accident Prevention*, but discusses neither Heinrich's papers (of which at least the National Safety Council-papers should have been available to him, after all, his book was published through the NSC), nor the reworked 1980 version of *Industrial Accident Prevention*. These additional sources might have answered some of his issues. Besides, the 1980-update even features some of the critique that Manuele comes with - only two decades earlier.

5 Findings: How 'new view' discusses Heinrich

The previous chapter discussed characteristics of the 'new view', selected a number of authors, and presented an overview of their work addressing Heinrich. One should expect that 'new view' authors apply these 'new view' characteristics, or at least some of them, to their analyses - including their discussions of Heinrich. As it turns out, 'new view' authors seem often to fail staying true to 'new view' principles in their analyses of Heinrich's work.

5.1 Are the 'new view' analyses 'old view'?

In this section, I will take some of the characteristics presented in Chapter 4.2 as a guide and look into the discussion of Heinrich and Heinrichian themes by 'new view' authors. This will give us an opportunity to see these discussions through both 'old' and 'new view' lenses.

We will first look at richness of the discussions, cherry picking and telling 'single stories' before turning to normative language, judgement, and 'bad apples'. We will finish with local rationality. It is worth noting that this is not a strict divide. Things like for example ignoring context, cherry picking and telling 'single stories' are related, and they overlap. In addition, all of these factors contribute to understand the actor's local rationality. I have chosen to discuss them in separate sections here in order to explain better the points.

5.1.1 Context, depth and richness

Seeing things within their context is an important characteristic of the 'new view'. Telling rich stories with a lot of depth is encouraged, because understanding the context helps to make sense of why people do things when they do them. (Dekker, 2014a; Pupulidy, 2015)

Even though they are critical, many 'new view' authors pay (some) respect to or acknowledge Heinrich's contributions. However, few go the length to add depth to the discussion and explore, discuss and explain properly what Heinrich actually wrote or meant. Often, Heinrich is rather mentioned in passing, for instance when various accident models are discussed (e.g. Hollnagel 2002; 2012; Pariès, 2007) and in some cases as part of a general rant against traditional approaches of safety (e.g. Long, 2017a; 2018b).

> "Let's just all fall in line with the nonsense conga line and like lemmings perform the Heinrich Dance forever and a day." (Long, 2018f)

Even when substantial critique is given, 'new view' authors often stay on the surface and do not delve much into the relevant context. Many examples of this can be found. For example

> "Another influencing factor in industry choosing this trajectory for the analysis of accidents was the work of Heinrich, who declared that 88% of all accidents are the result of human error." (Heragthy, Dekker & Rae, 2018, p.3)

While the quote is surely right in its assessment, this is also a limited reading of Heinrich's argument by picking out one (granted, highly known and prominently communicated) element of Heinrich's message and stripping away a lot of context[117]. One notable and relevant omission in this case is that the 88% ratio is about *direct and proximate* causes. This nuance is often forgotten, which then propagates into other statements, like when Gesinger opposes Heinrich's attribution of 88% of all accidents to 'man failure (Heinrich, 1931a; 1941), to Deming's view. The latter attributes 95% of failure to problems in the system and 5% to workers (Deming, 1986). The argument that Heinrich is wrong while Deming is right appears regularly in discussions[118]. However, it is an argument that does not seem to realise that comparing the statements of Heinrich and Deming is like comparing apples and oranges because they talk about different

[117] While at the same time imposing a contemporary interpretation on Heinrich's assertion, since Heinrich himself did not use the term 'human error' until very late in his work.
[118] The earliest written source I have seen so far is in *Heinrich Revisited: Truisms or Myths*. (Manuele, 2002)

levels of analysis. Heinrich's attribution deals with *direct and proximate* causes, while Deming speaks of *underlying* causes[119].

Sticking to the 88:10:2 ratio, another example of lacking depth in an argument is when Dekker rather stresses the dubious basis of the ratio than that he engages in a substantial discussion:

> "He reached this conclusion on the basis of supervisor's accident reports. Of course - if you are a supervisor, you might want to say that you and the work environment you helped create are both blameless. Instead, the worker is the problem to control." (Dekker, 2014a, p.164)

That Heinrich's data was biased is correct, but there is more to it than just dismissing the assertion this way. Marriott put things into perspective with his nuanced view that precisely hits the point, "At its core, the 88 per cent quote is no more useful than saying, 'Most of our activities involve people'." (Marriott, 2018, p.82)

Many of the attributions discussed in Chapter 5.4, for example assuming the triangle as having stable and fixed ratios, can also be seen as a result of ignoring context and/or telling singular stories instead of searching for greater depth in the analysis

5.1.2 Cherry picking

Ignoring context can lead to cherry picking - or create the suspicion that an author is cherry picking, of course. Cherry picking can be both a conscious, calculated strategy to reinforce assertions and partial views, but also an attribution assigned by someone else after an argument is presented. We will leave in the middle which of those it is, the line between them is most likely blurry anyway. No one is ever truly impartial and arguments will be influenced by for example framing or prioritizing, stressing or downplaying certain elements.

Cherry picking can be done in a number of ways. Authors can do so unintentionally by reading too little, which gives them an incomplete picture and possibly only part of the message. They can also do so intentionally, by reading and presenting Heinrich's work selectively, or by presenting selective counter evidence. We find examples of the latter when 'new view' authors present evidence that disproves *one* interpretation of a metaphor or model and then dismiss the entire metaphor or model.

When the triangle is discussed by 'new view' authors, they often argue that it must be wrong, and support this by pointing towards research and data that show 'inverted triangles' where organisations have higher fatality rates while they are having fewer incident reports. We find this for example in *Behind Human Error*[120] (Woods, et al., 2010), where the authors draw on U.S. airline data, or the *Field Guide* (Dekker, 2014a), which is one of the many sources where Dekker cites the 1998 paper by Saloniemi and Oksanen (e.g. Dekker, 2014c; 2018b). One problem with these 'counterproofs' is that they only discuss one possible interpretation/application of the triangle, namely counting all accidents together and then categorizing them by consequence, while none of the counterproofs seems to approach the matter scenario based (Hale, 2002)[121].

Dekker critiques 'old view' investigators for "making tangled histories linear by cherry-picking and re-grouping evidence" (Dekker, 2002, p.374). Ironically, other authors (e.g. Parasuraman, Wickens and Sheridan, 2008) have argued that 'new view' authors (specifically Dekker and Hollnagel) practice cherry picking to make a point, for example to critique constructs as situation awareness. Other examples would

[119] More precisely, Deming distinguishes between special and common causes. The latter belong to the system.
[120] Note that this book discusses the Bird version of the triangle, but does not reference Bird (and does not reference Heinrich either).
[121] Besides, would comparing the various data not mean that one also should say something about the levels of reporting, and their categories and whether they are comparable? Heinrich states that they barely had any no-injury reports and that his team estimated a conservative 1:10 ratio of no-injury to minor injury accidents (Heinrich, 1931a; 1941). How did that work for the later researches? One should expect similar discussions in other papers. A fascinating subject for another study.

include painting cartoon-like practices of applications of root cause analysis (Hollnagel, 2004) and the triangle (Dekker, 2014a; Conklin, 2017a), even though many practitioners use these tools and metaphors in constructive and positive ways.

One could argue that 'new view' authors use these extreme examples as a pedagogical device to make a point. Additionally, Malcolm Gladwell countered accusations of cherry picking:

> "That is what all of us do. That's what we ought to do. The thing that a thinking person does, is they go out in the world, they weigh all of the evidence and then they choose the evidence that they find the most compelling… That's not cherry picking; that is being an intelligent human being!" (Skavlan, 2014)

As a counterargument to Gladwell, one might point out that cherry picking to make an argument and sway the audience to one's view may indeed be a smart move. Do keep in mind that Gladwell is a journalist, not a scientist. Scientists should ask themselves whether generalisation of misguided applications of certain theories amounts to good science. In science, arguments should show *all* sides, including or even especially evidence that speaks *against* a point of view. After all, it is through attempts to falsify that scientists should test theories. (Popper, 1963)

Telling all the facts and describing the entire context is impossible in reality. One will always have to make some kind of a selection of what to present. An author or investigator will try to present what he or she thinks is most relevant to the case. However, relevance is in the eye of the beholder, and will also depend on what story one wants to tell. Which brings us to the next point, because if stories depend on a selection of the material available, they should at least be as balanced as possible - or be clear about their limitations.

5.1.3 Telling 'single stories'

The 'new view' emphasises complexity. This implies that telling one version of a story is not enough since one point of view is not able to capture the complexity and many facets of a case. One needs to see a case from various sides, because telling one story is at the same time *not* telling many other stories

Because things are too complex to catch in just one single narrative, a 'new view' analysis would generally require presenting several perspectives as part of the analysis. Good examples of this are Snook's analysis of the shooting down of two helicopters (Snook, 2000), or more recently some accident reports by the Danish Maritime Accident Investigation Board that discuss the perspectives of the involved parties[122].

Cartoon-ish representations of certain practices can be regarded as 'single stories' because they reduce complexity into a highly simplified - often over-simplified - straightforward and superficial narrative that has no room for nuance. Several of these 'single stories' deal with the triangle, often taking later interpretations and misconceptions of the triangle as their point of departure while ignoring historical paths and developments. Only rarely authors approach the subject(s) with an inquisitive, curious approach, exploring what Heinrich is saying, how he is saying it, why he would say such a thing or even thinking about 'what's in it for us', even if Heinrich's work is flawed. In almost all cases, authors take one explanation or interpretation as a given. Rarely do they explore more than one view.

This makes claims about the triangle being refuted or disproven, by for example Provan, et al. (2017) and Pariès (2018), problematic because they do not explain what interpretation(s) or parts of subject they are discussing. In some cases the literature they point to disproves a stable ratio across industries (which Heinrich did not claim, see 5.4.3), or show that there is no connection between all accidents - the 'preventing slips, trips and falls does not prevent well blow outs' argument. This means that in general the

[122] A good example for this is the report on the collision of the ships Kraslava and Atlantic Lady in July 2015: http://www.dmaib.com/Ulykkesrapporter/KRASLAVA%20and%20ATLANTIC%20LADY%20-%20collision%20on%201%20November%202014.pdf

delivered proof tends to debunk *one* particular interpretation of the triangle, but not necessarily the metaphor as such.

An in-depth discussion of the triangle, whether it is valid or not, and under what conditions, would require a full study which is way outside the scope of this thesis. Still, one might remark that most discussions of the triangle are rather un-typical for the 'new view'[123]. Most lack richness, an exploration of different interpretations, or seeking to understand what Heinrich wrote before offering judgement. Instead, most critique simply follows the road paved by Manuele (2002; 2011), echoing his arguments with a rather binary attitude. Few refer to Hale's (2002) richer critique. Exceptions are Hollnagel (2004; 2014b), Marriott (2018) and to some degree Anand (2015) who add some depth and nuance. Hollnagel (2014b) even discusses various looks on the triangle.

The examples mentioned above are among the rare occasions where 'new view' narratives of Heinrich offer glimpses of 'multiple stories'. Another good example of the 'on the other hand' approach is by Conklin, who is very clear, calling the 88% attribution "…perhaps his most impact-fully wrong idea…" (Conklin, 2017a, p.61[124]). Then he offers the other side, nuancing: "To be fair, Heinrich did go on to tell employers that the managing of workplace hazards was more effective than managing worker decisions and behaviours…" (Conklin, 2017a, p.61) Finally, he concludes with the most likely correct return to the first point of view that "…after the grand statement that almost all of the problem (88%) was of the worker's doing, you can't really blame management for going after worker behaviour." (Conklin, 2017a, p.61)

5.1.4 Normative language and judgement

Besides looking at *what* is discussed by 'new view' authors, it is also relevant to see *how* it is discussed. As they say in Germany, "Der Ton macht die Musik"[125]. Relevant are among others style, tone, depth, framing, nuance, how open one enters the argument (like the discussion of context and cherry picking above) and whether one is normative and judgemental.

The 'new view' tells us to avoid judgement and normative language. However, avoiding these is very hard. Already the simple act of labelling things as 'new' and 'old' is a mild form of judgement. Intuitively, many people do interpret 'new' not only as a chronological attribute, but often attach also the meaning of 'better' to it. A much stronger form of judgement is by ridiculing things. Sometimes there are touches of hindsight and 'should have known better' in comments when one uses today's point of view as reference.

There appears to be some kind of a generation gap among 'new view' authors regarding both depth of the discussion and the tone, style and framing. On one hand, Hollnagel tends to speak respectfully of Heinrich and his legacy. The 'younger' authors, Dekker and Conklin, and especially Long on the other hand are much harsher and range from ridicule like "goofy pyramid" (Conklin, 2017a) to various forms of dismissal, like "nonsense of Heinrich" (Long, 2017a), "that damn triangle" (Conklin, 2018) and many other derogatory terms.

In the section on Dekker (chapter 4.4.2) we saw already an example how some authors rhetorically frame their discussion of Heinrich putting him in a negative light and thereby priming the reader. In addition, there are also other ways of discrediting his work. For example by stressing the fact that Heinrich's research data is not available, or calling him an "insurance salesman" (Long, 2012; 2014a; 2015a; 2017b). The latter delegitimises all of Heinrich's claims. After all what do salesmen know about safety? There may

[123] As mentioned in Chapter 2.1, I must stress that that the 'new view' is about *accident accounts* and not about how to reference and discuss other authors. In this thesis, however, I evaluate 'new view' authors on the basis of the standard that they are requesting for the analysis of accidents.

[124] Conklin's assessment echoes strongly Manuele's argument, "Of all Heinrich's concepts, his thoughts on accident causation, expressed as the 88-10-2 ratios, have had a significant effect on the practice of safety, and have resulted in the most misdirection." (Manuele, 2011, p.55) This is one of the reasons to assume that Conklin is familiar with Manuele's work as noted in Chapter 4.4.7.

[125] Which loosely translates into "It's not what you say, but how you say it".

even the thought in the back of our heads that we cannot trust a salesman[126], and an insurance guy even less!

One of the simplest and most frequent forms of judgement and subtle discrediting of Heinrich's work is that several authors make a point out of Heinrich's work being 'dated', or just being 'old':

> "It is indicative of the development of safety thinking that a model developed almost a century ago remains an active, and indeed heavily relied upon, part of our current approach to safety management". (Marriott, 2018, p.23)

Similar arguments are found in Gesinger (2018), others speak of "tired and outdated" (Long, 2014c; 2018a) and point out that "The thinking on which it is based is getting on in age - soon a century" (Dekker, 2014a, p.123). The point is not elaborated upon, however, just as if age were a self-explanatory disqualifier[127]. Being 'old' in itself should not be a relevant argument, of course. Newton's laws and Pythagoras' theorem are even older. Is that a reason to question them?

It is most of all just another kind of framing a message by playing on the instinctive human preference of 'new' above 'old'.

> "…as modern people came to admit that they did not know the answers to some very important questions, they found it necessary to look for completely new knowledge. Consequently, the dominant modern research method takes for granted the insuffiency of old knowledge. Instead of studying old traditions, emphasis is now placed on new observations and experiments. When present observation collides with past tradition, we give precedence to the observation." (Harari, 2011, p.283)

5.1.5 Bad apples and blame

The 'new view' is critical of blame (Woods et al., 2010; Dekker, 2003; 2014a; Conklin, 2012; 2016), but on occasion, blame creeps into the arguments of 'new view' authors while discussing Heinrich. According to the 'new view', 'bad apples', "individuals who repeatedly display incompetent or grossly unprofessional behaviours" (Dekker, 2014a, p.9) do not exist. However, maybe they do in some circumstances after all, because one could argue that, while not using that term in their critique, some authors regard Heinrich as a 'bad apple' in several ways.

Firstly, apparently he was a 'bad apple' in the academic system. Heinrich claimed to follow a 'scientific approach', but did not as academics expect from a scientist, and he did not live up to today's scientific standards:

> "…the subtitle of his book was A Scientific Approach. That would supposedly require him to at least divulge the basis for his selections or the statistical power behind his sample size." (Dekker, 2018a, p.86)

Heinrich was also a scientific 'bad apple' because his data are not available in the scientific domain, which makes it impossible to replicate his research and verify his assertions. In most cases, critique of this subject draws on Manuele's (2002, 2011) arguments. The 'science issue' will be a subject of more discussion in Chapter 6.1.

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[126] Ironically, salespeople often know a lot about human behaviour and ways to influence their behaviour. This thereby slightly defeats Long's point about safety being stuck in mechanical engineering approaches.

[127] This in contrary to the Lindy-effect as explained by Taleb (2012; 2018): non-perishable 'things' that have been around for a while and have survived, have proven their value (or resilience - for better or worse) and are likely to be around for a while in the future. The older, the more likely and the longer 'things' are to survive. This suggests that the triangle may be around for another 80 years while we will have to see about the future of Safety Differently…

Secondly, he was a 'bad apple' who introduced many 'bad' practices into the scientific community. The introduction of practices like Taylorism, safety bureaucracy, 'chasing zero' and the use of lagging metrics is attributed to him. Chapter 5.4 discusses several of these attributions

Even worse, according to some of Long's writing he was definitely a 'bad apple' because he introduced them in safety practice willingly. After all, calling something a "concocted cook-up" (Long, 2017b; 2018d), "fictional manufacture" (Long, 2014b) or "hoax" (Long, 2017c) suggests foul play and blames him "…of course, this whole article is about injury rates. More delusion, apparently injury rates are a measure of safety, *thanks Mr Heinrich*." (Long, 2017f, emphasis added) Ironically, given Long's sceptical stance about mechanistic thinking, he even more or less picks Heinrich as a 'root cause' for the Deep Water Horizon disaster.

Conklin is a bit more forgiving, but with an interesting moral tone, nevertheless,

> "Ultimately it is probably not fair to fault William Heinrich for all of our organizational and industrial biases towards prevention - but he is not without sin[128] in this story." (Conklin, 2017, p.61).

5.1.6 Local rationality

One of the key questions in the 'new view' deals with local rationality: Why did things make sense to people, then in that situation, given their knowledge and objectives? Failing to apply the principles discussed above hinders looking for local rationality. E.g. when one judges, it will be much harder to ask 'why does it make sense'.

With a few exceptions, 'new view' authors do not ask for or try to explore Heinrich's local rationality, but rather impose their perception. To paraphrase Dekker (2014a), authors often point out that Heinrich zigged when we know now that he should have zagged. While not by a 'new view' author, the following quote is very illustrative. Discussing Heinrich's approach to accident analysis, Manuele comments,

> "Note that the first proximate and most easily prevented cause is to be selected. That concept permeates Heinrich's work. It does not encompass *what has been learned subsequently* about the complexity of accident causation or that other causal factors may be more significant than the first proximate cause." (Manuele, 2002, p.22, emphasis added)

But what does that hindsight knowledge really give us? Agreed, Heinrich's premise to focus on causes very close to the accident is very limited and quite contrary to what is taught to safety practitioners and incident investigators during the past decades (e.g. Petersen, 1971; Bird and Germain, 1992; Groeneweg, 1992). However, without access to a time machine or a crystal ball that actually works, it would be hard for him to "encompass what has been learned subsequently". In Chapter 6.2, I will try to offer a glimpse into Heinrich's local rationality regarding causation.

Only Hollnagel and his co-authors, as quoted previously, try to explain explicitly why things made sense to Heinrich:

> "For these situations, Heinrich (1931) proposed that the most proximate cause should be prevented, *following a recommendation from the US department of Labor (1920) suggested* that more distant causes should be pursued for severe accidents, such as train accidents. *Thus, the model proposed* by Heinrich is linear, considering only the immediate surroundings, including line management. Although commitment from higher management levels were seen as vital for success in implementing safety work, Heinrich *did not think it was a fruitful* approach to point to higher management levels as causes. It is noteworthy that two lines of enquiry were considered: The first went through the person or surroundings, looking for causes to actions that in hindsight seemed

[128] An interesting word in this context. One wonders what Dekker and Long, who both have written about safety and religion make of this. (e.g. Dekker, Long & Wybo, 2016; Dekker, 2017d)

incorrect, or for causes of problems with equipment or other items in the surroundings. The second line of enquiry went towards the line manager, looking for reasons why the accident was not prevented." (Lundberg, Rollenhagen and Hollnagel, 2009, p. 1298, emphasis added)

5.2 Referencing Heinrich by the 'new view'

Some crude bibliographic searches showed an increased number of academic safety publications in general, as well as an increased number of (academic) safety publications citing Heinrich. One might suggest that one factor for this increase in citing is the general increase in safety publications, along with the 'blanket-citing' of standard safety work suggested by Hopkins (2014). Given its influence, Heinrich's legacy certainly belongs to the standard safety canon. Because of the steep increase in citations from 2003 onwards that we saw in Figure 11, it is also likely that the critique by Hale and Manuele in the early 2000s sparked off something[129].

Figure 15 shows that most 'new view' authors citing Heinrich appear to have developed interest for Heinrich's work only recently. Most of the material is post-2012, the main exception being Hollnagel. Hollnagel is also the only 'new view' author among the authors most frequently citing Heinrich in the search shown in Figure 13. It is hard to determine with certainty whether this time-lapse, the late, post-2012, citing is a specific 'new view' phenomenon, or a delayed part of the larger general development mentioned before. I will return to this question at the end of this chapter and suggest that it is a bit of both.

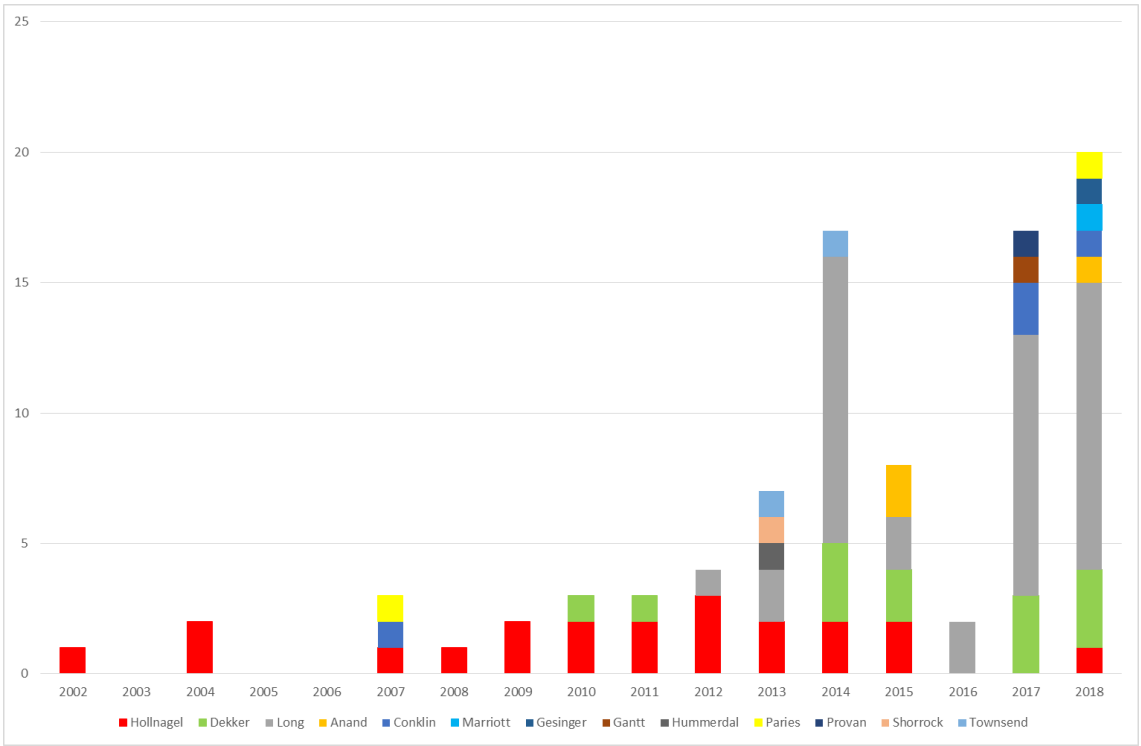

Figure 15: Heinrich citations of selected 'new view' authors per year. (Source: Appendices 3-6).

One should note that Figure 15 merely shows the number of publications that mention Heinrich, or Heinrichian themes. The figure does not say anything about the 'intensity' or 'amount' of discussion in a year. The most concentrated discussions can be found in a few publications, like Hollnagel's books *Barriers And Accident Prevention* and *Safety I And Safety II* and the Dekker titles *The Field Guide to Understanding 'Human Error'* and *The Safety Anarchist*.

[129] This could be tested further by looking into the number of publications continuing from Hale's and Manuele's work - and citing Hale and/or Manuele, but we will not do that in this thesis.

5.3 A side-track: Quotation error

Among other things, this chapter looks into referencing and citing. The practice of referencing and citing is important in academia. Doing so correctly is important too. Therefore, we should stop just for a moment and look into when things go wrong and quotation errors occur.

So far, there is not much study of quotation error in safety and human factors. Lock and Bearman (2018) have recently looked into the subject, drawing on work within other disciplines. They mention various negative effects of quotation errors, including obstruction of progress, misdirection of research, creation and spread of misinformation and myths, errors becoming a part of literature, and ultimately harm to credibility and reputation of academia and science.

Lock and Bearman (2018) use Diane Vaughan's concept of 'normalization of deviance' (Vaughan, 1996) as a framework to both study and explain quotation errors. Vaughan's three elements of normalization of deviance, 'culture of production', 'production of culture', and 'structural secrecy', offer plausible factors to explain how the academic system contributes to the rise and spreading of quotation errors.

- The pressure on academics to publish, using quantitative ratings and metrics, contributes to a 'culture of production' where shortcuts are taken in order to deliver, for example by browsing sources superficially, relying on memory instead of double checking, and using secondary sources instead of going to the original source.
- Within academic circles, quotation is considered important for a variety of reasons and this is enforced through standards (like APA) and peer review. Academic texts are expected to contain arguments supported by the work of others, through references. Through 'production of culture', quotation has therefore become part of 'academic culture' - it is the way things are done in academia. However, this may also be overdone, as for example seen in the Hopkins (2014) quote earlier this chapter.
- Lock and Bearman (2018) mention a number of factors how ETTO-ing practices (Hollnagel, 2009), that trade efficiency for thoroughness, like the shortcuts mentioned above, contribute to 'structural secrecy'. An ever-growing volume of academic texts (see the diagrams in Chapter 3 as an illustration) creates great difficulties to read everything, so one may rather rely on abstracts or secondary sources, and not grasp the full measure of an argument.

When looking through the material studied for this thesis, one may notice a rather large volume[130] of quotation errors. Some of these are simple individual mistakes, e.g. listing the wrong year (Long, 2018a, p.145). Others, however, are more structural or serious. The most common citation error with regard to Heinrich is that authors reference to the 1931 edition of *Industrial Accident Prevention* when discussing the domino model. This citation usually serves as a contrast to new models, or as an example for linear models and thinking, like:

> "…the approach we now know as Safety-I, still assumes at its heart that adverse outcomes can be explained by linear cause-effect chains, as originally proposed by the Domino metaphor (Heinrich, 1931)…" (Mannion & Braithwaite, 2017, p.686).

This example is quite typical in referring to the 1931 book, which does not feature the dominos - neither the drawing nor the term. The dominos did in fact not appear before 1934, with the accident sequence brochure (Travelers Insurance Company, 1934), and for most readers not before the 1941 edition of *Industrial Accident Prevention*.[131]

One may wonder where this relatively frequent error comes from. The suggestion to use the elements of 'normalisation of deviance' as a possible systemic explanation (Lock & Bearman, 2018) appears useful. No

[130] Check comments in appendices 3 to 6.

[131] Apart from checking the original sources, this knowledge can be gained from recent sources like for example Manuele, 2002; Van Gulijk, Swuste, Ale and Zwaard, 2009; or Busch, 2016.

proper analysis of the various cases has been carried out, but the below points can be regarded as suggestions:

- Culture of production: Authors and academics are busy people. Many are in demand as speakers, or are prolific writers. Verifying every single source is a demanding process. It is easier and more efficient to reuse something that has been written before, or make other trade-offs between efficiency and thoroughness (accuracy).
- Production of culture: Apparently, neither the peer-reviewing process of academic journals, nor the editorial work of book publishers do manage to catch and correct these mistakes. This may mean that established quality control processes actually help to normalise the error. One could also draw on Cialdini's (1984) principle of "social proof" at work: everyone - including highly renowned scholars - quotes 1931, so it must be the correct thing to do.
- Structural secrecy: Firstly, the 1931 version is notoriously hard to locate[132], so it is not easy if you actually want to check the original text. Secondly, the dominos appear in *all four* later versions of *Industrial Accident Prevention*. It is not entirely unreasonable that people, who actually take the effort to check one of the later versions, assume that the dominos also are found in the first one. Thirdly, also later versions are hard to find. With the book being out of print for several decades, it is tempting to rather rely on secondary literature. Especially when this is written by respected authors.

One of these respected authors is Erik Hollnagel. He is one of the authors who uses frequently this wrong citation - even though he is an author who appears to have studied Heinrich's work well, and is familiar with among others the 1934 domino paper (and even references this on a few occasions). When Hollnagel was asked whether we are dealing with an efficiency thoroughness trade-off (ETTO) (Hollnagel, 2009), he agreed that the quotation is indeed factually incorrect, and that this might be the case. Besides this, he also offered an alternative explanation, namely pointing to the sequence of events that according to Heinrich make up an accident[133]. This sequence is found as early as 1928 in Heinrich's work and may lead some to cite the first book[134], even though the graphic representation of the model with dominos came later. Hollnagel suggests as alternative for those who insist on quoting 1931: "The proper, but clumsy, way of describing this would be to say that "a theory of accident causation, today known as the Domino Theory, was described by Heinrich in 1931"."[135]

The '1931 error' is what Lock and Bearman call "reference accuracy" (Lock & Bearman, 2018, p.293), the accuracy with which a source is cited. They also identify another type of quotation error, namely "quotation accuracy" (Lock & Bearman, 2018, p.294), which deals with the accuracy with which an author is being cited. Of the two, this one is the more serious, according to Lock and Bearman, since this may mean that an author uses another author's argument to support his own, even if the reference makes a point that is quite the opposite. This may lead to "the propagation of misinformation" (Lock & Bearman, 2018, p.294).

In the studied material, we find an instance of this type of "quotation accuracy". Dekker arguing against the triangle, discusses the work of Wright and Van der Schaaf (2004):

> "The results they produced provided qualified support for the common cause hypothesis for only three out of the 21 types of causes. Only these three had significantly different proportions for the three consequence levels that were investigated: injury & fatality, damage and near miss. In other

[132] It took me over two years of serious, yet unsuccessful attempts on Amazon, eBay and through my network. Eventually my librarians managed to get one from abroad!
[133] This explanation does fit with the way Hollnagel presents the matter in his 2002 conference paper - his first discussion of Heinrich in the reviewed material.
[134] Although it would be more correct then to attribute the accident sequence to earlier authors, like for example DeBlois (1926). The link to the domino metaphor would become rather vague for most people, however…
[135] Personal communication with the author, 2 May 2018.

> words, for the data in this study, declaring zero[136] for small stuff would have been effective for bigger stuff only one in seven times." (Dekker, 2017b, p.4)

This, however, is not what Wright and Van der Schaaf actually found. The common cause hypothesis (i.e. accidents with minor and major consequences share similar causal paths) would be supported when *no* significant different proportions for the consequence levels were found. What Wright and Van der Schaaf did find was that only three out of the 21 causal codes did have significantly different proportions for the studied consequence levels, while 18 out of 21 codes showed non-significant differences. Based on this, Wright and Van der Schaaf conclude:

> "Therefore, overall, these findings provide qualified support for the common cause hypothesis within the railway domain." (Wright & Van der Schaaf, 2004, p.109)

Dekker uses this quotation error again in *The Safety Anarchist*[137], and - most likely based on these previous misinterpretations - continues[138] to use Wright and Van der Schaaf as a support of his arguments against the triangle, quite opposite to Wright and Van der Schaaf's argument:

> "As we have long known (…), there is of course no meaningful relationship between slips, trips and falls on the one hand and process safety disasters on the other (Hopkins, 2001; Salminen, Saari, Saarela, & Rasanen, 1992; Wright & van der Schaaf, 2004[139])." (Dekker, 2018b)

The interesting question is, of course, how to handle these quotation errors. Even though the '1931 error' does little harm, accepting quotation errors is not really an option. We know that mistakes will happen, but academia will probably strive for highest possible standards anyway, also for minor misquotes. And one should definitely strive to prevent serious errors. The question is thus: how? Answering this is not within the scope of this thesis, but let us just allow for some reflections:

As 'new view' authors teach us, blaming the author for sloppiness is not a useful way forward. Like most other workers, these authors come in general to work to do a good job, and most likely, it is not their goal to 'commit' quotation errors[140]. Also, whatever authors may claim in the forewords of their books, these are not their errors alone. Others and systems are in place around them. These systems and social redundancy play a role as well.

So, the question of how to handle these quotation errors becomes even more interesting when we consider that the barriers that are put in place to ensure quality - notably the peer review system, as well as quality assurance systems established by publishing houses - apparently are unable to catch and correct these errors. In some cases, they possibly even contribute to structural errors becoming part of the literature. How does this happen? Are reviewers also pressed for time? Do reviewers have the necessary knowledge to assess the entire material assigned to them? Do reviewers sometimes suffer from a 'halo effect' (Thorndike, 1920) when it comes to certain authors? Do reviewers assess the errors as not serious enough to react? Do authors and editors ignore the comments?

More research is needed - for the benefit of safety science. Since we know that it will be impossible to prevent quotation errors entirely, it is probably sensible to try to be more conscious about some ETTOs we make. In addition, one might suggest relying to a lesser degree on certain types of literature, notably 'guru books' and secondary sources.

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[136] From the triangle to zero - not quite what Heinrich's wrote, see Chapter 5.4.2 on that subject.
[137] Check pages 84 and 91.
[138] The error will be corrected in Dekker's forthcoming book *Foundations of Safety Science*. (Personal communication with the author, 15 December 2018)
[139] For the record - while they do not support Dekker's argument against the triangle, neither do Wright and Van der Schaaf claim that slips, trips and falls share meaningful relationships with process safety disasters.
[140] Although one sometimes might suspect that some authors build a strawman-argument…

5.4 Ungrounded attributions

In the thinking of the safety triangle (Heinrich, 1931a; 1941), precursors of a certain kind of accident can - if left unchecked - develop into accidents with more or less serious accidents. Not removing a tripping hazard may lead to actual trips and eventually to more or less serious injuries, in an extreme scenario even to a fatality (however, not to a well blow-out). We can use this analogy when looking at quotation error. One possible precursor of quotation error might be questionable attributions or unsubstantiated claims made in literature that others then copy, cite, and spread through literature. Eventually, misleading and uncorroborated attribution can be accepted as a fact and then contribute to spread disinformation and lead to the creation of new beliefs and myths. In the reviewed publications, we can find several questionable attributions or unsubstantiated claims. I will review some of these below.

5.4.1 Zero

Several authors (Dekker, 2018a; Long, 2017b; Conklin, 2017a) connect Heinrich with 'zero harm'. This may seem obvious, after all Heinrich states that nearly all accidents (98%) are preventable (Heinrich, 1931a; 1941). Even the remaining 2% are in his view mainly due to the fact that "in practice the cure for an accident cannot always be applied effectively" (Heinrich, 1931a, p.45) rather than the often-cited 'acts of God' (a term Heinrich only uses once in the 1941 edition of *Industrial Accident Prevention*).

That, however, is only one superficial side of the discussion. Studying Heinrich's work more closely, one will find out that Heinrich states that nearly all accidents are preventable, but that he is far from a zealous, starry-eyed 'Zero Harm' perspective. He is much more realistic and wrote, "In practice it is difficult to so perfect an industrial organisation that all of these accidents can be eliminated". (Heinrich, 1928a, p.11)[141] Most likely, Heinrich sees the preventability of nearly all accidents merely as a hypothetical possibility and something that is judged in hindsight: "We know that we can never attain perfection - that we can never achieve the ideal; and we know therefore, that accidents will continue to occur in sufficient numbers to keep the wheels of insurance turning". (Heinrich, 1929c, p.173) Also, he is clear about the fact that safety and production have to be balanced, "Safety at any cost, safety at all costs, is not to be desired" (Heinrich, 1930b, p.151).

Other places, he nuances the '98%'-statement drastically with practical realism:

> "Not more than 2 per cent of all accidents are of the so-called 'act of God' or wholly unpreventable type. Of the remaining 98 per cent, 50 per cent are practically preventable and 48 per cent could be prevented[142] if it were not for practical consideration of cost or interference with production and profit. All preventable accidents are controllable by management." (Heinrich, 1941, p.106)

It is also interesting to note that Heinrich is not adamant that 98% are preventable, period. Instead he calls them of a "preventable type" (Heinrich, 1931a, p.50) or "preventable kind" (Heinrich, 1941, p.20), meaning that they could be prevented given certain circumstances.

Still, there is some ambiguity. The text accompanying the 1959 version of the triangle, "Moral 1: Prevent the accidents and there can be no injuries" (Heinrich, 1959, p.27), can be interpreted as aiming at zero. Also, Heinrich is generally positive about the effect that 'no-accident contests' (proto 'Zero Harm') can have. However, he offers also critique. For example that these 'contests' usually are directed towards LTIs and the like (which they still are to this day) and Heinrich explains with examples how LTIs are a weak measure of safety: "The occurrence of lost-time accidents or serious injuries, in itself, does not always

[141] Similar rejections of perfection and thereby 'zero' can be found other places, for example: "…it is a practical impossibility to attain perfection…" (Heinrich, 1931b, p.9).
[142] Heinrich does not explain where he takes the 50% and 48% from. Most likely, he just made an educated guess. It is interesting to note that he lends a slight majority to the 'preventable' side instead of simply splitting evenly.

provide an accurate measure of the conditions out of which they arise". (Heinrich, 1931a, p.123). He also recognizes that these 'contests' are only useable as temporary actions because they wear off[143].

5.4.2 Triangle and zero

In general, authors attributing 'zero' to Heinrich, connect this to the triangle and see the triangle as an expression of striving for zero harm, "…with ideas like Heinrich's pyramid, the notion every accident is preventable." (Conklin, 2017a, p.51; similar statements are found in e.g. Dekker, 2018a; Long, 2017e). This is based on post-Heinrich interpretations of the triangle that a reduction of minor events will prevent major ones, and eventually make it possible to reach a 'goal' of zero accidents. Dekker (2018a) for example discusses the triangle and the 'numbers game' that some organisations have made out of it.

While a thorough study of the triangle is outside the scope of this thesis, we need to contrast this attribution to Heinrich's view. As mentioned before, Heinrich regarded the triangle in the first place as an opportunity. One does not have to wait until the harm is done, one can intervene and try to prevent accidents from happening before someone is injured.

> "…in prevention work, the importance of any individual accident lies in its *potentiality* of creating injury and *not* in the fact that it actually does, or does not, so result. When lost-time or so-called 'major' accidents are selected for study, therefore, as a basis for records and for guidance in prevention work, efforts are often misdirected, valuable data are ignored, and statistical exposure is unnecessarily limited". (Heinrich, 1931a, p.88, emphasis in original)

This should appeal to common sense (by lack of a better term), and yet still today, many investigations start mainly after major consequences. "…in general, attention is centred upon these more spectacular occurrences to the exclusion, in part at least, of adequate consideration of minor accidents" (Heinrich, 1929a, p.2), he wrote and Heinrich's quote rings true today "…present day accident prevention work is misdirected when it is based largely upon the analysis of major injuries". (Heinrich, 1941, p.30)

Dekker argues (rightly) against the fallacy of thinking that measures to prevent minor occupational incidents, like slips, trips and falls will prevent major (process) accidents. Based on applications like these, he writes that it is misguided to believe that, "Eliminating occurrences rather than injuries, then, should help estimate safety risks, even the risks of more grievous harm or fatality." (Dekker, 2018a, p.87) However, this is a confusing sentence. Since he disapproves of the triangle, the quote might suggest that one should concentrate on consequences, which would be a step into a *reactive* direction. This is not what Heinrich had in mind, and neither what one would expect from Dekker. Heinrich suggests aiming at events rather than consequences, because the consequences of accidents may be rather random (e.g. Heinrich, 1929a), as stated in his Sixth Axiom, "The severity of an injury is largely fortuitous…" (Heinrich, 1941, p.12), and there are fewer of them. It was not the outcome, but the *potential* that is interesting from a safety management (and prevention) point of view. Therefore, Heinrich meant one should address *all* accidents, not merely those that had led to injuries. It is important to understand that Heinrich did not distinguish between accidents and incidents (like others after him often would do). To him any unwanted event was an accident, regardless the consequences. However, the simple principle of addressing events instead of consequences is forgotten or ignored in many applications of the triangle. This leads to approaches that add little or nothing, or even waste resources and give a false sense of security.

In summary, the triangle as a metric is not Heinrich's message, and turning it into a 'number's game' as described by Dekker (2014a, p.176-177) has nothing to do with the principle, but rather with how safety is 'managed' (in various meanings of the word) in some organisations. One should also note that the triangle was originally an argument *against* "suppressing such learning opportunities" (Dekker, 2014a, p.176) and rather an invitation to *use* these opportunities.

[143] So much for all those companies with their proud LTI scores at the gates.

5.4.3 Fixed ratios

Some authors claim that Heinrich talked about a fixed ratio (e.g. Townsend, 2013; Long, 2014b; Dekker, 2018a). Among others Manuele (2002) mentions a case of safety professionals who actually believe so. Some talk even about 'Heinrich's Law' when discussing the 1:29:300 ratio[144]. Attributing the belief in a fixed ratio to Heinrich is not correct, however.

Sure enough, Heinrich invariably mentions the 1:29:300 ratio when he talks about the triangle[145], and his choice of wording is sometimes quite definite. Taking statements like "…it requires 330 accidents to produce only 1 major injury and 29 minor injuries" (Heinrich, 1931a, p.90) in isolation, may suggest a mechanistic view and a fixed ratio. However, one has to read this in its context where he lists many examples of different ratios (Heinrich, 1929a; 1929b; 1931a; 1941) and he stresses regularly the fact that we are dealing with averages and estimates, "…there are *at least* ten others" (Heinrich, 1929a, p.5, emphasis added) and "…we are able to estimate…" (Heinrich, 1929b, p.9), he wrote. Also,

> "…for every mishap resulting in an injury, there are many other accidents in industry which cause no injuries whatsoever. The investigation has enabled us to establish the conservative ratio of 10 to 1, between no-injury or potential-injury accidents and those causing injuries." (Heinrich, 1929a, p.1)

About the lowest level of the triangle, Heinrich says, "it probably never will be known exactly" (Heinrich, 1931a, p.89) and he suggests that some accidents do not have a ratio at all: "…it may be the result of an exceptional isolated accident-type that might never occur again" (Heinrich, 1929b, p.10).

As Manuele correctly remarks,

> "…ratios can be produced from most statistics on accident occurrences. And they may have value in their own settings. However, in a constantly changing world, those ratios may not have permanency, nor are they universally applicable in all work environments." (Manuele, 2002, p.40)

Hale (2002) makes a similar argument, as does Hollnagel (2014b).

5.4.4 Lagging indicators

Long suggests that Heinrich promoted the use of injuries and other lagging indicators as a measure of safety (Long, 2014a; 2015a; 2017d; 2017f; 2018f), making statements like "…apparently, injury rates are a measure of safety, thanks Mr. Heinrich" (Long, 2017f). While Heinrich may have contributed to a much wider acceptance of accident prevention as something that management has to pay attention to, the use of lagging indicators can hardly be attributed to him. Safety has been measured in terms of accidents and especially consequences (injuries and fatalities) since its earliest steps as a profession (e.g. Eastman, 1910; Beyer, 1916; Ashe, 1917; DeBlois, 1926), and some even rather talked about 'accident prevention' than 'safety' (Beyer, 1916; Ashe, 1917; Heinrich, 1931a; 1941).

So, it is easy to debunk the attribution to Heinrich, but studying his work, one can strengthen the argument against this attribution further. Firstly, Heinrich is very clear about the difference between accidents and outcomes, stressing the difference of the various phases of an accident many times in his work. The above discussion of the triangle showed us that he places little value on the consequences since these are rather random, as stressed in his Sixth Axiom (Heinrich, 1941).

Secondly, at times Heinrich is very outspoken and critical on the use of lagging indicators. As mentioned before, in his discussion of no-injury contests, Heinrich explains with examples how LTIs are a weak measure of safety: "The occurrence of lost-time accidents or serious injuries, in itself, does not always provide an accurate measure of the conditions out of which they arise". (Heinrich, 1931a, p.123). He is

[144] From the 'new authors' in this study we can point to Conklin (2007), Anand (2015) and Gesinger (2018).
[145] We will not discuss this in Chapter 6, but one might ask why this makes sense to him. One strong suggestion is that the ratio is highly recognizable and memorable thanks to the convenient numbers (1+29=30; 30+300=330) and provides thereby a good way to anchor the idea with the audience.

also very clear on the subject in the chapter on Accident Statistics: "For the average plant, a record of lost-time injuries only is insufficient" (Heinrich, 1941, p.342). Instead, Heinrich advocates including other - minor - events to be part of the statistics and suggest that one should pay attention to behaviour and conditions *before* something happens.

If anything, Heinrich has contributed to nudge safety management into a *less* reactive ('lagging') direction through the triangle, by suggesting to pay attention to accidents (events, conditions, acts) rather than injuries.

5.4.5 Safety bureaucracy

Because in many organisations "record-keeping and incident analysis" has become "a bureaucratic initiative" (Dekker, 2018a, p.82), some 'new view' authors associate Heinrich with safety bureaucracy.

> "…in tribute to my many safety colleagues who waste countless hours each week reporting on things that don't matter, tabulating data of irrelevance and maintaining worship to Heinrich and Bird by statistics…" (Long, 2018c)

While Heinrich on several occasions promotes the improvement of incident statistics (Heinrich, 1932c; 1935) and even dedicates full chapters to the subject in *Industrial Accident Prevention* (Heinrich 1931a; 1941) he did not intend them as a bureaucratic enterprise. Instead, he saw it as a way to support and improve accident prevention by presenting organisations with more and richer information to base their decisions on and direct their accident prevention work.

> "The value of statistics lies in the conclusions that may be drawn from them and upon which corrective action may be based. Statistics provide a valuable clue to the causes of future accidents. … with the conclusions drawn from statistics as a guide, a study of present conditions may be profitably made and a final decision as to the method of existing known accident causes more readily reached." (Heinrich, 1931a, p.263/264)

Even more, Heinrich was a practical man who was no fan of unnecessary paper work and unpractical solutions. "Practicability and common sense must prevail in safety as in other things..." (Heinrich, 1941, p.139), he wrote. In his *Safety in the Small Plant* speech (Heinrich, 1932a), he is quite clear about this. The second paragraph discusses how small plant owners may be reluctant to engage in safety because it looks overwhelming with procedures, records and "red tape"[146]. Heinrich even goes one step further later in the speech: "The accident preventionists, moreover, because they fail generally to emphasize simplicity and principles, share responsibility for this situation…". (Heinrich, 1932a, p.31) This reminds of *The Safety Anarchist* (Dekker, 2018a) and the "safetycrats" of Marriott's book (2018). Heinrich recognized how safety practitioners can be their own worst enemy.

5.4.6 Heinrich a Taylorist?

Scientific management, in 'everyday speech' often called Taylorism because of its promotor Fredrick Taylor during the early years of the twentieth century, is a highly successful and widespread management theory. It "changed the workplace for good" Donkin (2001, p.144) remarks, while at the same time noting that the principles were not new at all. Military had drilled soldiers since the dawn of time and the breakdown into separate tasks had also been practiced in many industries and activities for centuries, but probably not at a scale and with a rigour as launched after Taylor and Ford.

Taylor (1911) stated "the best management is a true science, resting upon clearly defined laws, rules, and principles, as a foundation". According to Taylor, any human activity can be improved through "rigorous analysis" (Stewart, 2009, p.30) and finding the 'best way' to perform the activity. For this he adopted a mechanistic approach, taking "…the logic of the machine shop into the human world. It rested on a

[146] The exact same argument returned also in the *Sand and Gravel Industry* paper later that year (Heinrich, 1932b).

freighted analogy between the technology of machines and the technology of human organisation." (Stewart, 2009, p.28) Taylor (1911) specified four essential elements of scientific management:

1. The development of a 'scientific approach' to work by reductionism and breaking work down into separate tasks, making the task measurable through time-motion studies and production criteria[147], simplification and standardization of tasks, specifying steps, and finding 'one best way' of doing the work.
2. Selection and training of workers according to these 'scientific' principles.
3. Cooperation with workers[148], to make sure tasks being performed according to these 'scientific' principles.
4. A division of work and responsibility (accountability) between management and the workforce; thinking/planning and doing are separated.

One of the strongest attributions made by 'new view' authors (and others) is when they place Heinrich squarely into Taylor's camp. Long and Dekker are among those who associate Heinrich directly with Taylorism in their publications (Long, 2013; 2014a; Dekker, 2018a). However, they do not offer any concrete explanation or support for their claims by pointing out specific references or practices advocated by Heinrich.

The association of Heinrich with Taylor is probably based on two things. Firstly, there is the subtitle of Heinrich's book *Industrial Accident Prevention*, which reminds of Taylor's 'scientific management'. Secondly, there is the fact that this book was written in the late 1920s/early 1930s and therefore common wisdom suggests that Heinrich must have been influenced by the successful major management movement of the period. This is seemingly confirmed by the fact that Heinrich wrote about controlling 'unsafe acts'.

These days, Taylorism is often seen as a synonym of 'bad', especially in the Human Factors community/'new view' circles. Other authors, like Stewart (2009), Peters and Pauw (2004), Schwartz (2015) and Pink (2009) are very critical as well. Dekker's discussion in *The Safety Anarchist* is relatively neutral, yet critical and he does classify Taylorism as "dehumanizing" (Dekker, 2018a, p.43) and speaks of "Orwellian managerial control" (Dekker, 2018a, p.103). Linking something, or someone, to Taylor is for many people not a positive association. Hollnagel notes, "Today Taylorism is unfortunately often used in a negative sense meaning an oversimplified and 'mechanical' approach to work management" (Hollnagel, 2014c, p.41 f1). It is worth nothing that Hollnagel offers a surprisingly nuanced brief discussion of Taylorism, stating "Scientific Management rightly deserves to be seen as a kind of proto-ergonomics" because of techniques like bottom-up task analysis and time/motion studies (Hollnagel, 2014c, p.41).

This thesis is not the place to do a thorough study, but based on reading Heinrich's collected work the answer to the question whether he was a Taylorist has to remain inconclusive for the time being. Heinrich does indeed have some elements that can be connected to Taylorism. He discusses job analysis, "break down the job into its several operations and show the hazards of each…" (Heinrich, 1931a, p.96), among other things as a guide for worker selection. On several occasions, he suggests that there are 'best ways' of doing a job, and separates management and workers; between them who do as they are told and "executives who are paid to do their own thinking" (Heinrich, 1932d, p.72) with management in an enforcing role (Chapter 5 of the 1931 edition of *Industrial Accident Prevention* is titled "Executive Enforcement of Corrective Practice"), echoing Taylor:

[147] Stewart (2009, p.54) notes that Taylor initiated a "dogma of a singular metric", e.g. efficiency, or sales, which is another form of reductionism since there are in general many different, competing objectives (Rasmussen, 1997).
[148] This point may seem remarkable since Taylorism is usually understood to be connected to mechanistic organisation, and command and control towards the workforce. Instead, Taylors speaks several times of "friendly cooperation" between management and workers. Still, Taylor's cooperation has to be understood in a paternalistic way and with the underlying aim that each should do that he is best suited for: management planning and preparing, workers doing, well, the 'dumb' work. Cooperation then could rather be seen as 'implementation' than an open exchange between thinkers and doers.

> "It is only through enforced standardization of methods, enforced adoption of the best implements and working conditions, and enforced cooperation that this faster work can be assured. And the duty of enforcing the adoption of standards and of enforcing-this cooperation rests with the management alone." (Taylor, 1911)

There is another similarity between Taylor and Heinrich, which might suggest that Heinrich was inspired by Taylor. When Taylor (1911) introduces his aims, he states the following:

> "First. To point out, through a series of simple illustrations, the great loss which the whole country is *suffering through inefficiency in* almost all of our daily acts.
>
> Second. To try to *convince the reader that the remedy for this inefficiency lies in systematic management*, rather than in searching for some unusual or extraordinary man.
>
> Third. To prove that the *best management is a true science, resting upon clearly defined laws, rules, and principles*, as a foundation. And further to show that the fundamental principles of scientific management are applicable to all kinds of human activities, from our simplest individual acts to the work of our great corporations, which call for the most elaborate cooperation. And, briefly, through a series of illustrations, to convince the reader that whenever these principles are correctly applied, results must follow which are truly astounding." (Taylor, 1911, p.2, emphasis added)

When we start reading *Industrial Accident Prevention*, Heinrich follows very much the same structure. He opens with a tale of waste and hidden costs, even connecting inefficiency and safety (Heinrich, 1931a, p.3). He then suggests a structured, systematic approach based on principles and says that the same principles used production and quality can be used for safety (Heinrich, 1931a, p.5). This resonates well with Taylor's build-up quoted above. Still, that does not make him a Taylorist per se.

The most obvious link to Taylorism is found in the title of the paper *Keep 'em Moving (War-time Motion Study and Foremanship)* (Heinrich, 1942[149]). In this text, he promotes a 'one best way' approach: "…there is but one right way - one best set of production motions to do a given job - and who knows that way to be the safest and quickest" (Heinrich, 1942, p.175), "They are in a certain sequence and *must be done in that sequence*" (Heinrich, 1942, p.177, emphasis in original) and "…every job or task is made up of a number of separate acts performed in a correct sequence…" (Heinrich, 1942, p.177). He even uses a men-as-machines analogy in the preceding paragraphs, and summarizing his point towards the end, he states:

> "…there are right and wrong motions of persons. Know the right ones and the safe ones. Analyze each personal task, write down the motions, if this will be helpful, watch for violations, instruct your men, and see to it that they do the job the way you want them to do it; namely the best way, which is invariably the safe way." (Heinrich, 1942, p.178)

On the other hand, however, Heinrich has a somewhat loose interpretation of 'motion study'. In his view 'motion' equals 'act', more or less, and he does not stress *measuring* time and motion, which was quite essential in Taylor's approach.

Next to the above quotes that seem to make Heinrich a follower of Taylor, we can also find passages in Heinrich's work where he positions himself apart from Taylorism. While making the distinction between management and workers, Heinrich does not promote a strict Taylorist distinction. Like the 'new view' he thinks that one should ask the people who actually do the job. They know best, Heinrich agrees: "…in many cases safety may be promoted by employing the ingenuity and mechanical genius of workmen in the average plant, in the revision of process and procedure." (Heinrich, 1931a, p.246)

[149] This paper lies outside the scope selected for this thesis, but has been included nevertheless because of its obvious link to Taylorism.

Jesse Bird tells in his biography about an experience Heinrich had during World War I that taught him about the advantages of non-Taylorist approaches and a positive view of human expertise: "detailed instructions are apt to do more harm than good with experienced personnel" (Bird, 1976, p.4). This is one of several examples that Heinrich does not want 'ox-men' (Taylor, 1911) who unthinkingly follow procedure, but that he appreciates, encourages and even expects competence, initiative and adaptation. This is definitely a non-Taylorist attitude. According to Stewart, Taylor did not want or care for the initiative of the workers. (Stewart, 2009, p.34)

Other examples are found in the anecdote that opens the *Message to the Foremen* papers (Heinrich, 1929d; 1929e), which is a praise of the initiative of an operator and the positive effects that sprung from it, and in the 1940 *Unsafe Habits of Men* paper. As we saw in section 3.3.5, the opening paragraph of this paper sees him making the non-Taylorist choice of preferring "…capable, and experienced men who work under unsafe conditions" (Heinrich, 1940, p.112) over untrained and unthinking working under safe conditions. This is almost prototypically resilience engineering thinking: people who have the capability to handle variations in uncertain environments.

Concluding, the attribution whether Heinrich was a Taylorist, or not, requires much more nuance, study and context. The most correct stance is probably that Heinrich moved along a Taylorist spectrum depending upon the requirements of the situation - as most of us do, probably.

5.4.7 Heinrich or not Heinrich?

As mentioned before, quite often when authors, researchers and practitioners claim to, or think to, discuss Heinrich or Heinrichian themes, they are rather discussing a derivate or development from Heinrich's work. This may be due to a variety of reasons, including lack of knowledge of the original texts, approaching the matter superficially or not appreciating the context or historical path of the ideas.

The success of the Heinrichian models and metaphors even contributes to the confusion. As these models and metaphors spread and are adopted by practitioners, consultants, organisations and even regulators[150], they may mutate and get new meanings. The end result may be like the result of a game of Chinese whispers where the original idea or message comes out significantly altered.

Researchers and authors may create new versions, like the Bird triangle (Bird & Germain, 1966), or the alternatives for the triangle offered by for example Hale (2002) and Hopkins (2008). In addition, practitioners will find new applications. As Le Coze concludes is his discussion of some other popular safety models as the Swiss Cheese Model, "…by making the models their own, these users have become its promoters but also illustrates how models can potentially escape their designers' initial intention." (Le Coze, 2013, p.203).

Many practitioners, educators, and also authors and researchers do not go to the original sources, or at best superficially. For many people it may be hard to understand what mutation of a model or metaphor they actually talk about, and then it is natural for them to just refer to the 'big well-known' idea, or to the 'originator' (if it looks like the triangle it is probably Heinrich's triangle). And for those who know of mutations, but are uncertain or unwilling to invest time in finding out, it may seem to be the safest option. So, in many cases, it is Heinrich's name that comes up. However, it is important to stress that it is not necessarily *Heinrich's* interpretation when a Heinrichian subject like the triangle is discussed.

[150] One example is the *Manual of Air Safety*, issued by the British Military Aviation Authority. This includes the triangle and suggests an ideal ratio of reports to accidents. (MAA, 2015, p.17-18)

5.5 Discussion and interim conclusion

From the review of 'new view' publications discussing Heinrich in this chapter, we can learn a number of things that I will sum up and discuss in this section.

1. In their discussion of Heinrich, 'new view' authors often do 'old view' analyses - if they bother to do an analysis at all. Their discussions are often limited, lack depth, ignore context, they cherry-pick, are normative and judgemental and often pack this in bold, absolute language with rhetoric and a negative tone.
2. There has been an increase in citations of Heinrich's work, especially since 2012. This applies to both general safety science literature and to publications by 'new view' authors.
3. In their discussion of Heinrich, 'new view' authors make a number of attributions that they do not support by evidence and that do not hold up well to closer scrutiny. Additionally, several quotation errors are made.

Why would 'new view' authors teach one thing and then do another? Why would they make unsubstantiated attributions? Why did they start discussing Heinrich only in recent years? Why would they attribute things like 'zero', lagging indicators and safety bureaucracy to Heinrich? And why would they bother to mention Heinrich at all? One wonders how all of this this makes sense.

5.5.1 Language, a pedagogical and discursive device

With the characteristics of the 'new view' discussed in Chapter 4 in mind, how would one expect 'new view' authors to be talking, given their teaching and discourse? We would expect them to ask for local rationality, to explore multiple stories, to strive for rich explanations, to pay much attention to context and their accounts would be free of blame.

However, when 'new view' authors discuss Heinrich they rarely do so by employing 'new view' approaches. Rarely do they seek deep explanations or explore alternatives. Mostly they take a position and discuss things from that point of view. In addition, they bring forward claims and attributions with regard to Heinrich that are not substantiated and are open for questions when studying Heinrich's work properly instead of cherry picking. Often this is framed in harsh language without context and nuance, judgemental statements, ridicule and absolutes.

Sometimes one might even suspects that authors are building strawman arguments when they present questionable attributions, or only discuss one possible explanation that suits the argument that they are building and fits the contrasts of 'old' and 'new' that they are creating. One may wonder why this is so.

Opposites and contrasts are powerful tools to convince and persuade (Cialdini, 1984; Pink, 2012). An example where we can see this at work is in the *Safety I and Safety II* book (Hollnagel, 2014b). Hollnagel uses the first four chapters - half the book - to decompose and point out downsides of traditional methods, before offering a 'new view', Safety-II (Hollnagel, 2014b). There is almost an explosion of Heinrich references in this book, as well as a more critical (yet nuanced) take on Heinrich's work than in Hollnagel's previous work. Apparently, there was a need to contrast and position 'new' approaches against something 'old'. Most 'new view' authors appear to be rather seeking and stressing opposition and posing views as contrasting, instead of presenting them as different and complementary ways to work on safety[151].

Absolutes, bold, clear-cut statements and polarized language can have a function as a pedagogical device to make a point clear. Therefore, this kind of language can be very instructive. Writing in a more nuanced language, and delivering 'on one hand/on the other hand' arguments may be experienced by readers as less certain and therefore less convincing and less 'true' than bold statements, even if these bold

[151] As Hollnagel in fact acknowledges later in the *Safety II* book, or in the Eurocontrol white paper, and as he often does when he presents the evolution of accident models from linear and sequential to more complex forms (e.g. Hollnagel, 2004; 2009).

statements only cover part of the 'truth'. Research into prediction and forecasting has shown that many people prefer 'hedgehogs' with big ideas and bold statements over 'foxes' with nuances and shifting ideas: "people find uncertainty disturbing" (Tetlock & Gardner, 2015, p.72).

So, from a pedagogical point of view, it makes sense that 'new view' authors present only one part of the message. Firstly to point out the elements and approaches that need improvement, and secondly to present and position their approach as different from the 'old ways'. The often one-sided discussions and representations of Heinrich and Heinrichian themes need not be an analysis per se, but could (just like Heinrich's ratios, as I will suggest in the next chapter) rather be seen as rhetorical devices and discursive tools.

Use of bold statements is not without risk, however. In the study into prediction and forecasting, 'hedgehogs' with big unnuanced ideas and beliefs would do significantly worse than more nuanced, and seemingly 'uncertain' forecasters (Tetlock & Gardner, 2015). In addition, there is a serious chance of over-communicating the message through painting binary, black and white pictures that the audience may take as truth. Thus the discourse may serve a goal, but is not without problems as this can lead to disinformation and new myths, as happened in the past (and is still happening) when practitioners only picked up part of Heinrich's argument without realising that essential elements were left out.

5.5.2 Timing

We saw that nearly all 'new view' publications mentioning Heinrich are post-2012. Also when looking at all (academic) safety publications in Figure 11, we see a (temporary) rise in Heinrich citations from 2012 to 2015. Firstly, it may be sheer coincidence. As we saw in Chapter 4.4.2, Dekker suggested it was his move from Europe to Australia and the difference in industries and their way of managing safety that brought Heinrich to his attention.

Another possible explanation is that the increase in Heinrich citations by 'new view' authors follows the publication of and publicity around Manuele's *Reviewing Heinrich: Dislodging Two Myths from the Practice of Safety* paper in late 2011. This paper got some attention, especially in the USA, and on various professional forums. This may have been one of the main factors that drew the attention of 'new view' authors to Heinrich. As we saw in Chapter 4.4.7, most 'new view' authors are aware of Manuele's work, and many reference to his work.

This explains, possibly, why the attention of 'new view' scholars turned towards Heinrich. However, one may wonder whether it is necessary for 'new view' authors to discuss Heinrich at all. Is the critique delivered by Manuele and others insufficient? Do they add to the discussion with their perspectives? Is the discussion of Heinrich relevant for the development of 'new view' ideas? We will not answer all of these questions at this point; especially the first would require a study of its own. The second and third question, however, deserve a cautious negative response. The 'new view' did *not* need Heinrich for its emergence and development, but as I will explain below as a means of spreading its message and creating acceptance.

The early 'new view' literature hardly mentions Heinrich or Heinrich's work, and as we saw in Chapter 4, neither do authors that have been influential on the development of the 'new view'. For example, when contrasting the 'old' and 'new' views on 'human error', Dekker (2002) does not need to draw on Heinrich or other 'old view' authors to make his point. Recent 'new view' literature, however, mentions Heinrich quite frequently, even when it does not really add much. For example, when looking at the quote in Chapter 5.1.1,

> "Another influencing factor in industry choosing this trajectory for the analysis of accidents was the work of Heinrich, who declared that 88% of all accidents are the result of human error." (Heragthy, Dekker & Rae, 2018, p.3)

One may wonder why the authors found it necessary to point at Heinrich, making an incomplete statement without context. Instead, they could have made a fully valid statement by simply pointing

towards prevalent beliefs among safety practitioners - even today as can for example be illustrated by publications like the '*Dirty Dozen*' flyer (Federal Aviation Administration, 2012).

Another example where Heinrich is mentioned even though it does not really add substance to the argument is in many discussions of the triangle. The message in most publications discussing the triangle is that near miss reporting in many organisations has become a meaningless and bureaucratic numbers game that misdirects efforts and can actually harm safety (e.g. Hopkins, 2008; Conklin, 2017a; Dekker, 2018a; Marriott, 2018). Even though a misconception of the triangle may be an underlying belief for these practices, one does not need to discuss Heinrich (who, as we saw, did not promote these practices) to address this problem[152], still much 'new view' literature does. One typical example we find in the short paper by Anand (2018). This spends approximately 60% of its space on a critique of Heinrich, mostly through a rehashing of Manuele, and only the remainder to address problematic applications of near miss reporting - although Manuele's critique is not related to these applications and a critique is created 'by association'. There are several other examples to be found where mentioning Heinrich adds little substance, like Shorrock's mocking (2013), Long's frequent snarls, and also Hummerdal's comment in passing (Hummerdal, 2013).

Summing up, there is an increase in Heinrich references, even though these do not actually add substance to the discussion. This suggests another factor with regard to timing, in addition to the possible impact of Manuele's work: 'new view' authors needed something to rally against, to antagonize, and preferably something visible and recognizable to position their new movement.

5.5.3 Creating a new movement

The increase of discussions and mentions of Heinrich and his work in 'new view' literature does not only follow the publication of, and publicity around, Manuele's critique. It also coincides with the establishment of the 'new view' as a serious movement within safety science and practice. In 2012, the Safety Differently website was established and especially from 2014 onwards, there has been a growing number of publications gaining wider attention and a clear crossing over from the academic realm to a wider audience[153].

This suggests a hypothesis: Heinrich became an interesting topic for 'new view' writers when Safety-II and Safety Differently became 'a thing'. At first, during the early 2000s when the 'new view' was in the process of developing itself, Heinrich's work was not a necessary part. Instead, the developing 'new view' drew on a variety of other traditions (e.g. cognitive engineering and cybernetics) rather than taking traditional safety approaches as a point of departure. Only after having established itself ideologically and theoretically, the 'new view' really turned against certain elements of the 'old view'.

While the 'new view' has some recognizable spokespersons like Dekker and Conklin, and some appealing thoughts (e.g. focus on positives, just approaches, against bureaucracy), it does not offer easy answers, stresses complexity and lacks catchy metaphors and symbols. That makes it more difficult to 'sell' to the masses than many established approaches. The 'new view' needed something to contrast its message to as a classical tool of persuasion. In the way of classical storytelling, the 'new hero' needed some 'villain' to overcome in order to make the message looking better.

The more recognizable villain to contrast to, the better of course and some of the best-known models and metaphors in safety are Heinrich's legacy. Conveniently, some of these like the linear dominos do conflict with underlying beliefs of the 'new view', like complexity and non-linearity. Additionally, Heinrich proved easy to connect to concepts like 'zero', lagging indicators, safety bureaucracy and other attributions. These are all phenomena the 'new view' is critical of. Heinrich also was an easy target, because his work was

[152] See for example Richard Cook's non-reporting initiative (2013) (alas no online source in English language seems to be available anymore), or the critical discussion of Macrae (2015).
[153] Even though one may comment that the language in some of the popular books by Hollnagel and Dekker still is fairly 'highbrow'.

'under fire' from more traditional safety scholars like Manuele and the SIF-movement anyway. 'Bashing' Heinrich had become fashionable, given the tone of discussions on some professional forums[154].

Approaching the question of why 'new view' authors discuss Heinrich in a certain way from this angle makes it more understandable, even when it may conflict with what they teach about how one should view behaviour and organisational events. Research in other fields has shown that ideology can affect analysis and judgement of data and it is reasonable to assume that also 'new view' authors can be prone to ideological motivated reasoning. Kahan, et al. (2017) even found that those best equipped to do an analysis showed stronger tendencies to construct an argument consistent with the beliefs of their 'tribe'. This mechanism may also affect 'new view' judgements about 'old view' approaches.

More importantly, a new movement will not want to be associated with beliefs, customs, tools, approaches and symbols of what they perceive to be their 'opponents' and almost 'need' to be critical of those, or at least avoid them as much as possible. One can see analogies to political rule where a new regime removes symbols and statues of the previous regime (think of the removal of many statues of Communist leaders like Stalin after the dissolution of the Communist regime), or when a new religious faith 'takes' over (at one point during the reformation churches were razed to remove statues of saints and other symbols associated with the Roman Catholic faith and anathema to the new protestant belief), or in art where a new stream is a reaction on what came before (e.g. punk as a reaction to stadium rock acts like Pink Floyd). If the 'new view' was to adopt triangles, icebergs, dominos and zeros (apart from theoretical problems), how would outsiders be able to tell the difference? Long says as much in a recent blog:

> "Sometimes the first moves are simply to change models, symbols and language. It is amazing what happens when those dumb symbols of cones, pyramids, matrices, boots, hard hats, gloves and glasses are substituted for humanising symbols." (Long, 2018f)[155]

Another angle related to the notion of 'villain', as we saw above, Heinrich and Heinrichian ideas are rarely separated. Critique regarding the triangle is often directed at Heinrich, or somewhat more roundabout at Heinrich and Bird, even when the critique is addressed at applications of the idea that are not Heinrich's. Maybe, when people mention Heinrich, they do not really intend to talk about Heinrich himself. In a conversation with Robert Long[156], he suggested another way of thinking. Not seeing Heinrich as the author, but rather as what he has come to symbolise and represent. Heinrich as a symbol and shorthand for mechanistic control, reductionism, and positivism with metaphors that suit to support these philosophies - no matter what the man Heinrich ever thought, said or wrote.

There is value in this perspective, but there can be side effects. One problem with unfounded attributions and 'symbolic use' of names or things (metaphors, subjects) may be that many readers will not get the symbolism, or have no way verifying the attributions. They do not study and have not read the primary sources and may take attributions and symbols at face value, especially when it comes from a big, established name. This can lead to the creation of new myths, for example that we use lagging indicators in safety due to Heinrich, or that Heinrich intended the triangle as a metric, which in fact combines Heinrich's idea and image, with a new explanation. Therefore it is important to remain critical as readers - especially with regard to non-peer-reviewed 'guru books' - while authors could make a greater effort to explain nuances instead of creating polarisation.

Since it seems that 'new view' authors often do not live up to their own 'standard' when discussing Heinrich, and seem to have a rather 'old view' approach, let us try a different ('new view') approach. As a contrast, I will try to find out why some things did make sense for Heinrich. Or not.

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[154] Just one example: https://www.linkedin.com/feed/update/urn:li:activity:6453885753075343360. A more recent example, and one of the most vicious, would be Phil La Duke's attack on Heinrich, equating his work with genocide (La Duke, 2018).

[155] A similar argument is found in the *Domino Delusion* blog (Long, 2018g).

[156] Personal communication with the author, 10 December 2017.

6 Discussion: Why did things make sense to Heinrich?

For a long time, there has been critique of Heinrich's work. An early example is the Heinrich - Blake debate about the 88:10:2 ratio in 1956. (Heinrich & Blake, 1956) This continued with people like Petersen in the 1970s and 1980s. At the beginning of this millennium Hale (2002) and Manuele (2002; 2011) were two notable safety scholars who offered their critique of Heinrich's legacy.

While the 'new view' proposes a different set of analytical tools than traditional safety approaches, as we saw in the previous chapters when discussing Heinrich, 'new view' authors rarely employ them, go for fairly superficial or 'old view' approaches and rather follow Manuele's arguments on these subjects.

In this chapter, I will try to apply a 'new view' analysis to Heinrich's work by trying to explore Heinrich's local rationality by using the thoughts from chapter 2.2. For this, I have selected three topics, two of which feature more or less frequently in 'new view' literature, and a third that puzzled me ever since I started reading Heinrich.

6.1 Topic 1: Science

6.1.1 Background

The subtitle of *Industrial Accident Prevention* was 'A Scientific Approach'. In the preface of the book, Heinrich writes, "The use of the word 'scientific' in the subtitle of this book indicates the author's belief that science may be applied practically and successfully to the prevention of accidents" (Heinrich, 1931a, p.v).

Mentioning 'scientific principles' returns in many of Heinrich's books and papers. He saw science as an essential tool that had to be used in practice: "Science is applied to accident prevention in the same manner that it is applied to any other problem" (Heinrich, 1931a, p.10)

Below, I will suggest that Taylor's 'scientific management' may have inspired Heinrich's subtitle. However, Taylor's ambitions appear to be 'higher' than Heinrich's. Taylor tried to find laws that were applicable to anything. Heinrich wants to use scientific principles for solving practical problems and preventing accidents. "Accident prevention can be portrayed as a science and as a work that deals with facts and natural phenomena" (Heinrich, 1941, p.16). However, in this thinking he does not quite go as far as Taylor who stated that his scientific management was "applicable to all kinds of human activities" (Taylor, 1911, p.2). Heinrich wanted foremost practical solutions, but not necessarily as strict and formalized as Taylor.

6.1.2 Critique

Labelling his books and work as 'scientific' has drawn a lot of critique, especially in recent years, from both traditional safety scholars and practitioners and from 'new view' authors. Many follow Manuele's (2002; 2011) critique about the missing and thus unverifiable data. More about this later in the chapter. Besides this, there has been some critique of the methods used. For example Dekker is very explicit in *The Safety Anarchist*:

> "…like Taylor, Heinrich announced his approach to be 'scientific', though a description of his method wouldn't pass scientific peer review today"[157] (Dekker, 2018a, p.86), and "…the subtitle of his book was A Scientific Approach. That would supposedly require him to at least divulge the basis for his selections or the statistical power behind his sample size." (Dekker, 2018a, p.86)

[157] That the value of peer review sometimes has to be taken with a pinch of salt is demonstrated in Dekker's book only five pages later, when he manages to get the argument from the Wright and Van der Schaaf reference the wrong way around. See the discussion in Chapter 5.3.

These statements are most likely based on assumptions about what 'scientific' means from our - or in any case Dekker's - contemporary point of view. Dekker follows very much the critique from a decade and a half earlier by Metzgar:

> "Heinrich subtitled his book 'A Scientific Approach'. Thus, it falls to him to demonstrate that he followed a scientific method in his development and writing" (Metzgar, 2002, p.27), and "A scientific method would demand that the research for such a significant claim - including the data and the method for handling it - be published. Such publication presents the opportunity for others to try to replicate the experiment, confirm it or show how it could be improved." (Metzgar, 2002, p.28)

6.1.3 Why did it make sense to call the approach 'scientific'?

There are indeed problems with the data, which were biased, and their analysis, which was arbitrary (Busch, 2016). This thesis touches at places on this, but in this chapter, I do not intend to discuss whether Heinrich's work was scientific or not, or how scientific it was. The thing we want to explore in this chapter is why it might have made sense to Heinrich calling his work 'scientific', when many authors and scholars like Dekker and Metzgar quoted above raise serious questions.

As we saw earlier in this chapter, the concept of local rationality does not care much what *we* in retrospect think of something, but it aims to explore the rationality of the person in the situation at that time. Therefore, it is important to keep in mind that it does not matter what *we* call scientific, eight decades down the road. What matters more is how it would make sense to subtitle the book 'scientific' at that time, given what came before, what the book contained, how it compared to the state of the art at the moment and what direction it pointed.

Below, I will offer four main hypotheses about why it would make sense to Heinrich to subtitle his book 'A Scientific Approach' even though we today may find the work anything but scientific:

1. Understanding of the term 'scientific'
2. Using structured methods, application of principles and basing this on facts
3. Practical application of what works and solves problems
4. Marketing

Let us discuss them one by one. I will conclude this sub-chapter with a discussion of the missing data.

6.1.4 Scientific: understanding the term

A common approach to understand a subject is by starting to look into what a term means, or how it is commonly defined. The Oxford Dictionary (n.d.) defines 'scientific' as:

> 1: Based on or characterized by the methods and principles of science.
>
> 2: *informal*: Systematic; methodical.

The definitions found in the Merriam Webster (n.d.) agree:

> 1: of, relating to, or exhibiting the methods or principles of science.
>
> 2: conducted in the manner of science or according to results of investigation by science: practicing or using thorough or systematic methods.

The first definition of both dictionaries points us in the same direction of much of the critique. Scientific means that research should be done according to the scientific method. That much seems obvious to *us*.

But what does Heinrich mean? Did he mean something different than that definition? He does only define science briefly in the preface to the first edition. Additionally, he puts descriptions in the text that suggest directions. Following these makes it possible to form an idea of what a definition of science for Heinrich

could be. We will discuss these in the next sections, but first let us ask the question whether Heinrich should have understood how to do things 'scientifically', such that it lives up to today's standards of scientific research.

The answer to that, I would say, is no.

It is important to keep in mind that Heinrich was not an academic. Despite the fact that he would teach at universities later on in his life, Heinrich never had an academic education himself. His education before he went to work was six years of grammar school. As his biographer, Jesse Bird, remarks: "Education at the university and doctoral levels was usually for professors, clergymen, barristers and people of leisure who inherited considerable wealth." (Bird, 1976, p.28) Heinrich did not fit these categories and rather was a self-made man who added knowledge and education as he went along. In this, he differs from other Hartford intellectuals that worked in the insurance industry and made important contributions to science or arts, like the poet Wallace Stevens or linguist and fire prevention engineer Benjamin Lee Whorf.

So, should he have known? He may have had some knowledge about scientific research and experiments, but not the formal training to adhere strict scientific guidelines. It was therefore not natural for him to write in an academic way or use academic approaches. He was very much a practitioner and wrote as one - despite the fact that he worked with, and was assisted in his work, by academics like Dr. Allan D. Risteen and Edward Granniss.

Heinrich's writing style is not academic. His books were foremost aimed at managers and practitioners. We see this in his language, the examples he uses, the stories he tells, and also by the relative absence of quotes and footnotes. Heinrich does not quote any philosophers or academics. When he quotes, he mostly draws on practical texts, like definitions from standards, for example the definition of accident causes (Heinrich, 1931, p.41-42), or practical safety texts, like the lengthy passage on illumination, taken from the work of another Travelers Safety Engineer (Heinrich, 1931, p.250-256).

One can just compare the limited number of references and use of footnotes by Heinrich (1931a; 1941) and DeBlois (1926) - both engineers and practitioners - with the academic Vernon (1935) who has one or more footnotes and references on almost each page. In America, safety was mainly a practical/applied field. Swuste et al. note that American safety authors all had an industry background and therefore had a "more applied and managerial interpretation of occupational safety" (Swuste et al., 2010, p.1009) in contrast to more academic European authors like Vernon.

There is even reason to believe that Heinrich would have good cause to shy away from an overly academic approach. Among others, Donkin (2001) and Stewart (2009) suggest an "antipathy" (Donkin, 2001, p.223) against academia among US entrepreneurs - which after all were Heinrich's prime audience.

Not having had a strict academic/scientific training, Heinrich may have had the impression that he actually did follow a scientific method. And in a way he did, implementing an approach, observing effects, and drawing conclusions, although arguably not in a rigorous way that lives up to the standards that we apply to scientific research today.

This opens for another hypothesis: although some practices in natural sciences had been around for a long time, the scientific standards from the 1920s and 1930s were most likely not the same that are applied today. When Heinrich and the Travelers engineers did their research during the mid- and late 1920s, Fisher's influential work on the design and analysis of scientific experiments was only just published (Yates & Mather, 1963). It is important to note that 'proper' scientific testing of the efficacy of treatments did not enter medical science until the second half of the 20th Century (Tetlock & Gardner, 2015; Blauw, 2018), which is several decades *after* Heinrich published his work for the first time. It is therefore reasonable to assume that applying these scientific methods was not best practice within safety during the

1920s and 1930s[158], and it is quite unreasonable to require this in hindsight[159]. Safety was not even widely recognised as a profession let alone as a science (Heinrich, 1928b).

Finally, There is a nuance that goes beyond mere semantics, I believe. The word *approach* is open for a less strict interpretation than *method*. Stewart contrasts scientific/science (according to the scientific method and living up to criteria for scientific research) with a "scientific attitude" which he loosely defines as "…a disposition to test hypotheses against facts through controlled observation" (Stewart, 2009, p.48). However, as Stewart argues, a scientific attitude alone does not make something (e.g. a construct or an activity) scientific - using the example of grocery shopping.

I think there is good reason to value Heinrich's statements in that light. He had a scientific attitude towards accident prevention, but that alone is not enough to make his work proper safety science.

6.1.5 Using structured method, based on facts and application of principles

The second definition from the consulted dictionaries fits very well to the interpretation of the subtitle as discussed in the previous section, meaning as 'with a scientific attitude', or following an approach inspired by science, but not necessarily through the scientific peer-reviewed processes of our time. The second, more informal, definition stresses the use of systematic and methodical approaches based on facts, whether they fully live up to scientific methods, or not.

To explore Heinrich's local rationality, we should have started by looking at what a dictionary entry would have told us in *his* time. While the entry for 'scientific' looks the same, "Agreeing with, or depending on, the rules or principles of science" (Webster, 1930b), 'science' is firstly defined as 'knowledge': "knowledge of principles or facts"[160], and then as "Accumulated and established knowledge, which has been systematized and formulated with reference to the discovery of general truths or the operation of general laws; knowledge classified and made available in work…" (Webster, 1930a).

We find this interpretation for example in the 1932 review of the first edition of *Industrial Accident Prevention*,

> "It is the author's contention that science may be applied practically and successfully to the prevention of accidents, *using the term 'science' in the sense of knowledge of principles or facts*. The principles laid down have been applied so extensively that they indicate beyond a doubt their practicability and effectiveness." (Hayhurst, 1932, p.119, emphasis added)

This seems to correspond with Heinrich's intention. In the preface of *Industrial Accident Prevention*, he states that "...if accident-prevention work is to be conducted scientifically, it must be founded upon well-established principles or facts that have been proved by application" (Heinrich, 1931a, p.v). On various occasions, he stresses that the book intends to offer principles and fundamentals, not specifics. This is one way in which Heinrich's work distinguishes itself from many of the earlier safety handbooks by for example Beyer (1916), Cowee (1917), Ashe (1917) and Lange (1926). Many of these safety texts discuss to a greater degree specific cases and applications, while Heinrich aims mostly at fundamental processes and methods. This not a strict divide: discussions of fundamental principles are found in the work of Lange (1926) and especially DeBlois (1927), while Heinrich spends attention on specifics (like the chapters on guarding and illumination). Mostly, however, *Industrial Accident Prevention* is characterized by offering an "organized framework of thinking" (Petersen, 1971, p.11) within accident prevention.

In addition, Heinrich stresses the use of 'logic' (Heinrich, 1928a/b), explained as first finding out what is 'wrong' before applying a solution. According to him, this approach is applied to other business problems, but not for safety.

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[158] Or today, for that matter (Shannon, et al., 1999).
[159] Just to be clear, this is not an excuse for people to quote his work as if it were 'scientific' after all!
[160] Heinrich himself defines sciences this way in the preface of the first edition of *Industrial Accident Prevention*.

The importance of following a structured approach to safety work is found in Heinrich's work as early as his first writings, e.g. the *Bedford Stone Club Speech* (Heinrich, 1923b) where he offered the audience ten "fundamental principles" for successful safety organisation, some of which can be linked to his future axioms.

Like other things in Heinrich's work, the principles and their descriptions changed throughout the years (Manuele, 2002). I will not present all variations and nuances here, but highlight a few versions to illustrate Heinrich's systematic and methodical - and thus 'scientific' approach. In the first edition of *Industrial Accident Prevention*, we find "four principles of scientific accident prevention":

1. Executive interest and support
2. Cause-analysis
3. Selection and application of remedy
4. Executive enforcement of corrective practice (Heinrich, 1931a, p.6)

He called this "successfully applied modern accident-prevention methods in a business-like way" (Heinrich, 1931a, p.6), and therefore,

> "…inefficient plans and devices should be discarded because research and investigation have brought to light new modes of procedure, based on correct practice, which are producing highly satisfactory results." (Heinrich, 1931b, p.5)

The principles would change slightly and evolve over time, and be adjusted in some papers. In the *Safety in the Small Plant* paper (Heinrich, 1932a), for example, he stresses that the principles of accident prevention between small and large plants are the same, only the details differ. The principles are then presented in a somewhat simplified form, probably because of his audience, which he does not want to give unnecessary burden:

1. Executive interest, support and action.
2. Knowledge of accident facts
3. Appropriate and effective action based on these facts. (Heinrich, 1932a, p.30)

In a paper specifically aimed at managers, stressing the importance of planning in accident prevention, Heinrich even calls the principles "planned executive work" (Heinrich, 1932d). Yet another version appears in the *A Place in the Sun* paper where he chooses to elaborate on the various steps:

1. Recognition of responsibility by the employer, and his supervisory staff, followed by his resolve to act.
2. Investigation and recording of the two major facts of accident occurrence; namely (a) the specific unsafe act of some person, and (b) the physical or mechanical hazard at fault.
3. Corrective action directed against the unsafe act or the physical hazard. (Heinrich, 1934, p.118)

In the second edition of Industrial Accident Prevention, the principles then have been streamlined once more

1. The creation and maintenance of active interest in safety[161].
2. Fact-finding.
3. Corrective action based on the facts. (Heinrich, 1941, p.6)

It is possible to see elements and similarities between applying Heinrich's principles and following the Shewhart/Deming-cycle (Deming, 1986, p.88). The plan-do-check/study-act cycle can be seen as a

[161] It is interesting to note that in the latter version, the stress on the role of (top) management seems to have been reduced. It is unclear whether this is intentional, or not. Heinrich does still stress the important responsibilities of employers and top managers in this edition of the book. Reasons why he omitted them from this version of the principles may have been editorial (to make them more 'catchy'), or because he wanted to stress that the principles apply to anyone, regardless their position in the organisation.

scientific approach as well. The PDCA-cycle correspondents nicely to the scientific method and elements of both PDCA and the scientific method can be found in Heinrich's principles, yet incomplete.

Very central in the principles offered by Heinrich, is the knowledge of facts. He mentions for example, "knowledge as to specific unsafe practices and unsafe physical or mechanical conditions, and the reasons for the existence of them" (Heinrich, 1931a, p.98), and "investigation and recording of the two major facts of accident occurrence…" (Heinrich, 1934, p.118). This leads us to yet another view of science, namely as something that is fact-based. Swuste et al. conclude, "His books had as subtitle 'a scientific approach', referring to an approach based upon facts, and less on believes." (Swuste, et al, 2013)

Heinrich stresses the importance of facts on many occasions,

> "In this age of exact knowledge, when facts of proved value are replacing theories and when business, under pressure of economic necessity, must concentrate upon the things that count, it is startling to find that the efforts of thousands of individuals are misdirected and that the attainment of a worthwhile objective is seriously delayed through failure to recognize an obvious truth". (Heinrich, 1928a/b, p.9)

One of the most 'flowery' and imaginary occasions is in the *The Reward of Merit* paper (Heinrich, 1930b) where he opens with a discussion of "outworn beliefs", myths and superstitions, contrasting these to beliefs supported by facts, drawing on examples as the fear of falling off the edge of a flat earth, the Salem witch trials, blood-letting as a medical treatment and other superstitious practices,

> "One of the most beneficent results of intellectual progress in the human race is that which evidenced by the smashing of popular idols - the overturning of pet beliefs unsupported by fact." (Heinrich, 1930b, p.141)

In an earlier paper, discussing the safety problems of the construction business (Heinrich, 1925) contrasts the approach advocated by him to that of 'quacks'. Heinrich argues that one must know the problem in order to be able to address it effectively.

> "Accident prevention engineers must know *why* accidents occur; they must know the *causes* of accidents and direct their attack at the removal of these causes, instead of selecting a remedy blindly or arbitrarily." (Heinrich, 1931a, p.268)

For Heinrich this is also a reason to often stress the importance of better statistical data. Not, as discussed before, as a bureaucratic enterprise, but in order to get better knowledge and have a greater evidence-based foundation for preventive actions. These appeals show us that calls for 'bigger data' are not something of recent years: "Conclusions derived from judgment or from one or two serious cases, are never as valuable as are those drawn from a review based on greater exposure" (Heinrich, 1935, p.32), he wrote many decades before the term 'big data' caught on.

This focus on facts - which still permeates our contemporary thinking - was very much a sign of the time and may, again, partly have been inspired by Taylor, "…scientific in Taylor's context meant a decision making process based on rational arguments" (Swuste, et al., 2010, p.1004). Muller, in his discussion of Taylor's legacy notes "Decisions based on numbers were viewed as scientific, since numbers were thought to imply objectivity and accuracy." (Muller, 2018, p.35) Heinrich's approach fits this scheme, by stressing the knowledge of facts, through use of better statistics, and by creating ratios.

6.1.6 Practicable and useful

As if to underline that he was no 'ivory tower' academic, Heinrich states in the second edition of *Industrial Accident Prevention* that the principles offered by him "…are not based on theory as much as on time-proved practice"[162] (Heinrich, 1941, p.6). This speaks of a view that sees science as something practical,

[162] Taleb (2012; 2018) would approve!

not merely theoretical. Therefore he stresses that "Practicability and common sense must prevail in safety as in other things..." (Heinrich, 1941, p.139).

Heinrich was an engineer, engineering is an applied science with a strong preference for practical applications rather than pure theory. Heinrich mentions on several occasions, that knowledge or critique of inefficient practices in itself is not useful. One has to come with suggestions for improvement, and these must be practicable:

> "This information concerning accident costs may be interesting, but it is not necessarily of tangible value unless it is supplemented by concrete suggestions as to how best the costs may be reduced" (e.g. Heinrich, 1931d, p.97)

Also the *War-time Motion Study and Foremanship* paper (Heinrich, 1942) shines an interesting light on Heinrich's relationship with science. Again, it is confirmed that he is no scientist. First of all, he is a practitioner who wants practical results for his audience, and he understands his audience: "Foremen don't care much for the term 'motion study'. It sounds unnecessarily 'high-brow'." (Heinrich, 1942, p.177) Therefore, they should rather use their "…God-given common sense to motion study…" and "…find it no hodge-podge of theory but merely the practical application of knowledge and facts that you have long made use of in connection with the mechanical[163] phases of your work." (Heinrich, 1942, p.178)

Heinrich is not alone in this view. Common sensical everyday understanding, interpretation and use of the term 'scientific' does not necessarily relate to the first definition from the dictionaries before. Most people do not necessarily think of the scientific method and peer review. For many lay persons the understanding of 'scientific' correspondents more to that the second definition from the Oxford Dictionary and how the magazine Popular Science advertises itself:

> "Popular Science gives our readers the information and tools to improve their technology and their world. The core belief that Popular Science and our readers share: The future is going to be better, and science and technology are the driving forces that will help make it better."[164]

Therefore, (applied) science can also be seen as 'problem solving' and 'what works' (Davies et al., 2003). Arguably Heinrich's way worked better and was an improvement over what was before. The way he proposes causal analysis and implementation of measures for prevention goes beyond where many of his contemporaries were. Even if we see problems with his approach today, many were convinced of the improvement, not the least himself. Just take as an example the by his accounts serious reduction of the number of "not preventable" accidents (Heinrich, 1931a). His proposed approach provided him with means to come to useful solutions.

Other scholars share Heinrich's view on science as something that needs practical application. Hudson, discussing implementation of a safety culture program, wrote,

> "Fine distinctions of theory, the daily fare of the fundamental scientist at the cutting edge, are too fragile to base a system on if that system is to work. If an approach does not work in the long run there will be a lot of problems created, including the believability of the academic world. So this means that we need to reframe the role of the scientist as implementer as more like that of the engineer, who knows how to take a wide range of established scientific knowledge, plus hard won experience, and design and construct something people can bet their lives on." (Hudson, 2007, p.719)

Also 'new view' authors acknowledge that Heinrich "…was probably a practical man. He needed to find things that could work, that the insurers' clients could use in their daily practice, and that could ultimately

[163] Not the subject of this thesis, but from a human factors perspective, some critique would be in place here. Humans are after all not quite the same as machines!

[164] https://www.popsci.com/ - The step from this quote to 'science fiction' is not a large one, as can be evidenced from some of the magazine's features over the years.

save his company money"[165] (Dekker, 2018a, p.86). This focus on practical application is something that one also might expect from 'new view' authors, given their interest in 'work-as-done' (Hollnagel, 2014b). This leads several 'new view' authors rather to write books for practitioners than for academics. Hollnagel says of *Industrial Accident Prevention* that the "…background for the book was practical rather than academic…" (Hollnagel, 2014b, p.35), and then follows Heinrich's example:

> "This book is intended for practitioners rather than researchers (...) The reason for this partiality is simple – *it is the practitioner who can makes changes to practice, not the academic*. The intention is that the practically minded reader should be able to read the book without constantly consulting the references and even without caring much about them" (Hollnagel, 2004, p.xiii, emphasis added).

Also the *Safety Anarchist* (Dekker, 2018a), the *Pre-Accident Investigation* series (Conklin, 2012; 2016; 2017a) and many others publications discussed in this thesis would fit in the 'practical' rather than the 'academic' ('science') category. One might be tempted to say that the various authors are striving after similar goals as Heinrich, just in different eras and with different approaches.

To round up this section, few 'professions' are more interested in practical solutions than management. "The aim of management thought, say the guru's supporters, is not to produce scientifically rigorous theories but to supply practical tools and concepts for the managers of the world." (Stewart, 2009, p.247) It must therefore be stressed that *Industrial Accident Prevention* is not a scientific text as such. It is very much a management book. In the summary, Heinrich identifies (top) managers as his primary audience: "It is chiefly to the employer, therefore, that this work is directed". (Heinrich, 1931a, p.271; 1941, p.365) As such, the subtitle of the 1980 version of *Industrial Accident Prevention*, whatever one may think of that book, was rather suitable: *'A Safety Management Approach'* had replaced the 'scientific' tag.

Not only should one regard *Industrial Accident Prevention* as a management book first, and as a safety book second. There are even elements in the book that might justify regarding it as a self-help book. Some of the 'stories' in the 1931 edition, and the regularly appearing encouragement of "this is simple" and "you can do this"-like comments remind of self-help literature. Interestingly, the big sellers from the era that lasted until today, Napoleon Hill and Dale Carnegie, came only *after* Heinrich's first book (1937 and 1936 respectively).

Typical for the self-help management side of Heinrich's work, is the story that opens the 1931 edition of *Industrial Accident Prevention*, that in a nutshell presents some core concepts, among which hidden costs and the principled approach, in a management meeting setting. Here he is clearly 'selling' his method, which indicates from the start that this is more of a management book than science. Speaking of 'selling', 'scientific' is also a fashionable and marketable word, as we will explore in the next suggestion why things made sense to Heinrich.

6.1.7 Marketing

The first suggestion why Heinrich might have chosen the 'scientific' claim in the subtitle of his book may be plain and made intuitively by many people. It was a tag to attract attention and market the book. Adding a scientific touch to something to sell it is a well-established marketing practice for toothpaste,

[165] Indeed this may have been one of the main drivers. However, reducing it to a matter of money is oversimplifying the matter. As noted in Chapter 2, it is not intuitive for readers today to understand the role of insurance companies in the early decades of the 20th Century. Stone's review of the first edition of *Industrial Accident Prevention* discusses both the financial aspect and the important role of insurance companies in the formation of safety theory and practice:

> "It is fortunate the casualty insurance companies have found it so distinctly to their economic interest to reduce accident claims by taking an aggressive part in promoting safety engineering. The insurance companies provide in major part the support of the National Safety Council. They are active in promoting the work of standard safety code committees. They publish and distribute, free of charge, educational literature of high merit. They have promoted the statistical reporting of accidents. They have themselves maintained a large corps of safety engineers for consultation work. These companies, then, are largely responsible for the extension and improvement of accident prevention methods" (Stone, 1931, p.324)

washing powder, and so on. Starting with Taylor (1911), also management books have a long-standing tradition of presenting themselves as works based in science.

Heinrich does not reference Taylor, and as we saw, Heinrich should not be regarded as a 'hardcore' Taylor adept. There are some similarities, however, for example analysis as a basis for action, choosing from a set of causes, pre-defined 'best' actions, and so on. Therefore, it is not surprising that many people associate the subtitle 'A Scientific Approach' with 'Scientific Management' and an easy explanation for the subtitle is that Heinrich was inspired by Taylor's successful management method. If readers made the same link back in Heinrich's time, connecting to a popular management 'fad' must have been an attractive prospect.

Finally, another reason for Heinrich to add the subtitle may have been to set his book apart from the 1916 book by the exact same title of *Industrial Accident Prevention*. David Stewart Beyer, Manager of the Accident Prevention Department of the Massachusetts Employees Insurance Association[166], wrote this book. Beyer's (1916) book was much more a 'how to' book with specific examples of tools, hardware, equipment, machines and environment with attention to specific industries and hazards. As mentioned before, Heinrich's book is more concerned with a philosophy of accident prevention and principles and methods to guide this work, although there is a similarity to Beyer's book in for example the long chapter on guarding and the chapter on illumination. It has also been a long established practice - also in science - to stress that what the author presents here is 'better' than what came before. In this case done by adding the 'scientific' label in the subtitle.

6.1.8 How relevant is the missing data?

In this chapter, we have discussed a couple of suggestions why Heinrich was talking about science, but not as we tend to know it[167]. That covers the book's subtitle, but still leaves the issue of research. Heinrich frequently mentions research done by Travelers engineers which is the basis for the ratios of hidden costs (the 1:4 ratio), the 'origin of accidents' (the 88:10:2 ratio) and 'foundation of a major injury' (the 1:29:300 ratio and triangle). (e.g. Heinrich, 1926; 1927a; 1928a; 1929a; 1931a; 1941)

Several authors (e.g. Dekker, 2018a; Conklin, 2017a; Townsend, 2014; and Gesinger, 2018) point out that it is not possible to verify and replicate the findings because Heinrich's data is not available. This is usually the core of their critique on the scientific element of Heinrich's work, and mostly they draw on Manuele (2002; 2011). Keeping the previous suggestions of alternative understandings of 'science' in mind, one could wonder whether this is relevant at all. Sure enough, we cannot go back and check how Heinrich got his ratios from the data available to him. However, we should reflect on whether we should regard the ratios as a result of research, or rather as an idea and argument in themselves.

Firstly, should the 'exact' ratios (which are, after all, the result of the data) be replicable? Most of the critique seems to suggest this. Regarding the cost and triangle ratios, Heinrich himself points out repeatedly that the numbers presented by the ratios are approximations and averages. Therefore, variations may be found (e.g. Heinrich 1926; 1927a; 1927b). About 'hidden' costs, he says,

> "It is not contended that the four-to-one proportion holds true for every industrial accident, nor every individual plant, and it is granted that in nation-wide application the ratio may vary; yet it has already been tested sufficiently to provide approximate confirmation." (Heinrich, 1931a, p.17)

Some papers suggest for example that cost in the construction industry may be higher,

> "In construction work it was estimated by the Associated General Contractors of America that the ratio was probably closer to 6-to-1 than 4-to-1, due largely to the effect of accidents on delays…" (Heinrich, 1938, p.374).

[166] The name of this company was changed to Liberty Mutual in 1917.
[167] I am no Trekkie and prefer Star Wars, but found this fitting.

Regarding the triangle, Chapter 5.4.3 discussed the attribution of 'fixed' rations, and pointed out that the 1:29:300 ratio was nothing but an average based on numerous unique ratios. Heinrich provides many examples of cases from which his average ratio is determined. All these examples have wildly different ratios. This not only illustrates that ratios are different, but also that they are scenario or context specific, as also suggested by Manuele (2002), Hale (2002) and Hollnagel (2004).

In a reply to many misunderstandings, Heinrich even found it necessary to be explicit in the fourth edition of *Industrial Accident Prevention*, stressing that the "…actual ratio may never be known exactly" (Heinrich, 1959, p.30). This was not new knowledge that suddenly surfaced, as Heinrich had said this long before, "The number of such no-injury or potential-injury accidents in comparison to actual injuries has always been a nebulous quantity, and it probably will never be known exactly." (Heinrich, 1929a, p.4)

Heinrich does not make any of these caveats about the 88:10:2 ratio. However, also here it is of little use to discuss the numbers because there are much more fundamental issues that render them irrelevant. After all, Heinrich is trying to measure something that cannot be measured objectively - causes are constructed and selected[168] and thereby inherently subjective. Besides, Heinrich talked about direct causes which from a contemporary point of view are the least interesting point of attack (e.g. Manuele, 2002). Not for Heinrich, however, as we will discuss later in this chapter.

Secondly, instead of focusing on the numbers derived from the data and their validity[169], one should rather look at the principles than at the concrete numbers, seductive as they may be. As Hollnagel says in *Barriers And Accident Prevention*, "the importance lies not in the actual numbers, but their meaning" (Hollnagel, 2004, p.24). So what is Heinrich in essence saying? I suggest the following:

- The 1:4 ratio says that there will be costs that are not accounted for directly, and often cannot be accounted for, but the total costs of accidents will be larger than the direct costs from medical treatment and insurance.
- The 88:10:2 ratio tells us effectively that almost every accident has a human component.
- The 1:29:300 ratio teaches us that there are more near accidents than accidents; most (major) injuries are preceded by precursors that can be acted upon before actual harm is done. It suggests an opportunity for more proactive accident prevention.

One does not need numbers to understand these fairly basic concepts. Read the above bullet points once more and skip the ratios this time. The message is still there. Numbers do have some major advantages over no numbers, however, and therefore we should see the numbers and ratios for what they are. They are not scientifically determined 'laws', despite the fact that the 1:29:300 ratio is labelled by some as 'Heinrich's Law'[170]. Just as the stories Heinrich tells throughout the books and papers, the numbers and ratios are tools meant to *convince* and *persuade*. This applies also to data and the research done to reach these numbers. Most likely, the research was done to confirm the common sensical hunches about these issues, to find a ratio that was not totally off the mark (instead of merely guessing or estimating) and to make the principles more credible by backing them with research, no matter how questionable. Besides, the ratios provided an easy to remember 'anchor' for the concept.

Thirdly, let us keep in mind who Heinrich was writing for. He is not a scientist writing for other academics. As we saw, despite the 'scientific' sub-title, *Industrial Accident Prevention* was mostly intended as a practical safety management book. He explicitly mentions (top) managers as his primary audience.

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[168] Even Heinrich said as much on several occasions.

[169] Which especially in the case of the 88:10:2 ratio can be questioned on basis of the fact that the data (insurance files) most likely was biased in one direction or the other.

[170] It must be noted that Heinrich in fact does refer to natural laws in the summary of the first two editions of *Industrial Accident Prevention* when discussing that injuries are preceded by "hundreds of accidents" (Heinrich, 1931, p.269; 1941, p.363). So, he may have contributed somewhat to this misunderstanding.

(Heinrich, 1931a; 1941[171]) It is them he tries to convince, and the ratios and numbers are pretty powerful tools of persuasion. Numbers and mention of research lend credibility to the concepts - just as an actor in a white coat tends to give a veneer of credibility to a toothpaste advertisement on television. These practices are not necessarily fraud, but neither do they represent 'science' in the 'pure' sense of the word. The fact that Heinrich's ratios are still around today says something about their persuasive power. As does an anecdote documented by Heinrich:

> "As one employer recently stated when confronted with his direct monetary loss, 'It may not be four-to-one, but I can see that it is something-to-one, - and whatever it is, it is too much'." (Heinrich, 1926, p.247; 1927b, p.47)

Petersen and Roos would remark something that echoes this manager's sentiments in their update of *Industrial Accident Prevention* many years later, "attempt to actually quantify hidden costs is an almost impossible task, and probably not worth the effort. If management believes in the concept, it is often unnecessary to have to quantify" (Heinrich, Petersen & Roos, 1980, p.90).

So, should we be worried that we do not have access to Heinrich's original research data[172]? If we insist that what he did was proper exact science in the strictest sense of the word, maybe we should indeed. However, by interpreting the meaning of 'a scientific approach' differently, and seeing the numbers and ratios as something else than scientifically determined laws of nature, we can relax and rather focus on the greater picture and lessons to draw from this.

One could compare this to Sanne Blauw's discussion of the problems with Alfred Kinsey's late 1940s' research into sexual behaviour. She concludes that his research was basically activism packed in a scientific guise of diagrams and tables. (Blauw, 2018, p.93) A similar argument can be made about Heinrich; he was very much an activist trying to promote what he regarded as better approaches in safety.

6.2 Topic 2: Dominos and direct causes

6.2.1 Background

One of the best-known models/metaphors by Heinrich is the accident sequence, often popularly called the dominos or domino model, sometimes even 'Domino Theory'[173] (e.g. Petersen, 1971). We can find early descriptions of the sequence already in some of Heinrich's earliest papers. "When a person is injured the sequence of events is, first, the cause, second, the accident, third, the injury" (Heinrich, 1928a, p.9) may be the first, and also most simple description of the sequence. However, the idea did not originate with Heinrich per se, most likely it is inspired by the work of DeBlois (1926) and others before him. Heinrich would develop the accident sequence through a number of papers in the early 1930s. Then, in 1934, the dominos suddenly appeared in fully finished form, only to be ignored for the next six-seven years when the 1934 text re-appears virtually unchanged in the second edition of *Industrial Accident Prevention*.

This development prompts several questions, including where did the metaphor come from? How and why were the various 'tiles' assigned? Why is there an explicit mention of 'ancestry', and not other (management) factors that Heinrich does discuss (and Bird would include some decades later)? Why the split in man and machine? Why focus on the 'middle tile' (direct cause)? We will not look into all these questions, but at this point restrict ourselves to the issues of linearity and the focus on direct causes, because in this sequence Heinrich says where the focus should be,

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[171] The second edition was also intended as more of a textbook (Heinrich, 1941, p.vi) where he includes some others to the primary audience, "employers, the industrial executives, and the directors of safety" (Heinrich, 1941, p.72).
[172][172] Another question to ask, but which I have never seen raised nor have an answer to: do other branches of science have access to the data from the 1920s and 1930s?
[173] Which is confusing, because there are several 'domino theories' around, e.g. political and for escalating process safety events.

> "In accident prevention the bull's eye of the target is in the middle of the sequence - an unsafe act of a person or a mechanical or physical hazard." (Heinrich, 1941, p.13)

6.2.2 Critique

One can find relatively early critique of simple, linear accident investigation techniques, for example in the 1963 paper by Ross A. McFarland, drawing on the work of Jacobs (1961).

> "The level of causal analysis thus represented usually does not go beyond the identification of the immediate injury-producing factors in the environment. The other causes important in the sequences eventuating in accidents are given less attention." (McFarland, 1963, p.687)

An earlier section quoted Manuele's critique of Heinrich's focus on direct causes, saying that there are other, more important causal factors to pay attention to.

> "Note that the first proximate and most easily prevented cause is to be selected. That concept permeates Heinrich's work. It does not encompass what has been learned subsequently about the complexity of accident causation or that other causal factors may be more significant than the first proximate cause." (Manuele, 2002, p.22)

As we saw, many 'new view' sources, notably Hollnagel's work, refer to the dominos. Regularly, they point out that linear models are insufficient to explain events and effects in complex, dynamic systems (e.g. Hollnagel, 2004; Dekker, 2011; 2014b)[174]. In addition, many 'new view' authors display a critical stance towards 'causes'. Hollnagel in particular has some strong arguments against the concept of root causes and the "causality credo" (Hollnagel, 2014b):

> "If accidents have explanations, then we should rather try to account for how the accident took place and for what the conditions or events were that led to it. The response should not be to seek out and destroy causes, but to identify the conditions that may lead to accidents and find effective ways of controlling them." (Hollnagel, 2004, p.29)

Hopkins, agrees with this view in this footnote of his *Issues in Safety Science* paper:

> "Some authors (e.g. Ladkin, 2001) argue that it is possible to identify a discrete set of factors that together provide a sufficient cause. However their analysis assumes that all other factors that might affect the outcome remain unchanged. This is a crucial limitation. It may be that the best way to prevent recurrence is not to focus on a discrete set of causes but to identify some background factor that, if changed, would prevent a recurrence." (Hopkins, 2014, p.12, f.7)

Hopkins mentions that others, like Betrand Russell even point out that no finite set of causes can ever be regarded as sufficient - you can always add more detail to the description, which reflects the problem of the stop rule in accident analysis - how far back should one go? Creation? The Big Bang?

But this is yet another discussion that lies outside the scope of this thesis. Instead, let us try to see why it may have made sense for Heinrich to use a simple, linear model and focus on direct causes.

6.2.3 Why did linearity and simplicity make sense?

While the 'new view' is critical about linear and sequential models, Hollnagel, who refers to them most frequently, offers on several occasions an explanation why it made sense to propose a simple, linear model of accidents in the early 20th Century (and why this is insufficient to explain accidents now). As Hollnagel argues, industrial work in the 1920s was much more comprehensible, tractable, easy to understand, often

[174] It is worth noting that Petersen (1971) argues for a less 'narrow' understanding of the dominos, and suggests multiple causation as a way to expand that view. Petersen does speak of root causes, however and is still in a fairly linear paradigm.

manual work, regular, stable and relatively simple with few variables, loosely coupled and often linear. This allowed simple models to be sufficient (Hollnagel, 2014b, p.70).

Not only were they sufficient to grasp important factors, apparently, linear, sequential models were successful. They provided their practical value and gave guidance to safety practitioners and managers to find measures that would prevent accidents. As a start, we should realise that the approach advocated by Heinrich (and before him, DeBlois) was a vast improvement over common practice at the time.

> "Heinrich's emphasis on separating the cause of the accident (the hazard) from the cause of the injury encouraged more sophisticated injury investigations." (Aldrich, 1997, p.152)

As such, the accident sequence (and the highly memorable dominos) represent the state of the art of the accident prevention thinking that was around at the time - despite the fact that even more progressive safety thinkers were already found at the time[175]. Sure enough, with what we know today, he could or should have gone further, but simplicity makes it useful, even though reality is much more complex.

This usefulness must be stressed. As said before, Heinrich did not merely write for safety experts and accident investigators. His main audience were those who did not work with safety as their main interest. A simple, understandable, memorable and practical model is what these readers, often managers, needed and wanted, and Heinrich gave to them "one of the most understandable and the clearest theories defining accident processes" (Sabet, et al., 2013, p.73). It was very understandable and clear because of an "easy visual representation of the 'path' of causal development leading to an accident" (Toft, et al., 2012, p.3), and therefore suitable for "those who are not specialists in safety" Sabet, et al., 2013, p.75)[176]. The model also guided the search for, and more importantly finding of, solutions.

> "The simple linear models assume that accidents are the culmination of a series of events and circumstances which interact sequentially with each other in a linear fashion, and thus accidents are preventable by eliminating one of the causes in the linear sequence." (Toft, et al., 2012, p.3)

Such thinking appeals to 'common sense', and offers a practical solution to busy managers, just as for example Toyota's Five Why approach does. Actually, the dominos could be seen as an early (and graphically, and metaphorically more appealing) version of Five Why. The use of simple models like Five Why or the dominos may lead to missing out on a lot of nuance and context, but they offer managers and workers a practical tool to make a trade-off between a search for solutions to prevent recurrence of accidents and other objectives. "While a search for the root cause may be efficient - in the short run, at least - it can never be thorough" (Hollnagel, 2014b, p.86) The dominos and similar tools can thus be seen as an ETTO (Hollnagel, 2009) with regard to accident analysis. Besides, despite the critique that linear, sequential models are insufficient to deal with today's complexity, Hollnagel concedes,

> "On the other hand, a closer study of the many cases in the book shows that little has changed in how humans go about accomplishing their work, differences in tasks and technology notwithstanding." (Hollnagel, 2014b, p.36)

This suggests that linear models still have a place and application - even in today's complex, connected and dynamic world.

6.2.4 Why did focus on direct causes make sense?

Today's safety professionals and incident investigators are taught to concentrate on underlying, 'root' causes, or for those who have embraced the 'new view', on the context. This was not always so. Lundberg, Rollenhagen and Hollnagel comment,

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[175] As DeBlois, hinting on complexity in the lengthy quote later this chapter. There we find for example this sentence: "Many superficially simple industrial accidents arise out of a highly involved network of condition and circumstance." (DeBlois, 1926, p.47)

[176] Another advantage according to the authors is its usefulness to allocate blame.

> "It should however be noted that different methods have historically had different foci - for instance, Heinrich (1931) promoted a focus on the *most easily preventable causes* that were *most proximate* to the accident." (Lundberg, Rollenhagen & Hollnagel, 2010, p.2133, emphasis added)

This focus may be puzzling and ineffective for us nowadays. Studying Heinrich's writings, we can identify at least two reasons why it made sense for him to focus on direct causes, on that which happens right before the accident. Firstly, he was influenced by the standards of the time, secondly he had most likely his audience in mind and he needed to offer them a solution for their problems.

Starting with the first and most likely suggestion of why Heinrich chose to focus on direct causes, we can refer to the applicable definition for accidents and causes. As Heinrich discusses, the Committee on Statistics and Compensation Insurance Cost of the International Association of Industrial Accident Boards and Commissions recommended in 1920 to assign accidents to their "proximate and immediate cause":

> "…the accident should be charged to that condition or circumstance the absence of which would have prevented the accident; but if there be more than one such condition or circumstance, then to the one most easily prevented." (quoted in Heinrich, 1931a, p.42)

On one side, it makes sense that Heinrich would choose to define a term in a way in which he was to use it in his every-day work, or that he would follow a 'best practice', especially given the fact that much of his work is a compilation and systemisation of 'best' practices within safety from his time. On the other hand, Heinrich does not shy away from delivering critique on many other practices, among which how causes were assigned by many of his contemporaries. In addition, he defines accidents in a quite novel way by classifying them as an accident regardless their consequences. Therefore, pointing towards a standard in itself is probably not enough to explain why this made sense to Heinrich.

Which brings us to the second suggestion. Heinrich's work very much reflects the thinking of the era. Interestingly, not everyone aimed for direct causes at the time. While Heinrich seems to have been strongly influenced by DeBlois with regard to causation, he deviates from DeBlois's thoughts. In his discussion of causation, DeBlois writes,

> "Most accidents are not the result of a single, well-defined cause but of a train of events or combination of circumstances each of which contributes in some degree to cause the final accident and consequent injury. Many superficially simple industrial accidents arise out of a highly involved network of condition and circumstance. They appear simple solely because we do not make the effort to trace the causative relationship to its source and are content merely with what is termed *proximate cause*. The proximate cause may or may not be the cause which it is most desirable or efficacious to remove in order that future accidents may be prevented. The only way to find out is to ascertain all the causes and then determine which are remediable and, in particular, what we may term *the principal remediable cause*.
>
> A definition of proximate cause is "a cause which directly, or with no mediate agency, produces an effect or a specific result." It bears, therefore, the closest causative relationship to the accident of any of the contributing events or circumstances. The principal remediable cause may be defined as that cause which is most readily and effectively remediable, and the remedy of which will go farthest towards removing the possibility of repetition. This term which has, to some extent, originated with the author, seems to adapt itself to the recommendation of the Committee on Statistics and Compensation Insurance Costs of the International Association of Industrial Boards and Commissions, that accidents be assigned to their "proximate and immediate cause." In defining this they stated that:
>
> - the accident should be charged to that condition or circumstance the absence of which would have prevented the accident; but if there be more than one such condition or circumstance, then to the one most easily prevented." (DeBlois, 1926, p.47/48, emphasis in original)

This quote shows that DeBlois suggested a more thorough analysis than just aiming for a direct cause. After this, the feasibility and efficacy of actions to 'remove' particular causes should be identified. Heinrich did not follow this suggestion, and instead simplified this process by stating that,

> "It becomes necessary therefore, to draw a line and limit this discussion and, in fact, restrict the definitions… to an extent that will permit ready understanding and practical application of the thoughts involved." (Heinrich, 1928b, p.123)

Apparently, Heinrich is thinking once more of his audience and their needs. An important keyword from the above quote is therefore 'practical', which is kind of a recurring theme. He did not want to make things unnecessary complicated, "expediency and practicability" (Heinrich, 1941, p.105) were guiding principles. Things had to be practicable and within reach of managers, "…in order to avoid impractical and too extensive analysis, by establishing the first, proximate, most readily eliminated cause…" (Heinrich, 1931b, p.9). The approach and causal categories recommended by Heinrich were "crude", but good enough to "serve as a practical guide" (Heinrich, 1931a, p.268). In a way, he suggested a basic stop rule for accident analysis, namely practicality: "…there is danger of delving deeper than is practical…" (Heinrich, 1928a, p.9).

This limited depth in accident analysis would also find its way into the 'Heinrich Cause Code'. Kossoris writes in his evaluation of this standard,

> "The underlying working philosophy of the Heinrich code is characterized by two items: (1) the fact that the classification of accident factors is *not intended to deal with obscure causative factors, or factors too far removed in the accident sequence to be definitely ascertainable*; and (2) the rules for the selection of the accident factors." (Kossoris, 1939, p.527, emphasis added)

We can link this to another set of explanations that Heinrich gives in his work for his recommendation to focus on direct causes. While he acknowledges, and to some degree discusses, underlying causes, chose not to spent too much time or space on them. For this, he has three reasons.

Firstly, in Heinrich's opinion, industry was not ready to embrace and practice such more advanced approaches. Many did not even understand and practice the more simple basics: "…the exclusion of detailed treatment is well justified because industry in general is not fully conversant with the more simple and direct approach to accident prevention and does not apply it in practice." (Heinrich, 1941, p.109/110) Therefore, they first had to understand these simple principles and act on them before being able to proceed

Secondly, Heinrich believed strongly in a systematic approach where things had to be done in order. "It is axiomatic, however, that error is invited if we act on underlying data without first having determined and made use of the more direct facts" (Heinrich, 1941, p.40). He has some support here. While McFarland offered critique of simple and straightforward investigation techniques and their diminishing returns, he also offered a reason that focus on causes in the proximity of the event may make sense: "…effective measures may sometimes be introduced to interrupt a sequence of events prior to complete understanding of the causal chain and the specific details of the etiology." (McFarland, 1963, p.687) One could read this as an argument for interim measures, awaiting something more systematic, but this must not necessarily so, with regard of the illustration given (preventing access to polluted water prevents cholera without understanding of the organisms involved).

Thirdly, if the domino metaphor is taken literally, it makes sense to remove the middle tile (the one right before the accident) to prevent the next tile from toppling (the accident from happening). If one would remove the utmost to the left, the middle one can still tip over and tumble the 'accident' tile. Heinrich suggests this for example in his graphical explanation of the domino sequence. The caption of Fig.4 illustrating how the 'direct cause' tile is removed in the sequence tells us, "The removal of the central factor makes the action of preceding factors ineffective" (Heinrich, 1941, p15). This suggests that one

possible reason to 'aim' for the 'middle' domino was that underlying causes may be necessary, yet not sufficient for direct cause to arise. Direct causes may be necessary to trigger the pre-existing conditions.

An additional benefit of a focus on direct causes is that it is possible in many, or most, cases to gleam 'a direct cause' from only very limited information (Jacobs, 1961). This is very appealing to managers who have little time to spare and need to be done with safety issues as quickly as possible.

As an aside, Mowery (1915), writing one to two decades before Heinrich, also argues to focus on direct causes. "Before accidents can be eliminated the *immediate* causes of those accidents must be removed" (Mowery, 1915, p.365, emphasis in original), he thought, because

> "We cannot expect to remove all the sundry contributing and predisposing causes of accidents, but if the immediate causes are eliminated the advance towards the goal of absolute safety, though probably never reached, will be accelerated greatly." (Mowery, 1915, p.365-366)

This is interesting, because unlike Heinrich several years in the future, Mowery saw human behaviour like 'carelessness' and 'haste' not as the direct causes of accidents, but rather as an underlying factor. Mowery attributes the direct cause to physical hazards. He illustrated his point with several examples, including a stairway on the Pennsylvania Railroad:

> "…it should be noted that the predisposing causes [e.g. haste or carelessness - cb.] were still present after the change of threads but the immediate cause having been removed by material means, there were no further casualties." (Mowery, 1915, p.366)

Finally, it must be noted that Heinrich is a bit contradictory and ambiguous with regard to his focus on direct causes. For example in the *Unsafe Habits* paper, he stresses "reasons" for the direct causes,

> "By far the most sensible thing to do is to find the *reasons why* unsafe acts are committed and then to devise practical action for correction, be it in the engineering-revision or educational field". (Heinrich, 1940, p.112, emphasis in original).

Also in the second edition of *Industrial Accident Prevention* (1941), Heinrich places great value on what he calls subcauses and he recognizes that a focus on direct causes does have its limitations and therefore, "…if the accident problem does not yield to the more direct approach, a herein advocated, it is advisable to dig a bit deeper in the work of fact finding." (Heinrich, 1941, p.110) In this section, he even describes latent conditions at the managerial level that remind of what Reason would write many years later, "The underlying accident causes in management and supervision, such as described, can and often do occasion or permit the existence of improper methods and procedures, these in turn being followed by direct and proximate accident causes." (Heinrich, 1941, p.110) This resonates well with Reason's writing how sharp-end practitioners inherit problems higher up in the system: "Human error is a consequence not a cause" (Reason, 1997, p.126).

But, again, he does not spend a lot of effort on this aspect of accident analysis in his work.

6.3 Topic 3: Real causes

6.3.1 Background

If one studies Heinrich's work, one will quickly see that causation is a very central theme in his work. Causal analysis was also an important element in what he calls the "principles of scientific accident prevention" (Heinrich, 1931a, p.6). Reading his work, one will also see that he discusses various kinds or types of causes. He mentions 'basic causes', 'real causes', 'true causes', 'so-called causes', 'direct causes', 'proximate causes', 'sub-causes', 'underlying causes', and 'reasons' - and most likely a couple of others that have escaped this list. Heinrich did not clearly define all of these, but often one can understand what he means by them from the context and examples given.

It is important, however, to pay attention, because on a few occasions these terms change meaning. Most notably 'basic cause' which in the *Origin of Accidents* papers (Heinrich, 1928a/b) has the same meaning as 'real' or 'true' cause. In the second edition of the book, however, it is used as a kind of synonym for 'underlying' cause. This is more or less the contemporary understanding of 'basic cause' or 'root cause', as it is used in many accident analysis tools, like for example the Tripod methodology (Groeneweg, 1992). As we will see below, the term 'real' and 'true' causes changed its meaning as well over the period of about a decade.

6.3.2 Critique

> "The history of accident analysis clearly demonstrates that the notion of a cause itself is an oversimplification, since a cause is an attribution after the fact or a judgement in hindsight, rather than an unequivocal fact. This acknowledgement notwithstanding, accident models seem to be firmly entrenched both in the idea that a 'true' or root cause can be found, and in the idea that 'human errors' necessarily must be part of the explanations. This view should be contrasted with the so-called ecological view which points out that action failures are both an unavoidable and necessary element of efficient human performance." (Hollnagel, 2000, p.40)

Apart from the above quote, none of the 'new view' thinkers, or other authors I have read so far, comments on the fact that Heinrich talks about 'real' or 'true' causes, and not even Hollnagel critiques directly that above (his aim is at 'root' causes), so I have to deliver some critique myself.

Having adopted a constructivist view (Le Coze, 2012) on accident causes over the past years, one thing that struck me as odd, when studying Heinrich's work was the use of terms like 'real' or 'true' cause[177]. I would never use this term, nor condone its use.

Davies et al. (2003) argue that causality is a property of the human mind, not a property of the natural world, and according to Rasmussen, causes are constructed, not found. They depend on our "categorization of human observations and choices" (Rasmussen, 1990, p.451, also Dekker, 2014a, p.76). Hollnagel (2004) says that causation is inferred from observation, but cannot be observed directly. The cause is constructed from understanding the situation, rather than found. Even more, a cause is selected from a set of possible causes[178], so it is rather the result of an act of inference rather than an act of deduction. As a consequence of the stance that causes are constructed the notion of a 'real' or 'true' cause must be rejected. From a constructivist view, no such thing can exist, because a construct (like e.g. a cause) is subjective and therefore there cannot be just one truth or reality.

A good example of causes being constructs rather than 'real' phenomena is the earlier quoted text by Mowery (1915). Where most of his contemporaries attributed 80% of all injuries to human carelessness, the author reached a radically different conclusion and put the direct causes of these events in the context of the situation.

6.3.3 Why did it make sense? - Early use

There are two explanations for use of terms like 'real' or 'true' cause throughout Heinrich's writings. One explanation is rooted in the early use of the word, the other in the later use.

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[177] Interestingly, while doing literature research for this study, I revisited the book *Real Risk* by 'new view' author Robert Long. Apparently, not even the 'new view' is immune to the effect to call something 'real'.

[178] It is interesting to see that this is exactly what Heinrich argues in the 1931 edition of *Industrial Accident Prevention* and the papers leading up to this. For example, the *Origin of Accidents* paper (1928b) is absolutely littered with Heinrich talking about causes being assigned or charged to something - e.g. "we find almost invariably that accidents are assigned to…" (Heinrich, 1928b, p.122), "…which results in the assignment of accidents to…" (p.123), "…when an accident is clearly chargeable to…" (p.125), "…should therefore be charged…" (p.126), and many more. Whether this choice of language was a conscious constructivist approach or something else will not be explored in this thesis. His language in the 1941 edition turned more into a deterministic direction.

Reading Heinrich's early work, early papers up until and including the first edition of *Industrial Accident Prevention*, one sees that the term 'real cause' and 'true cause' are used as opposed to what Heinrich labels "so-called causes" (Heinrich, 1928a, p.10). Heinrich's paper on the *Relation of Accident Statistics to Industrial Accident Prevention* (Heinrich, 1929c) is in this respect very illustrative for the question why he chose to speak about 'real causes' in his book:

> "In short, the so-called cause-of-accident code is not a cause code at all. The title is misleading. Nor are there any other codes that deal with actual accident codes". (Heinrich, 1929c, p.172)

One important point from the *Origin of Accidents* articles (Heinrich, 1928a/b) is the difference between the event and its cause(s), and between the cause of an accident and the cause of the injury. In Heinrich's opinion, accident prevention of his time was "inaccurate and partially effective practice" (Heinrich, 1928b, p.131), because many safety practitioners (and others) muddled up these things[179]. Heinrich therefore distinguished between 'basic causes' (in the book renamed to 'real causes') and 'so-called causes' (also labelled 'ordinary', as this was how most practitioners at the time would use them). The latter were causes assigned by Heinrich's contemporaries, often descriptions of the event or mechanism, like "hit by" or "fall from". One can find such classifications in many safety texts and statistics of the first decades of the 20th Century. Taking Beyer's book as an example, we find 'causes' as "Shifting by stick or hand", "Caught between belt and pulley", "Blasting and drilling", and "Falls from fixed ladders" (Beyer, 1916, p.9-10)

So, while it may look strange from a constructivist point of view to talk about 'real' or 'true' causes, Heinrich's intention with this term was to distinguish his way of attributing cause from the commonly used categories that were rather description of the event or causes for injuries. With that intention in mind (introducing a 'new view'), it makes sense to talk about 'real' or 'true' causes.

Heinrich kept this use of the terms 'real' and 'true' cause up until the first edition of *Industrial Accident Prevention*. The examples discussed on pages 50 to 54 of this book show "incorrect analysis" and "incorrect cause", naming the event ("sliver in finger") or consequence ("sprain"), according to the "existing inaccurate and partially effective practice" (Heinrich, 1931a, p.50) as opposed to the way recommended by Heinrich[180].

Heinrich would keep the argument against in his eyes 'incorrect' causes, "…so-called 'accident-cause codes' have not really been *cause* codes at all, but have merely indicated accident *types* or the agencies involved in the occurrence of accidents" (Heinrich, 1941, p.330, emphasis in original). However, in his later work, he would no longer refer to 'his' way as 'true' or 'real'. At some point in time he started using these terms for something else.

6.3.4 Why did it make sense? - Later use

You will find the terms 'real' and 'true' cause throughout the first edition of *Industrial Accident Prevention*. In the second edition from 1941 they appear much less frequently, as can be seen from the overview in Appendix 1.

There are only a few mentions of 'real' causes early on in the second edition, indicating that they are "specific" (Heinrich, 1941, p.4). Given its discussion in the first edition of *Industrial Accident Prevention*, the term re-appears relatively late in chapter IV, Fact Finding of the 1941 edition. The first appearance here is on page 125 (the chapter starts on 102) and the reader familiar with earlier work discovers that Heinrich has changed the meaning of the term somewhat - without explaining that or why he did so.

The reader will notice that the term 'real' or 'true' cause is only discussed here in relation to remedy and corrective action (Chapter V). Heinrich argues that a reversal of a cause will provide a useful measure to prevent reoccurrence. For example, when someone slips and falls and a slippery floor is chosen as causal

[179] In a way, these papers were a call for professionalization of safety work.
[180] It is interesting to see that Heinrich's analysis shown in these examples is considerably richer that the original analysis

factor, then reversing this cause will provide guidance for a corrective action: a non-slippery floor. Like many other things, this line of reasoning appeals to common sense and may work for many situations, but is not without problems. We shall not discuss those at this point, however.

Apparently, the later use is merely a 'label' taken from a term that Heinrich had used before, changing the former meaning to provide a contrast to other practices to a new meaning where 'real' or 'true' causes are the ones that will provide you with a remedy when you reverse them, while other causes do not provide that explicit guidance. In a way this explanation is also applicable for the earlier use of 'real' and 'true' cause, because the 'so-called' causes of his time (e.g. fall from height) would rarely give concrete guidance. This new use of the term does not come entirely out of the blue. Already in his earlier use of the terms, Heinrich hints at this the fact that causes should provide concrete clues of what to do. "Basic causes must be the guide for prevention" (Heinrich, 1928b, p.137), he wrote.

As a closing note, in a way, 'true' cause in the later meaning does make some sense. Take for example the often-heard conclusion that an accident happened because of 'a poor safety culture'. In general, these conclusions ('causes') do not give a concrete clue to useful actions and improvement and are merely substitution of one term or label for another (Dekker & Hollnagel, 2004). Pointing towards more specific factors (e.g. conflicting objectives, scarce resources, power issues) - 'true causes' in the terminology of Heinrich's 1941 book - might actually give useful suggestions.

The discussion of three topics in this chapter attempted to suggest explanations why some things may have made sense to Heinrich, while they may not make (as much, or not at all) sense to us. In the final chapter, I will summarize some of the findings and give some suggestions for possible further research.

7 Conclusion and final reflections

I would like to suggest that this thesis contributed to safety science and practice in various ways. Firstly, this has been one of the most in-depth studies of Heinrich's work (up and until 1941). Part of the thesis meant literally archaeological research, uncovering more of Heinrich's work than has been available/accessible to safety science before and through this it presents a unique collection of resources that give a richer picture of both the person Heinrich, and his work.

Manuele (2002) states that since Heinrich's source data is no longer available, all we have to go on in studying Heinrich's work is what he wrote down in his books. That statement deserves some qualifications. With access to Heinrich's papers, and other documentation that was uncovered in the research for this thesis, we have a much richer source that can help to understand his work and changes in his work. This thesis provides some of that understanding, but there is much that remains to be unpacked and analysed.

Secondly, by comparing 'new view' critique to Heinrich's original work, and the 'new view's' characteristics, this thesis illustrates that critique of 'old' safety theories and approaches contains substance as well as ethical implications. When we offer critique, we have a choice of what story we want to tell - just as is the case with accident investigations. Critique does not only serve scientific purposes, or to propose better/alternative approaches. The discourse of this critique can also serve other goals, for example ideological purposes, or even as a way to market a product one has to sell.

Thirdly, just as they give us a better and richer understanding of accidents and organisational events, 'new view' approaches prove to be useful for the analysis of texts. Looking for the local rationality of an author suspends judgement and contributes to a better and deeper understanding. This is in line with Covey's (1989) fifth habit: seek first to understand, then to be understood.

7.1 Heinrich and the 'new view' - Heinrich differently

One central theme in this thesis has been the contrast between Heinrich and the 'new view', and I just want to reflect some more about this. Firstly, the reader may have noticed that I have put 'new view' between apostrophes throughout the entire thesis. 'New' is a relative adjective, not an absolute one. A 'new view' is always in the eye of the beholder. Instead, there is continuous development and evolution of ideas, though synthesis and changed representation of existing knowledge with emerging new insights. Le Coze's (2013) discussion of four different safety models can serve as a good illustration of this. At some point, he even asks, "How could it be another way?" (Le Coze, 2013, p.209), because "New propositions must start from somewhere. Our opinion is therefore always a matter of judgment based on our appreciation of these transformations, explorations and associations of earlier works, but also the rhetoric of authors." (Le Coze, 2013, p.209)

Thus, if there are revolutions and 'paradigm shifts', these are often not of a 'Kuhnian' kind (Kuhn, 1962), but exist most likely merely in the popular perception, for example because a new buzzword suddenly appears frequently in the public view and goes quasi viral[181]. Many ideas were already around many decades ago, but lacked a theoretical framework and maybe the time was simply not ripe for them, for example because there was no 'movement' to present them to a wider audience.

As noted earlier, Heinrich actually was part of a 'new view' himself (Aldrich, 1997). A view that did not see accidents as things that just happened, or happened because of carelessness[182]. A view that instead saw accidents as events that were caused and that could (and should) be prevented[183].

[181] In so far as anything in safety ever goes viral… except for video clips of 'silly accidents', of course.
[182] Although Heinrich refers frequently to carelessness as part of 'man failure'.
[183] "That the vast majority of injuries were either due to 'trade risks' or the result of 'careless" worker behaviour was an article of faith among most nineteen-century business people. In either case, injuries were neither the fault of nor

From today's point of view, this is a view that is concerned with the absence of negatives (already the title of Heinrich's book gives that away: "accident prevention") and a view that sees people not necessarily as a solution, but rather as a problem to be controlled (even though Heinrich does have more nuanced opinions on the matter too), and so on. With today's knowledge, we can critique much of what was 'new' in the 1930s and relabel these approaches as 'old', or worse.

So, when we ask ourselves why it makes sense to contemporary 'new view' authors to critique Heinrich and Heinrichian themes sometimes quite harshly, we can surely point to progress made over the last decades. There have been many new insights in (safety) science with regard to human factors, management, social psychology and much more. However, it is not merely a matter of 'better' knowledge.

Howarth, in his discussion of Foucault's archaeological approach, mentions the problem of "the relationship between discourses and the realities they claim to represent." (Howarth, 2000, p.70) This applies also to 'new view' discussions of Heinrich. Many authors, and the 'new viewers' are rarely an exception, often only show one version and no 'second stories', leaving it to readers to explore other accounts. Not many readers will do so, however, and there may be many reasons why not.

For authors seeking to establish *another* 'new(er) view', it makes sense to illustrate and stress the contrast of their own message/product and that which came before, especially with the emergence of Safety-II and Safety Differently almost as a 'brand' of safety. Like Coca Cola versus Pepsi, it makes sense to contrast against the other 'brand' and highlight the positive sides of one's own 'brand' and the negative sides of the 'competition' - of which Heinrich happens to be one of the most recognizable flagships. To quote Johan Bergström[184], this may lead in some cases to situations where Heinrich is positioned as "the old view Satan".

While the highlighted contrasts may be a very useful and powerful pedagogical device and an important tool in influencing and persuading others, over-communicating distinctions like 'old' and 'new' is that it may contribute to create separation and polarisation between various schools of thought, and thereby limiting learning opportunities - along with the creation of new 'myths'. However, it is not a choice between one approach and the other. As Hollnagel stresses, 'old' and 'new' views are complementary and we need both (Hollnagel, 2014b).

The irony is that the same rationale that prompted some people to start talking about a 'new view', or 'safety differently' is what most likely got Heinrich to label his book 'a scientific approach'. One wonders whether eighty years from now someone critiques Hollnagel and Dekker for being neither 'new' nor 'different'…

7.2 But isn't the past, the past?

One may wonder whether it makes any sense at all to dive this deep into theories and ideas that go back seven or eight decades and more, and deeper still since I will list a number of suggestions for further research in the next section. Should we spend time and resources on theories and ideas that have been used and abused so much that most of their contemporary use is rather counterproductive? Should we instead follow Craig Marriott's suggestion when he finishes his discussion of the "triangular fallacy", stating, "Unfortunately, it has been so tainted now, that it would be better to remove it altogether and consign it to history." (Marriott, 2018, p.30) Marriott is not alone, also Scott Gesinger advocates leaving the past behind and look forward, "…it is time for the old ideas to be swept into history…" (Gesinger, 2018, p.2).

My immediate reply to the question whether we should bother at all is a clear "Yes!" Heinrich's legacy has proven to be a subject of discussion among practitioners, professionals and academics for years. Many

preventable by employers, or so most of them thought." (Aldrich, 1997, p.114) This thinking was opposed by the 'new view' of safety thinkers of the 1920s and 1930s, including DeBlois and Heinrich.

[184] A statement popping up during one of the discussions about this thesis, circa May 2018.

safety professionals (and scholars) have not even read his work, but lack of information and knowledge has never stopped humans of having an opinion. The analysis in this thesis, and the discussion of numerous misconceptions and attributions, shows us that there is some need for clarification and better understanding. I think it is important to have an *informed* opinion, which means one has to engage and study. Study critically, taking in view both how things looked back then and from the benefit of today's knowledge.

To study, one needs to engage with an open mind. Instead of flatly rejecting an 'old' approach as some seem to suggest, it may be wise to first take a look at the baby and only throw out the dirty water from the bath - even though there may be the possibility that there is only dirty water to be found in the tub. However, I think that much of Heinrich's work is still relevant today, at least within certain applications.

Besides, let us just imagine for a moment if the entire community decided to go for a wholesale rejection of traditional safety approaches rooted in engineering, bureaucracy and management techniques. Surely, this just wild speculation, but losing some of its engineering and management approaches, safety would probably be regarded as 'new agey' feel good stuff instead of something manageable and useful. Apart from the question how this would affect the production of goods and services.

More and critical research and reflection with a non-binary view is therefore advisable.

7.3 Suggestions for further research

The subjects presented in this thesis provides many suggestions for further research - not in the least because there was a number of possible thesis subjects that were *not* selected, and at best addressed cursory in this work. In addition, several interesting side-tracks have popped up during the discussion that are worthy of further exploration.

I would like to suggest the following subjects for further study:

- A thorough genealogy and archaeology of Heinrich's work, including:
    - what influenced Heinrich's work,
    - how did Heinrich's work (e.g. the main themes) develop over time, and why,
    - in particular the changes between the first and second edition of *Industrial Accident Prevention*,
    - how did Heinrich's work influence safety science and practice, including
    - a genealogy of his concepts, notably the triangle,
- Looking deeper into the various (main) themes of Heinrich's work, what they mean, how they connect.
- Studying and discussing the critique of Heinrich's work, including that of others than 'new view' thinkers.
- Doing an in-depth study of the meaning, interpretations, limitations and validity of the triangle.
- Doing an in-depth study of Heinrich's view on the role of the human.
- Tracing how post-Heinrich developments have influenced the view of Heinrich's themes.
- Exploring the endurance of Heinrich's ideas.

Not related to the study of Heinrich's work, I would suggest separate studies looking into:

- The increased number of academic safety publications.
- The practices of citing within safety literature.
- Ways of dealing with and reducing quotation errors, notably concentrating on systemic elements as enabling easy access to primary sources and reducing pressures that encourage taking shortcuts.

7.4 Famous last words

Allow me to close this thesis with the words of my friend, Jos Villevoye:

> "Heinrich made a significant and memorable contribution to the evolution of safety management. Wrong, right or partly agreeable. I'd like to use his legacy to create a flexible mindset and not to create a rigid divide."[185]

Amen to that.

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Glossary/Abbreviations

ASME	American Society of Mechanical Engineers
ASSE	American Society of Safety Engineers
ASSP	American Society of Safety Professionals
BBS	Behaviour Based Safety
HOP	Human & Organizational Performance
IOSH	Institution of Occupational Safety and Health
LTI	Lost Time Injury
NSC	National Safety Council
NVVK	Nederlandse Vereniging voor Veiligheidskunde (Dutch Society for Safety Science)
SIF	Serious Injuries & Fatalities

Appendix 1: Use of 'real' and 'true' cause

The table below shows the appearances of 'real' and 'true' cause in the 1931 and 1941 editions of *Industrial Accident Prevention*. In the table, the comparable chapters are placed side-by-side as much as possible to make comparison easier - therefore the chapters of the 1941 version are not in proper order.

Table 3: Comparison of appearances of 'real' and 'true' cause in the 1931 and 1941 editions.

Comparison[186] of 1931 and		**1941**	
Chapter 1[187] Principles	2	Chapter 1 Principles	2
Chapter 2 Costs of accidents	0	Chapter 2 Basic philosophy	3
		Chapter 3 Creating interest	0
Chapter 3 Cause analysis	14[188] + 1[189]	Chapter 4 Fact finding	11
Chapter 4[190] Selection remedy	16[191] + 1[192]	Chapter 5 Corrective action	2
Chapter 5 Executive enforce	4		
Chapter 6 Education employee	2	Chapter 14 Education employees	1 + 1[193]
Chapter 7 Safety psychology	5	Chapter 8 Safety psychology	4
Chapter 8 Guarding	0[194]	Chapter 6 Guarding	0
Chapter 9 Process revision	0	Chapter 7 Process revision	0
		Chapter 9 Fatigue	0
		Chapter 10 Occupational disease	0
Chapter 10 Illumination	0	Chapter 11 Illumination	0
		Chapter 12 Safety organisation	0
Chapter 11 Statistics	2[195]	Chapter 13 Accident statistics	2
Chapter 12: Summary	2	Chapter 15 Summary	2
Appendix I	1		
Appendix IV Message foremen	1	Appendix III Message foremen	1
Total	53 + 2	Total	30 + 1

[186] Based on a manual count, so accept that I may have missed a few. The numbers are indicative!
[187] First mention on p.5
[188] Not counting the numerous "correct" and "incorrect" cause/analysis in the cases.
[189] "definite cause" (Heinrich, 1931a, p.39)
[190] Used here in connection to "reversal" - even in the 1931 edition.
[191] Including one in fig.2
[192] "proper cause analysis"
[193] "Specific accident causes" (Heinrich, 1941, p. 346)
[194] To be honest, I have not checked too thoroughly, but I would be surprised if there were any.
[195] Additionally, there is a mention of the opposite: "so-called accident codes"

Appendix 2: Heinrich's 'main themes'

The table below presents an overview of how the nine main themes from Chapter 3 appear in Heinrich's work up until the 1941 edition of *Industrial Accident Prevention*.

Explanation of the indicators in the cells below: X indicates a main theme of the paper, x an important theme and (x) that the theme is mentioned as an aside.

*, # and § indicate papers that are more or less identical, but published different places.

Table 4: Appearance of main themes in Heinrich's work up until 1941.

Source	Science	Cost	Causation	Human	Triangle Weak signal	Role of Management	Axioms	Professional	Practical remedy
1923a	(x)								
1923b		X				X			x
1925	(x)	X		x		X			x
1926 *		X							
1927a *		X							
1927b *		X							
1927c		X		(x)	x	(x)	(x)		
1928a #	(x)	(x)	X	X	x	(x)	(x)	(x)	
1928b #	(x)	(x)	X	X	x	(x)	(x)	(x)	
1929a	(x)	(x)	x	x	X	(x)		(x)	
1929b	(x)	(x)	x	x	X	(x)		(x)	
1929c	(x)	(x)	X					(x)	
1929d §			x	x	x	X			
1929e §			x	x	x	X			
1929f		(x)	x		x	X			
1930a §			x	x	x	X			
1930b	(x)	(x)		x		(x)	(x)		
1930c		X			x	x			
1931a book	x	X	X	X	X	X	(x)	(x)	X
1931b	(x)		X	x	(x)	x	(x)	(x)	
1931c			(x)	x		x		x	x
1931d	(x)	X	(x)	X	(x)	X	(x)		
1932a		X	X	(x)	(x)	X	(x)		

Source	Science	Cost	Causation	Human	Triangle Weak signal	Role of Management	Axioms	Professional	Practical remedy
1932b	(x)	X	X	(x)		X	(x)		
1932c			(x)		(x)			x	x
1932d	(x)					X	(x)		
1933a		X							
1933b		x	X			X			
1933c	(x)		x	X			(x)		
1934	(x)		(x)		(x)	X	(x)		
1935	(x)		x					x	x
1937a	(x)		X	x	x	x			
1937b		x				x			
1938a				(x)		X			(x)
1938b		X		(x)		x			(x)
1940	(x)		X	x				(x)	x
1941 book	x	X	X	X	X	X	X	(x)	X
Travelers, 1934			X	X					

Appendix 3: Dekker literature

The table below gives a brief overview of the literature by Sidney Dekker that has been reviewed for inclusion in this study[196]. The first column indicates the document. The second column indicates whether Heinrich is referenced in the document, and what source. The third column indicates the page(s) Heinrich, or Heinrichian themes are discussed. The last two columns show what (theme) is discussed, including relevant quotes and some remarks on the material. Literature that does not mention Heinrich or Heinrichian themes is not taken further into the study - unless it does have other relevance.

Table 5: An overview of the literature by Sidney Dekker reviewed for inclusion in this study.

Title	Heinrich reference	Page	What	Remarks
Woods, D.D. & Dekker, S.W.A. (2000) Anticipating the effects of technological change: A new era of dynamics for human factors. *Theoretical Issues in Ergonomics Science*, 1 (3): 272-282.	None			
Dekker, S. (2001) Disinheriting Fitts and Jones '47. *International Journal of Aviation Research and Development*, 1,1.	None			
Dekker, S.W.A. (2001) Follow the procedure or survive. *Human Factors and Aerospace Safety*, 1(4): 381-385.	None			
Dekker, S.W.A. (2001) The re-invention of human error. *Human Factors and Aerospace Safety*, 1(3): 247-266.	None			
Dekker, S. & Woods, D.D. (2002) MABA-MABA or Abracadabra? Progress on Human–Automation Co-ordination. *Cognition, Technology & Work,* 4: 240–244.	None			
Dekker, S.W.A. (2002) Reconstructing the human contribution to accidents: The new view	None			Defines 'new view' and discusses local rationality.

[196] Scopus shows 107 documents, none of which return "Heinrich", even though the third edition of the Field Guide is included in the result, and at least that one should give a 'hit'. Scopus appears to have limitations. (Searched 8 May 2018: https://www.scopus.com/authid/detail.uri?authorId=7004055480)
One paper is included in Appendix 6 with Provan as main author and Dekker as one of the co-authors.

Title	Heinrich reference	Page	What	Remarks
of human error and performance. *Journal of Safety Research*, 33(3): 371-385.				
Dekker, S.W.A. (2002) Human error after all. *Human Factors and Aerospace Safety*, 2(2): 193-196.	None			
Dekker, S.W.A. (2002) *The Field Guide to Human Error Investigation*. Farnham: Ashgate.	None			
Dekker, S.W.A. (2003) Accidents are normal and human error does not exist: A new look at the creation of occupational safety. *International Journal of Occupational Safety and Ergonomics*, 9 (2): 211-218.	None			Defines 'new view'
Dekker, S.W.A. (2003) Illusions of explanation: A critical essay on error categorization. *International Journal of Aviation Psychology*, 13(2): 95-106.	None			
Dekker, S.W.A. & Hollnagel, E. (2004) Human factors and folk models. *Cognition, Technology & Work,* 6:79–86.	None			
Dekker, S.W.A. (2004) The hindsight bias is not a bias and not about history. *Human Factors and Aerospace Safety*, 4(2): 87-99.	None			
Dekker, S.W.A. (2004) Why we need new accident models. *Human Factors and Aerospace Safety*, 4(1): 1-18.	None			
Dekker, S.W.A. (2006) *The Field Guide to Understanding Human Error*. Farnham: Ashgate.	None			
Dekker, S. (2007) *Just Culture: Balancing Safety and Accountability*. Farnham: Ashgate.	None			
Dekker, S. (2007) Criminalization of Medical Error: Who Draws the Line? *Royal Australasian College of Surgeons*, 77: 831-837.	None			
Dekker, S.W.A. (2007) Eve and the Serpent: A rational choice to err. *Journal of religion and health*, 46(1): 571-579.	None			

Title	Heinrich reference	Page	What	Remarks
Dekker, S.W.A. (2008) Just culture: who gets to draw the line? *Cognition, Technology & Work,* 11 (3): 177-185.	None			
Huber, S., van Wijgerden, I., de Witt, A. & Dekker, S.W.A. (2009) Learning from organizational accidents: Resilience engineering for high-risk process environments. *Process Safety Progress,* 28(1): 90-95.	None			
Woods, D.D., Dekker, S.W.A., Cook, R., Johannesen, L., & Sarter, N. (2010) *Behind Human Error (second edition)*. Farnham: Ashgate.	None, but mentions (1931)	41	Dominos	Does not reference, bus discusses linear accident model.
		43-45	Triangle (Bird version)	
		16-17 / 137	Local rationality	
Dekker, S., Nyce, J., Van Winsen, R. & Henriqson, E. (2010) Epistemological Self-Confidence in Human Factors Research. *Journal of Cognitive Engineering and Decision Making*, 4 (1): 27–38.	None			
Dekker, S.W.A. (2010) We have Newton on a Retainer: Reductionism when we need Systems Thinking. *The Joint Commission on Quality and Patient Safety*, 36 (4): 147-148.	None			
Dekker, S.W.A & Woods, D.D. (2010) The High Reliability Organisation Perspective. In: E. Salas, F. Jentsch & D. Maurino (Eds). *Human Factors in Aviation (2nd Edition)*. New York: Academic Press. 123-143	None			
Dekker, S.W.A., Hummerdal, D.H. & Smith, K. (2010) Situation awareness: some remaining questions. *Theoretical Issues in Ergonomics Science*, 11:1-2: 131-135.	None			

Title	Heinrich reference	Page	What	Remarks
Dekker, S.W.A. (2011) The criminalization of human error in aviation and healthcare: A review. *Safety Science,* 49: 121-127.	None			
Dekker, S.W.A., Bergström, J., Asmer-Wåhlin, I. & Cilliers, P. (2011) Complicated, complex, ac: best practice in obstetrics. *Cognition, Technology & Work*.	None			
Dekker, S.W.A., Cilliers, P. & Hofmeyr, J.-H. (2011) The Complexity of Failure: Implications of Complexity Theory for Safety Investigation. *Safety Science,* 49: 939-945.	None			
Dekker, S.W.A. (2011) *Drift Into Failure: From Hunting Broken Components to Understanding Complex Systems*. Farnham: Ashgate.	None, but indirectly	91	Mentions domino model, linearity, fixed order	
Dekker, S.W.A. & Nyce, J.M. (2011) Cognitive Engineering and the moral theology and witchcraft of cause. *Cognition, Technology & Work*: 14(3): 207-212.	None			
Åsberg, R., Hummerdal, D.H. & Dekker, S.W.A. (2011) There are no qualitative methods – nor quantitative for that matter: the misleading rhetoric of the qualitative–quantitative argument. *Theoretical Issues in Ergonomics Science*, 12:5: 408-415.	None			
Mikkers, M., Henriqson, E. & Dekker, S.W.A. (2012) Managing multiple and conflicting goals in dynamic and complex situations: Exploring the practical field of maritime pilots. *Journal of Maritime Research*, 9(2): 13-18.	None			
Dekker, S.W.A. (2013) *Second Victim: Error, Guilt, Trauma and Resilience*. Boca Raton: CRC Press.	None			
Dekker, S.W.A. & Nyce, J.M. (2013) Just culture: "Evidence", power and algorithms. *Journal of Hospital Administration*, 2(3): 73-78.	None			

Title	Heinrich reference	Page	What	Remarks
Dekker, S.W.A., Nyce, J.M. & Myers, D.J. (2013) The little engine who could not: Rehabilitating the individual in safety research. *Cognition, Technology & Work*, 15: 277-282.	None			
Dekker, S.W.A. & Hugh, T.B. (2014) A just culture after Mid-Staffordshire. *BMJ Quality and Safety*, 24: 356-358.	None			
Dekker, S.W.A. (2014) *The Field Guide to Understanding 'Human Error'*. Farnham: Ashgate.	1980[197]	123	Chain of events, 88%[198], biased data, unsafe act[199] - almost too much in so limited space!	Connects to SCM, "The thinking on which it is based is getting on in age - soon a century".
		124	Triangle, common causes, fixed ratios, chain of events	"…incidents in very safe systems are caused by radically different things than accidents or fatalities"[200]
		164-5	88%, bias and blame in data, behaviourism	BBS interventions are based on "psychology that was dominant in 1930s"[201] "He reached this conclusion on the basis of supervisor's accident reports. Of course - if you are a supervisor, you might want to say that you and the work environment you helped create are both blameless. Instead, the worker is the problem to control." (Dekker, 2014a, p.164)
Dekker, S.W.A. & Nyce, J.M. (2014) There is Safety in Power, or Power in Safety. *Safety Science,* 67: 44-49.	None			

[197] The 1980s book is a weak source if you want to reference to Heinrich because only a minimal part of the text is still Heinrich's. On the upside: it suggests at least that Dekker read the book (or parts of it), not that he merely unthinkingly references to 1931 as many others do.
[198] See remark in chapter 5.2.2.
[199] Was Heinrich really the first to articulate the idea of worker unsafe acts? Most likely not, but he is about the only pre-War safety author who is widely known today.
[200] A highly confused, and confusing statement.
[201] Note that Heinrich is not a behaviourist per se!

Title	Heinrich reference	Page	What	Remarks
Dekker, S.W.A. (2014) The Bureaucratization of Safety. *Safety Science,* 70: 348-357. doi:10.1016/j.ssci.2014.07.015.	None, but indirectly	--	Triangle, via Wright & Van der Schaaf	
Dekker, S.W.A. (2014) Safety Leadership: The Role Of The Executive in Leading Safety. *Conexus*, 27 February.	None			
Dekker, S.W.A. (2014) Employees: A problem to control or resource to harness? *Professional Safety*, 56(8), 32-36.	None		Role of the worker Triangle	Discusses Heinrich related topics indirectly: the subject of 'man failure' and the negative correlation between incident rates and fatalities.
Dekker, S.W.A. (2014) The problems of vision zero in work safety. *Malaysia Labour Review*, 1(8), 25-36.	None			
Leveson, N.G. & Dekker, S.W.A. (2014) Get to the Root of Accidents. *Chemical Processing*, published online 28 February.	None			
Dekker, S.W.A. (2015) *Safety Differently (second edition)*. Boca Raton: CRC Press.	1980	174	First axiom, linear accident sequence	Acknowledges the analytical and explanatory leverages, but critiques its simplicity. The first axiom is a Cartesian-Newtonian view which does not apply to complex systems.
Dekker, S.W.A. (2015) The danger of losing situation awareness. *Cognition, Technology & Work,* 17:159–161.	None			
Dekker, S.W.A. (2015) The psychology of accident investigation: epistemological, preventive, moral and existential meaning-making. *Theoretical Issues in Ergonomics Science,* 16:3, 202-213.	None			
Dekker, S.W.A. & Pitzer, C. (2015) Examining the Asymptote in Safety Progress: A Literature Review. *International Journal of Occupational Safety and Ergonomics*, 22(1): 57-65.	None, but indirectly	--	Triangle, via Wright & Van der Schaaf	
Dekker, S.W.A. (2016) *Just Culture: Restoring Trust and Accountability in Your Organization*. Boca Raton: CRC Press.	None			

Title	Heinrich reference	Page	What	Remarks
Dekker, S. W. A., & Breakey, H. (2016) 'Just culture': improving safety by achieving substantive, procedural and restorative justice. *Safety Science*, 85: 187-193.	None			
Dekker, S. W. A., Long, R. & Wybo, J.L. (2016) Zero vision and a Western salvation narrative. *Safety Science*, 88: 219-223.	None			
Dekker, S.W.A. (2017) *The End of Heaven: Disaster and Suffering in a Scientific Age.* Milton Park: Routledge.	None			
Dekker, S. (2017) The original hearts and minds campaign, and the dereliction of behaviour-based safety.	1980	--	connects BBS to 88%, negative qualifiers: highly dubious 'finding'	But, adds a nuance: "…even Bird and Heinrich…"
Dekker, S. (2017) Zero commitment: commentary on Zwetsloot et al., and Sherratt and Dainty. *Policy and Practice in Health and Safety*, 15(4):1-7.	None, but Heinrich is mentioned on p.5	5	Triangle	Rages against the triangle, references Wright & Van der Schaaf and gets their argument upside-down, later repeated in *The Anarchist*. See chapter on quotation error.
Dekker, S. (2017) Zero Vision: enlightenment and new religion. *Policy and Practice in Health and Safety*, 15 (2): 101-107.	None			
Dekker, S. (2017) The Safety Profession Can Be Like A Priesthood. Retrieved 16 October 2017 from http://www.safetydifferently.com/the-safety-profession-can-be-like-a-priesthood/	None			
Dekker, S.W.A. (2017) Rasmussen's legacy and the long arm of rational choice. *Applied Ergonomics*, 59: 554-557.	None, but Heinrich is mentioned.	555	Unsafe acts	"Unsafe acts", a term coined by Heinrich in the 1930s, remains a trope in Reason's popular accident model…"
Dekker, S. (2018) *The Safety Anarchist. Relying on Human Expertise and Innovation, Reducing Bureaucracy and Compliance.* Milton Park: Routledge.	1931	85-88	Science	Connects to Taylorism "…the subtitle of his book was A Scientific Approach. ……..
	1980	87	88%	The 1980 (p.4) quote is actually Heinrich's, also found in 1959, p.4.

Title	Heinrich reference	Page	What	Remarks
		87	Triangle, fixed ratio	Don't think that Heinrich discussed the ratio as 'fixed'.
	1959	88	No-injury cases	1959 p.31: volgens mij zegt ie dat al eerder (e.g. 1929a/b, footnote 1931, p95 suggests research)
		88-94	Triangle	Gets Wright & Van der Schaaf wrong
		94		"prescriptions inspired by Heinrich" - correct way of putting it
		97n2	Missing data	The co-authors of 1980 were not actually co-authors - if anything, Granniss would have been
		97-98n3	88%, domino tiles, other actions	Nuances things somewhat by acknowledging Heinrich's focus on a.o. guarding. Still, I think that Dekker only has one part of the explanation here. I guess it also had to do with the phase of the accident - besides, an unsafe act is only an unsafe act within its context (although Heinrich never had that realisation).
		101-103	88%, behaviour	"Heinrich's 1931 claim that 88% of occurrences are caused by 'man failure' or human error or worker behaviours has inspired many to believe that they need to reduce worker errors." - Agree. Because most don't look any further. See also Manuele's statement that this has done most damage to safety…
		103-104	puts Taylor and Heinrich together	"Orwellian managerial control that was once advocated by Taylor and Heinrich: setting strict standards and instituting a program to measure and manage any deviation or slippage of these standards" (p.103/4) - I don't think that H.'s message is quite that grim, although he does focus on supervision, of course

Title	Heinrich reference	Page	What	Remarks
Dekker, S.W.A. (2018) Oil and Gas in a Post-Truth World.	None, but indirectly	-	Triangle	"There should be no need to point this out any longer: the so-called safety triangle is of course wrong, as it always was. That much is trivial." - references Wright & Van der Schaaf to support his point while their work does in fact not does so
Heraghty, D., Dekker, S.W.A. & Rae, A. (2018) Accident Report Interpretation. *Safety*, 4(4), 46: 1-25. doi: 10.3390/safety4040046.	1931	3	88%	"This led those within the field of accident analysis to place a disproportionate amount of time focussing on human issues and viewing them as the main cause of accidents. Another influencing factor in industry choosing this trajectory for the analysis of accidents was the work of Heinrich, who declared that 88% of all accidents are the result of human error [24]. A key issue with focussing upon the symptoms of human error is the underlying causes which helped create the error are ignored [25], …"
Dekker, S.W.A. (2018) I Am not a Policy Wonk. Retrieved 24 October 2018 from http://www.safetydifferently.com/i-am-not-a-policy-wonk/	None			Tells about origins and philosophy of Safety Differently

Appendix 4: Hollnagel literature

The table below gives a brief overview of the literature by Erik Hollnagel that has been reviewed for inclusion in this study[202]. The first column indicates the document. The second column indicates whether Heinrich is referenced in the document, and what source. The third column indicates the page(s) Heinrich, or Heinrichian themes are discussed. The last two columns show what (theme) is discussed, including relevant quotes and some remarks on the material. Literature that does not mention Heinrich or Heinrichian themes is not taken further into the study - unless it does have other relevance.

Table 6: An overview of the literature by Erik Hollnagel reviewed for inclusion in this study.

Title	Heinrich reference	Page	What	Remarks
Hollnagel, E. (1983) What we do not know about man-machine systems. *International Journal of Man-Machine Studies*, 18(2):135-143.	None			
Hollnagel, E. (1997) Modelling The Orderliness of Human Action. In: R. Amalberti & N. Sarter (Eds) *Cognitive Engineering in the Aviation Domain*. Lawrence Erlbaum Associates, 1996-97.	None			
Hollnagel, E. (1999) Accident Analysis and Barrier Functions. Report IFE/HR/F-99/1121.	None			
Hollnagel, E. (1999) Accidents and Barriers. In: Hoc, J.-M., Millot, P., Hollnagel, E. & Cacciabue, P. C. (Eds.), *Cognitive Science Approaches to process Control*, Lez Valenciennes, 28, (p. 175-182), Presses Universitaires de Valenciennes.	None			
Hollnagel, E. (2000). Analysis and prediction of failures in complex systems: Models and methods. In: Elzer, P. (Ed.) *Lecture notes in control and information sciences* (p. 39-41). London: Springer.	None			Discusses various accident models - kind of build up to Hollnagel's later classification.
Hollnagel, E. (2000) When All Things Fail. *Cognition, Technology & Work*, 2 (4): 221-223.	None			

[202] Scopus shows 151 documents, 15 of which contain "Heinrich" (all of which have been included in this table). Searched 8 May 2018: (AU-ID ("Hollnagel, Erik" 55750000000) OR AU-ID ("Hollnagel, Erik" 7003466612) OR AU-ID ("HOLLNAGEL, ERIK" 7003466616)

Title	Heinrich reference	Page	What	Remarks
Hollnagel, E. & Amalberti, R. (2001) The Emperor's New Clothes. HESSD 2001	None			
Hollnagel, E. (2001) *Anticipating Failures: What Should Predictions Be About?* Defense Technical Information Center Compilation Part Notice, ADPO10439.	None			Discusses various accident models (simple, intermediate, contemporary) - kind of build up to Hollnagel's later classification.
Hollnagel, E. (2002) Understanding accidents - From root causes to performance variability. Proceedings of the 2002 IEEE 7th Conference on Human Factors and Power Plants: New Century, New Trends; Scottsdale, AZ; United States; 15 September 2002 through 19 September 2002: 1-6.	1980	1	First axiom Domino	Claims wrongly that the original is from 1931. "This Axiom was also called the domino theory and visualised in terms of a set of dominos. As everyone knows, if one domino falls it will knock down those that follow. If the dominos therefore represent accident factors, the model represents how these factors constitute a sequence of events where the linking of cause and effect is simple and deterministic."
Hollnagel, E. (2004) *Barriers And Accident Prevention*. Aldershot: Ashgate.	1931	xi	Importance	Mentions 1931 book as "the classical work"
	1980	20-24	Triangle	Nuanced discussion: opportunity to learn, less costly, direct relation. "the importance lies not in the actual numbers, but in their meaning" (p.24) Relates to Hale: "In order for this approach to be effective it is, however, necessary that the study is confined to the minor incidents and near misses that are directly related to the accidents at the top of the pyramid." (p.23)
	1931/1980	26-29	Causality, axioms, sequence, root causes	Axiom, wrong year referenced. Critique of simple (linear) model of causality - instead of explanation.
	1931/1980	47-54	Dominos, first axiom	Wrong year referenced Discusses various accident models
		48		"…the sequential accident model has a clear assumption about causality, specifically that

Title	Heinrich reference	Page	What	Remarks
				there are identifiable cause-effect links that propagate the effects of the unexpected event."
		49		"a sequence of events where the linking of cause and effect is simple and deterministic" Acknowledges that the domino model can take account for work environment, through social environment in first domino. Mentions political use of dominos (Eisenhower, cold war).
		50	Sketches roughly post-domino developments. Explains why they made sense:	"Sequential models are attractive because they encourage thinking in causal series rather than causal nets (cf. Dörner, 1980). As everyone knows, it is much easier to follow a line of reasoning step by step than to keep track of several parallel lines at the same time. Sequential models are furthermore easy to represent graphically, which facilitates communication of the results."
				"Sequential models require that the events correspond to the model assumptions, i.e. that the cause-effect relations underlying the accident are relatively simple. So while sequential accident models were adequate for socio-technical systems up until the middle of the 20th Century, they turned out to be limited in their capability to explain accidents in the more complex systems…"
	1931	55	Dominos	Wrong year referenced Suggests that even the dominos contain the possibility to account for 'latent conditions'
		56	Suchman (1961) referenced in 1980	Not Heinrich's work, but Petersen/Roos

Title	Heinrich reference	Page	What	Remarks
		79	Haddon is linked to the Dominos	Which is probably fine, Heinrich wrote about hierarchies of control (even though it is strange that he on one hand advocates focus on direct causes, and on the other action much earlier in the 'chain')
	1931/1980	211		They indexed the bibliography
Dekker, S.W.A. & Hollnagel, E. (2004) Human factors and folk models. *Cognition, Technology & Work,* 6:79–86.	None			
Huang, Y.-H., Ljung, M., Sandin, J. & Hollnagel, E. (2004) Accident models for modern road traffic: Changing times creates new demands. Conference Proceedings - IEEE International Conference on Systems, Man and Cybernetics 1: 276-281.	1980	278	Domino	Sequential model, limitations
Hollnagel, E. (2005) The natural unnaturalness of rationality. *Proceedings of the Seventh International NDM Conference* (Ed. J.M.C Schraagen), Amsterdam, The Netherlands, June 2005	None			
Hollnagel, E. & Woods, D. (2005) *Joint Cognitive Systems: Foundations of Cognitive Systems Engineering.* Boca Raton: CRC Press.	None			
Woods, D. & Hollnagel, E. (2006) *Joint Cognitive Systems: Patterns in Cognitive Systems Engineering.* Boca Raton: CRC Press.	None			
Hollnagel, E. (2007) Resilience - the Challenge of the Unstable. In: In *Resilience engineering: Concepts and precepts*, Hollnagel, E., Woods, D. D., & Leveson, N. (eds.) Aldershot: Ashgate Publishing, Ltd.	1931	10-11	Dominos, first axiom	Wrong year referenced "The archetype of simple linear model" "…model associated with one of the earliest attempts of formulating a complete theory of safety, expressed in terms of ten axioms of industrial safety" "According to this view, an accident is basically a disturbance inflicted on an otherwise stable system."

Title	Heinrich reference	Page	What	Remarks
				"Although the domino model has been highly useful by providing a concrete approach to understanding accidents, it has unfortunately also reinforced the misunderstanding that accidents have a root cause and that this root cause can be found by searching backwards from the event trough the chain of causes that preceded it. More importantly, the domino model suggests that system safety can be enhanced by disrupting the linear sequence, either by 'removing' a 'domino' or by 'spacing' the 'dominos'.
Nouvel, D., Travadel, S. & Hollnagel, E. (2007) Introduction of the Concept of Functional Resonance in the Analysis of a Near-Accident in Aviation. 33rd ESReDA Seminar: Future challenges of accident investigation	None			
Hollnagel, E. (2008) Human Error: Trick or Treat? In: *Handbook of Applied Cognition (second edition)*.	1980	227	First axiom	Determinism in accidents, does not need to automatically lead to 'human error', explains how it came that it often does.
Hollnagel, E. (2008) Risk + Barriers = Safety? *Safety Science*, 46: 221-229.	None			
Hollnagel, E. (2009) *The ETTO Principle: Efficiency-Thoroughness Trade-Off - Why Things That Go Right Sometimes Go Wrong*. Farnham: Ashgate.	1931	15	Fundamental ETTO taken from an example from *Industrial Accident Prevention* (p.94)	Literal quote confirms that Hollnagel has read the book!
		20	Comments on source	"This book pioneered the practical study of industrial safety, and introduced a number of models and methods, several of which are still in use." "…the book was based his extensive practical experience in accident investigation."
		103-106	Domino, linear models	Root cause analysis as a form of ETTO?
		119	Domino	Wrong reference

Title	Heinrich reference	Page	What	Remarks
Lundberg, J., Rollenhagen, C. & Hollnagel, E. (2009) What-You-Look-For-Is-What-You-Find – The consequences of underlying accident models in eight accident investigation manuals. *Safety Science*, 47 (10): 1297-1311.	1931 1928 1959	1298 1298/9 1299	Simple cause and effects Management control 90% VERY USEFUL PAPER!	"For these situations, Heinrich (1931) proposed that the most proximate cause should be prevented, following a recommendation from the US department of Labor (1920) suggested that more distant causes should be pursued for severe accidents, such as train accidents. Thus, the model proposed by Heinrich is linear, considering only the immediate surroundings, including line management. Although commitment from higher management levels were seen as vital for success in implementing safety work, Heinrich did not think it was a fruitful approach to point to higher management levels as causes. It is noteworthy that two lines of enquiry were considered: The first went through the person or surroundings, looking for causes to actions that in hindsight seemed incorrect, or for causes of problems with equipment or other items in the surroundings. The second line of enquiry went towards the line manager, looking for reasons why the accident was not prevented." (p.1298)- not entirely true, higher management….
	1959	1300	Three factors (dominos)	"the linear sequence was not primarily a sequence of events, but a sequence of factors that in turn caused an accident".
Lundberg, J. Rollenhagen, C. & Hollnagel, E. (2010) What you find is not always what you fix- How other aspects than causes of accidents decide recommendations for remedial actions. *Accident Analysis & Prevention*, 42 (6): 2132-2139.	1931 / 1934		Dominos Focus on direct causes	"It should however be noted that different methods have historically had different foci—for instance, Heinrich (1931) promoted a focus on the most easily preventable causes that were most proximate to the accident."
Hollnagel, E., Pruchnicki, S., Woltjer, R. & Etcher, S. (2010) Analysis of Comair flight 5191 with the Functional Resonance Accident Model	1931	1	Domino	References wrong year. "Models have over time gone from simple linear models, such as the domino model (Heinrich,

Title	Heinrich reference	Page	What	Remarks
				1931), via complex linear or epidemiological models, such as the Swiss cheese model (Reason, 1990), to systemic models (e.g., Leveson, 2004). Despite their differences, they all adhere to the principle that accidents are caused and that the causes can be understood as failures or malfunctions of technology, humans or organizations – either alone or together."
Hollnagel, E. (2011) When things go wrong: Failures as the flip side of successes. In D. A. Hofman and M. Frese (eds), *Error in organizations*. New York, NY: Routledge: 225-244.	1931		*Unable to locate this particular text!*	*Unable to locate this particular text!*
Sundström, G. & Hollnagel, E. (2011) *Governance and Control of Financial Systems: A Resilience Engineering Perspective*. Boca Raton: CRC Press.	1959	2	First axiom	Linearity, root cause
	1959/1934	165	Dominos	"Simple models such as the Domino model are attractive, because they are simple and therefore easy to understand and communicate. But even if simple models are adorned with mathematics, they remain fundamentally simple."
Besnard, D. & Hollnagel, E. (2012). I want to believe: some myths about the management of industrial safety. *Cognition, Technology & Work*, 16(1): 13-23.	1931 1934	16	Human error, 90%, accident proneness Dominos	"The concept of a human error became part of the safety lore when Heinrich (1931, p. 43) noted that as improved equipment and methods were introduced, "accidents from purely mechanical or physical causes decreased, and man failure became the predominating cause of injury". This assumption became the second of the five dominoes in the famous domino model, described as 'Fault of person – proximate reason for committing unsafe act, or for existence of mechanical or physical hazard' (Heinrich, 1934, p. 1)."
			- Interesting that this paper discusses 6 myths of	1: Human Error / 2: Procedure Compliance / 3: Increasing Protection Increases Safety / 4:

Title	Heinrich reference	Page	What	Remarks
			industrial safety, and that the triangle is not one of them	Accidents Have Root Causes / 5: Accident Investigation is a Rational Process / 6: Safety First
Lundberg, J., Rollenhagen, C., Hollnagel, E. & Rankin, A. (2012) Strategies for dealing with resistance to recommendations from accident investigations. *Accident Analysis & Prevention*, 45: 455-467.	1934	455	Dominos (although not explicitly discussed)	- Mere mention as one of "many different methods and models", no critique
Hollnagel, E. (2012) *FRAM - The Functional Resonance Analysis Method: Modelling Complex Socio-technological Systems.* Farnham: Ashgate.	1959	127-129 134	Dominos First Axiom	Compares dominos and root cause analysis, discusses strength of models and their advantages/limitations.
Hollnagel, E. (2012) A Tale of Two Safeties (Draft).	None			
Hollnagel, E., Leonhardt, J., Licu, T. & Shorrock, S. (2013) *From Safety-I to Safety-II: A White Paper*. Luxembourgh: Eurocontrol.	1931	5	Linearity, Dominos	"The understanding of the how the technology worked was based on simple cause-effect relations and the models used to explain accidents or incidents were linear, e.g., Heinrich's Domino Model (Heinrich, 1931)." - references wrong year
Hollnagel, E. & Fujita, Y. (2013) The Fukushima Disaster – Systemic Failures As The Lack Of Resilience. *Nuclear Engineering and Technology*, 45 (1): 13-20.	None			
Hollnagel, E., Braithwaite, J. & Wears, R.L. (2013) Preface: On the need for resilience in health care (Editorial). Resilient Health Care. pp. xix-xxvi.	1931		*Unable to locate this particular text!*	*Unable to locate this particular text!*
Hollnagel, E. (2014) Human factors/ergonomics as a systems discipline? "The human use of human beings" revisited. *Applied Ergonomics,* 45: 40-44.	None		Interesting comments on Taylorism	
Hollnagel, E. (2014) Is safety a subject for science? *Safety Science*, 67: 21-24.	1929	22	Distinction between accidents and injuries	"who by rights must be considered the pioneer of industrial safety,"

Title	Heinrich reference	Page	What	Remarks
		23	Domino	"well-suited to situations that resemble what work was like in the 1920s and 1930s, but not to the 1970s and beyond."
Hollnagel, E., Hounsgaard, J. & Colligan, L. (2014) FRAM Functional Resonance Analysis Method.	None			
Hollnagel, E. (2014) *Safety I and Safety II: The Past And Future Of Safety Management*. Farnham: Ashgate.	1931	26	Concern for safety, reliability	"highly influential book"
		35-36 68	Importance of *Industrial Accident Prevention*. Background practical rather than academic. Cautions to take everything as fact. But…	"It is impossible to overrate the importance of the first[203] book on safety…" "On the other hand, a closer study of the many cases in the book shows that little has changed in how humans go about accomplishing their work, differences in tasks and technology nothwithstanding." (p.36) "…the first book to provide a comprehensive description and analysis of accidents" (p.68)
		64-65	Dominos	Linear model with underlying logic: find the thing that failed.
	1929/31/59	67-69	Triangle, ratios,	"A pyramid of problems" Predictability: "The myth is that the ratios described by the accident pyramid can be used to determine whether the actual distribution of different types of outcomes for a given time period… is 'normal' or not." (p.67)
	1929/31/59	70-72, 74	Triangle, ratio	p.70: relationships are "simple, tempting and dubious". Discusses problem with definition of consequence categories. Hollnagel mentions one post-Heinrich change: from levels of injuries to types of events.

[203] *Industrial Accident Prevention* was not *really* the first safety book. Most likely, however, the first safety book got this kind of exposure and distribution.

Title	Heinrich reference	Page	What	Remarks
				Looks like nuanced discussion of problems, see conclusion on p.74, seeks to understand. Discusses three different interpretations of the triangle, linking the triangle to dominos and triangle to SCM-thinking. Bit pity that he does not add a fourth with scenarios. Does not discuss opportunity-angle, either.
		75-78	Human error, accident proneness, domino	"90% solution" Does explain why: "…as improved equipment and methods were introduced, accidents from purely mechanical or physical causes decreased and (hu)man failure became the predominant cause of injury." (p.76)[204] - became second of five dominos. Then proceeds to explain futility of using human error as an explanation.
		82-83	Dominos	Connects to root cause (for the dominos this was a.o. ancestry)
		88-89	Comments on the sources	--
	??	95-96	Axiom, sequence of events, domino, causality	Adverse events are caused
	1931	149	Case of slipping and injured worker	Mentions the 1:1800 ratio! Look at daily success (1800 cases)
Hollnagel, E. (2015) Introduction to the Resilience Analysis Grid (RAG).	None			
Hollnagel, E., Wears, R.L. & Braithwaite, J. (2015) From Safety-I to Safety-II: A White Paper.	1931	8	Dominos	References wrong year. "Just as any disease must have a cause that can be diagnosed and treated, so will any adverse event have a cause that can be found and fixed. Simple linear models, such as Heinrich's (1931) Domino Model that is at the heart of Root Cause Analysis, later supplemented by composite linear models such as Reason's Swiss

[204] Matches also with Heinrich's paper stating that machines do not hurt people… (Heinrich, 1933c)

Title	Heinrich reference	Page	What	Remarks
				Cheese Model, were soon adopted as the basic safety tools in health care. Few people noticed that the very same models were being progressively challenged by industrial safety outside healthcare as inadequate to the newer, more complex working environments."
Braithwaite, J., Wears, R.L. & Hollnagel, E. (2015) Resilient health care: Turning patient safety on its head. *International Journal for Quality in Health Care*, 27(5): 418-420.	1931	418	Dominos	References wrong year. "…adverse outcomes can be explained by linear cause–effect chains, as originally proposed by the Domino metaphor"
Hollnagel, E. (2018) *Safety-II in Practice. Developing the Resilience Potentials*. Milton Park: Routledge.	1931		Dominos	References wrong year. Example of root cause analysis.

Appendix 5: Long literature

The table below gives a brief overview of the literature by Robert Long that has been reviewed for inclusion in this study[205]. The first column indicates the document. The second column indicates whether Heinrich is referenced in the document, and what source. The third column indicates the page(s) Heinrich, or Heinrichian themes are discussed. The last two columns show what (theme) is discussed, including relevant quotes and some remarks on the material. Literature that does not mention Heinrich or Heinrichian themes is not taken further into the study - unless it does have other relevance.

Table 7: An overview of the literature by Robert Long reviewed for inclusion in this study.

Title	Heinrich reference	Page	What	Remarks
Long, R. & Long, J. (2012) *Risk Makes Sense: Human Judgement and Risk (2nd edition)*. Kambah, ACT: Scotoma Press.	None	88	Behaviour triangle	Not really about Heinrich, yet interesting quote: "Some people get impressed more with the presentation than the accuracy of the content".
Long, R. (2012) *For The Love of Zero: Human Fallibility and Risk*. Kambah, ACT: Scotoma Press.	1931	116	Heinrich's occupation	"Heinrich was an insurance salesman…" - not quite correct (Long claims that HRO do not have this approach of risk, but misses the point that the triangle in the first place is about reacting on weak signals - one of the HRO traits…)
		116-117	Triangle	"whilst popular in the safety industry, has no validity either as a predictive or explanatory tool of how humans and organisations manage risk" - misses probably the main point
		117	Taylorism	"Heinrich's approach is Tayloristic…" - is it?
Long, R. (2013) A Comparison of Safety Paradigms. Retrieved 3 June 2018 from https://safetyrisk.net/a-comparison-of-safety-paradigms/	None, but mentions	--	Links - actually, more or less equates - Heinrich to Taylorism	
Long, R. (2013) And the Formula is, There is no Formula. Retrieved 3 June 2018 from	None, but mentions	--	(actually, the debate was originally about the 88%[206])	"There has been a debate raging on Linkedin for sometime about the mythology of Heinrich's Pyramid. The debate has focused on causality

[205] Scopus returned only one hit, searched 4 June 2018: https://www-scopus-com.ludwig.lub.lu.se/authid/detail.uri?origin=resultslist&authorId=56985193200

[206] The link to the discussion: https://www.linkedin.com/groups/113464/113464-68622385. It was one of the most active discussions for a long period, but it appears to have been deactivated.

Title	Heinrich reference	Page	What	Remarks
https://safetyrisk.net/and-the-formula-is-there-is-no-formula/			data	and percentages, as if humans are machines. The debate has been blindsided by the fixation on a formula create 80 years ago by speculation on the basis of insurance data."
Long, R. (2014) Nonsense Curves and Pyramids. Retrieved 3 June 2018 from https://safetyrisk.net/nonsense-curves-and-pyramids/	None, but mentions	--	Triangle	"Safety likes nothing more than curves and pyramids, nothing so exciting as parading out the Bradley Curve or Heinrich's Pyramid to get the troops excited about failure and loss."
			Same text as in *For The Love of Zero???*	"The pyramid is a much older creation than the curve but is nonetheless as fixed. Despite all the evidence to show Heinrich's pyramid as the fictional manufacture of an insurance salesman in 1931, safety defends this myth more than a fundamentalist defends the Bible. There is no ratio to risk, this is why risk is about uncertainty."
				"So whilst safety accepts the imagination of Bradley and Heinrich it can't imagine that these are just dated constructs. It can't imagine a safety without such misguided props and their misdirected focus."
Long, R. (2014) *Real Risk: Human Discerning and Risk*. Kambah, ACT: Scotoma Press.	None			
Long, R. & Ashhurst, C. (2014) *Following-Leading in Risk: A Humanistic Dynamic*. Kambah, ACT: Scotoma Press.	None			
Long, R. (2014) Shopping for Safety. Retrieved 3 June 2018 from https://safetyrisk.net/shopping-for-safety/	None, but mentions	--	Triangle	Satirical mention
Long, R. (2014) Is BBS Credible? Retrieved 3 June 2018 from https://safetyrisk.net/is-bbs-credible/	None, but mentions	--	Connects BBS and Heinrich's work	"The expression 'behavior based safety' was first coined by Dr Scott E. Geller in 1979 but many for some strange reason, seek to authenticate BBS by anchoring its evolution to Herbert Heinrich in the 1930s. BBS was most influenced

Title	Heinrich reference	Page	What	Remarks
				by developing interest in Organisational Behavior Analysis and Behavior Modification in the 1970s. More recently Geller has joined DuPont and has rebadged BBS as 'People-Based Safety', 'Values-Based Safety' or 'Human-Based Safety'. This change in language indicates a sense of concern about the identification with behaviourism. Regardless of the badge, the model remains focused on behavior and error management."
Long, R. (2014) What is Psychosocial Safety? Retrieved 3 June 208 from https://safetyrisk.net/what-is-psychosocial-safety/	None, but mentions	--	'role of workers'	"The beginnings of psychosocial safety are usually linked to Herbert W. Heinrich an insurance investigator in the 1930s and 1940s." - is that so?? - a bit more correct on H's occupation
Long, R. (2014) Safety Leadership Essentials. Retrieved 3 June 2018 from https://safetyrisk.net/safety-leadership-essentials/	None, but mentions	--	Mentions triangle as part of course's curriculum	
Long, R. (2014) The Non-Science of Safety Science. Retrieved 3 June 2018 from https://safetyrisk.net/the-non-science-of-safety-science/	None, but mentions	--	Triangle Taylorism	"The various matrices and Heinrich-type pyramids about the industry are at best entertainment in the search for objectivity in safety." "When we believe that humans conform to some kind of Heinrich formula we simply delude ourselves into thinking we can 'control' others."
Long, R. (2014) We need hearing protection. Retrieved 3 June 2018 from https://safetyrisk.net/we-need-hearing-protection/	None, but mentions	--	Mentions triangle on front of WHS book.	
Long, R. (2014) Essentials in Observation and Safety. Retrieved 3 June 2018 from	None, but mentions	--	Triangle Dated	"It does however have all the tired and out-dated models of Swiss chess, nomogram tie

Title	Heinrich reference	Page	What	Remarks
https://safetyrisk.net/essentials-in-observation-and-safety/				lines, matrices and Heinrich's pyramid and one third of the text devoted to legislation but…"
Long, R. (2014) Deconstructing Safety and Humans. Retrieved 3 June 2018 from https://safetyrisk.net/deconstructing-safety-and-humans/	None, but mentions	--	Triangle	"I see the constant rehash of Heinrich's pyramid as if it somehow validates human behaviour and decision making, causality and understanding of risk."
Long, R. (2014) When the Safety Tool Becomes the Method. Retrieved 3 June 2018 from https://safetyrisk.net/when-the-tool-becomes-the-method/	None, but mentions	--	Mentions triangle as an example	
Long, R. (2014) The Seduction of Measurement in Risk and Safety. Retrieved 3 June 2018 from https://safetyrisk.net/the-seduction-of-measurement-in-risk-and-safety/	None, but mentions	--	Triangle Links to Taylorism 'role of workers' /BBS	"The idea that lag indicators are a measure of performance is based upon the ideas of Herbert Heinrich (1931) and similar approaches to incident prediction, causation and mechanistic approaches to understanding risk. Heinrich was an insurance salesman and sought to impose a 'scientific' approach to understanding of risk. Heinrich's Safety Pyramid whilst popular in the safety industry, has no validity either as a predictive or explanatory tool of how humans and organisations manage, or make decisions about risk. Heinrich's approach is Tayloristic and in the genre of 'scientific management'. There is no evidence to show that the ideas of Heinrich or the later Behavioural-Based Safety (BBS) discipline, equate to reality or explain social-psychological or neuropsychological evidence about human judgment and decision making. Heinrich's Pyramid is present in the discourse of most calculative organisations and remains in Certificate IV and Diploma studies in WHS qualification."
Long, R. (2015) Do You Believe in Good and Bad Luck? Retrieved 3 June 2018 from	1931	--	Triangle	"The idea that lag indicators are a measure of performance is based upon the ideas of Herbert

Title	Heinrich reference	Page	What	Remarks
https://safetyrisk.net/do-you-believe-in-good-and-bad-luck/			- is this a correct attribution? I think not - see above Links to BBS	Heinrich (1931) and similar approaches to incident prediction, causation and mechanistic approaches to understanding risk. Heinrich was an insurance salesman and sought to impose a scientific approach to an understanding of risk. Heinrich's Safety Pryamid whilst popular in the safety industry has no validity either as a predictive or explanatory tool of how humans and organisations manage risk. There is no evidence to show that the ideas of Heinrich or that of later Behavioural-Based Safety (BBS) disciples, equate to reality or explain socialpsychological or neuropsychological evidence about human judgment and decision making." "Heinrich's Safety Pyramid is present in the discourse of most calculative organisations, it is a mechanistic paradigm that is appealing mostly to engineers and professions that adore quantitative measurement. However one tries to impose a measureable and predictive paradigm to humans, one will be greatly disappointed."
Long, R. (2015) Incrementalism, Catastrophism and All That's In-between. Retrieved 3 June 2018 from https://safetyrisk.net/incrementalism-catastrophism-and-all-thats-in-between/	None, but mentions	--	Triangle ? does Long even criticize Turner and the concept of drift? ? does Heinrich indeed speak of accumulation? ? does Heinrich encourage counting?	"One of the continuing assumptions of research in the risk and safety sector is that risk 'incubates', 'evolves' and 'develops'. This is mostly observed in hindsight and is popular in theories originally proposed by Heinrich and Reason. The general idea is that a collection of small indicators and events accumulate in time to create a catastrophic outcome. In Heinrich's and Bird's models for example, the idea is that: counting near misses, near hits and incidents provide an indication of incident ratio to fatality.

Title	Heinrich reference	Page	What	Remarks
				Therefore, the reduction of incidents decreases the likelihood of catastrophe."
Long, R., Smith, G. & Ashhurst, C. (2016) *Risky Conversations: The Law, Social Psychology and Risk.* Kambah, ACT: Scotoma Press.	None			
Dekker, S. W. A., Long, R. & Wybo, J.L. (2016) Zero vision and a Western salvation narrative. *Safety Science*, 88: 219-223.	None			
Long, R. (2016) A Critique of Pure Reason. Retrieved 3 June 2018 from https://safetyrisk.net/a-critique-of-pure-reason/	None, but mentions	--	Incorrect reference	"In the Eurocontrol paper (2006) Reason deconstructs the reductionist view of accident causation (p. 17) including distancing from Heinrich's Pyramid and states…" - the paper does not discuss the triangle, but the accident sequence/dominos
Long, R. (2016) Calculators, Matrices and Mumbo Jumbo Risk Assessment. Retrieved 3 June 2018 from https://safetyrisk.net/calculators-matrices-and-mumbo-jumbo-risk-assessment/	None, but mentions	--	Triangle	"I look at the worship of Heinrich's Pyramid and associated distortions (in every WHS text) and, Reason's swiss cheese and despair of how these have ended up warping any sense of helpful approach to safety. Both have been distorted well beyond any of their original intentions. Yet, Safety clings to these constructs and models as gospel, defending the Bible with all the gusto of a fundamentalist. The fact that these and many safety tools are now beyond question is evidence that their use has been objectified and culturally normalised as true and effective." - correct about the distortion
Long, R. & Fitzgerald, R. (2017) *Tackling Risk: A Field Guide to Risk and Learning.* Kambah, ACT: Scotoma Press.	None			
Long, R. (2017) Safety Curves and Pyramids. Retrieved 3 June 2018 from https://safetyrisk.net/safety-curves-and-pyramids/	None, but mentions	--	Triangle - is connection between triangle and zero correct?	"Following the video on Zero Harm, Rob discusses the ideology of zero embedded in the Bradley Curve and logic of the Bird and Heinrich Pyramid."

Title	Heinrich reference	Page	What	Remarks
			Triangle Science Connects to zero	"The video concludes with a brief discussion on the construct of the pyramid concocted by an insurance salesman in the 1930s without any validation, now used by the risk and safety industries to justify zero and the establishment of intolerant regimes of zero fixated on counting injury statistics as a demonstration of safety."
Long, R. (2017) Curves and Pyramids. Retrieved 3 June 2018 from https://vimeo.com/124273239	None, but mentions	--	Triangle - attributions that are not entirely correct or substantiated	Claims that pyramid is based on idea that absence of something proves existence of something else. If we can count the statistics of the escalating injuries then we can see that we are heading for a fatality and so statistics in themselves become prophetic.
Long, R. (2017) The Great Heinrich Hoax. Retrieved 3 June 2018 from https://safetyrisk.net/the-great-heinrich-hoax/	None, but mentions	--	Triangle	"There is no greater hoax in the safety industry than the myth that injury data or injury rates have any connection at all to causality or the management of risk. Yet despite this the safety texts and WHS curriculum remain focused on Heinrich's pyramid and the mythology that minor injuries are an indication of an **escalation** of unsafety and the likelihood that a major injury is just around the corner." - Heinrich does not discuss escalation, but opportunity!
Long, R. (2017) The Real Story of Zero. Retrieved 3 June 2018 from https://safetyrisk.net/the-real-story-of-zero/	None, but mentions	--	Triangle	"Talk of zero harm for paper cuts and petty risk is the stuff of Safety. (We need that Heinrich pyramid more than a cross in a Cathedral)."
Long, R. (2017) Zero Accident Vision Non-Sense. Retrieved 3 June 2018 from https://safetyrisk.net/zero-accident-vision-non-sense/	None, but mentions	--	Injury rates - is this a correct attribution?	"And of course, this whole article is about injury rates. More delusion, apparently injury rates are a measure of safety, thanks Mr Heinrich."

Title	Heinrich reference	Page	What	Remarks
Collins, D. & Long, R. (2017) CLLR Christmas Newsletter 2017. Retrieved 3 June 2018 from https://safetyrisk.net/cllr-christmas-newsletter-2017/	None, but mentions	--	Triangle	"The language of zero adopts the myth of Augustine in demonizing what it means to be fully human and mortal. This is no greater evidence than in The Bradley Curve or Heinrich's Pyramid rituals that have been created in risk and safety to deny uncertainty and deify risk aversion."
Long, R. (2017) The New Enemy of Safety – The Unconscious. Retrieved 3 June 2018 from https://safetyrisk.net/the-new-safety-enemy-the-unconscious/	None, but mentions	--	Triangles, linearity - Is this so much different from Heinrich's statement of opportunities?	"Near misses are lessons in learning not necessarily precursors to accidents. This is an assumption of the Heinrich myth. Causation is neither linear nor based upon the nature of a near miss, people ought to be more focused on the random nature of decision making than near miss as a precursor to accidents. The more we think of causation in randomness and as a wicked problem, the better we will be able to tackle risk in the workplace. Again, the Heinrich myth drives such thinking and then we end up counting and reporting on near misses rather than focus on learning – dumb."
Long, R. (2017) Short-sighted Safety. Retrieved 3 June 2018 from https://safetyrisk.net/short-sighted-safety/	None, but mentions	--	General part of negative comment on 'Safety'	"If there is one thing Safety does well is the propagation of disproportionality and paranoia about the petty pissy safety. I'm sure this is all fostered by the nonsense of Heinrich, TRIFR rates and zero."
			General part of negative comment on 'Safety'	In comments to this blog, Long adds "We can thank Heinrich who is in every WHS text book and counting LTIs defined as safety for this absolute nonsense."
Long, R. (2017) Bells and Whistles and Due Diligence. Retrieved 3 June 2018 from https://safetyrisk.net/bells-and-whistles-and-due-diligence/	None, but mentions	--	Same as in *Fallibility and Risk*.	"Here your honour, Heinrich's Pyramid for your entertainment?"

Title	Heinrich reference	Page	What	Remarks
Long, R. (2017) Speaking a New Language in Safety. Retrieved 3 June 2018 from https://safetyrisk.net/speaking-a-new-language-in-safety/	None, but mentions	--	General part of negative comment on 'Safety'	"Similarly, talking about 'safety differently' doesn't make it so. Neither does holding to old paradigms and symbols (Heinrich is still being taught, Swiss cheese is still popular and numerics still define safety) help move thinking in safety forward."
Long, R. (2018) *Fallibility and Risk. Living with Uncertainty*. Kambah, ACT: Scotoma Press.	1950	145	Reference source	Clearly wrong year - should be the 1980 edition because he lists Heinrich, Petersen & Roos.
		82	Triangle	"sacralised" concept "fictional manufacture of an insurance salesman in 1931" - unprecise date, misattributes H's background, discredits "There is no ratio to risk, this is why risk is about uncertainty" - unsure whether this attribution is correct, the triangle is not about risk (not in the first place, anyway) Also I wonder about "language of absolutes" in this paragraph.
		83	Triangle	"dated constructs" Variation of triangle shown, but not explained. Captioned: "The Incident Pyramid Delusion"
		83	Probably about dominos	"The SRMBoK also endorses the linear model and ideology of Petersen's, Heinrich's and Reason's Swiss Cheese (p.54) although it does acknowledge that such a perspective can be misleading."
		85	Triangle	One of the examples of tools that seem to fit, but drag us down, connected to measurement. - don't think the triangle was ever intended as measurement tool (although H. did urge for better statistics, I do not think he proposes the triangle as a tool)
		118	Triangle	"Are these the comments that will come out in court: 'Here your honour, Heinrich's Pyramid

Title	Heinrich reference	Page	What	Remarks
				for your entertainment?"' - Not effective to demonstrate due diligence. So?
		9, 47, 74, 75, 100	Triangle	Various mentions as examples of tools (myths, symbols) that are believed in, but not work and should be departed according to Long.
		82	Triangle	"One of the things that is convenient about curves and pyramids is that they are neat and tidy, giving a sense of order and control."
		139	Triangle	"cultic practices and objects"
Long, R. (2018) Human Dymensions Newsletter May 2018.	None, but mentions	--	General part of negative rant (Heinrich and ratios, suggests triangle)	"…all forms of literature including texts and discourse in risk, shape and influence the cultural formation of a group. In the case of the industry of safety, much of this literature influences a culture of mis-education and the perpetuation of ignorance. This is evidenced in curriculum that teaches the irrelevance of injury data and ratios, Heinrich, Reason's Swiss cheese and a host of reductionist ideas about causation."
Long, R. (2018) Target Trade-Offs and Numeric Goals. Retrieved 3 June 2018 from https://safetyrisk.net/target-trade-offs-and-numeric-goals/	None, but mentions	--	As above	"The fixation on low-order goals by Safety is a direct result from the mis-education of the WHS curriculum in pyramids, Heinrich, Bird and Bradley Curve."
Long, R. (2018) Envisioning Risk in Canada. Retrieved 3 June 2018 from https://safetyrisk.net/envisioning-risk-in-canada/	None, but mentions	--	As above	"…given up his CRSP accreditation, thereby freeing up his mind and actions to undertake a real approach to risk beyond the indoctrination of Heinrich, Bird and Reason."
Long, R. (2018) I am a Spreadsheet King. Retrieved 3 June 2018 from https://safetyrisk.net/i-am-a-spreadsheet-king/	None, but mentions	--	Statistics rhetorics	"…in tribute to my many safety colleagues who waste countless hours each week reporting on things that don't matter, tabulating data of irrelevance and maintaining worship to Heinrich and Bird by statistics…"

Title	Heinrich reference	Page	What	Remarks
Long, R. (2018) Anchoring Safety to Objects. Retrieved 3 June 2018 from https://safetyrisk.net/anchoring-safety-to-objects/	None, but mentions	--	Triangle/ratio	"When one looks at all the curriculum in safety one observes the extensive use of symbols to 'anchor' people to myths in symbols. Once someone has been indoctrinated with the symbology of Heinrich's Pyramid the process has started. The nonsense narrative of ratio correlation of injury data to the definition of safety is then anchored to the symbol." "There is no correlation between injury data and the definition of safety. Unfortunately when Heinrich is used as the reference point, that pyramid symbol becomes the new truth." - not entirely sure what he actually says
Long, R. (2018) The Safety Data Delusion. Retrieved 3 June 2018 from https://safetyrisk.net/the-safety-data-delusion/	None, but mentions	--	Triangle rhethorics	"BP were celebrating the attribution of safety to injury data and giving out awards for 7 years LTI free on the day they killed 11 people and destroyed the Gulf of Mexico with 200 million tonnes of oil! A hard way to learn that both zero and metrics are meaningless! A hard way to learn that Heinrich's pyramid is a concocted cook-up and that Swiss cheese is a reductionist irrelevance!"
Long, R. (2018) But We Have Safety Systems in Place. Retrieved 3 June 2018 from https://safetyrisk.net/but-we-have-safety-systems-in-place/	None, but mentions	--	Triangle	"This is why risk matrices, Heinrich pyramids and Swiss cheese are all dismissed by the law as nonsense because none of this Mumbo Jumbo works."
Long, R. (2018) New Year Safety Trade-Offs and By-Products. Retrieved 3 June 2018 from https://safetyrisk.net/new-year-safety-trade-offs-and-by-products/	None, but mentions	--	Triangle/ratio rhetorics	"How many microlives does Safety ignore in the silly insane TRIFR counting process? How many Heinrich ratios can we fit on the head of a needle? How silly is it to count band-aids out of the first-aid cabinet and ignore the epidemic of loneliness at work?"

Title	Heinrich reference	Page	What	Remarks
Long, R. (2018) The Curse of Behaviourism. Retrieved 21 October 2018 from https://safetyrisk.net/the-curse-of-behaviourism	None, but mentions	--	BBS, behaviourism 'dated'	"Unfortunately, Safety remains infused with the behaviourist assumptions of Heinrich and BBS. Safety is still stuck in the 1940s!"
Long, R. (2018) The Fear of Freedom in Safety. Retrieved 13 December 2018 from https://safetyrisk.net/the-fear-of-freedom-in-safety	None, but mentions	--	A sneer in passing Interesting comments on symbols.	"Let's just all fall in line with the nonsense conga line and like lemmings perform the Heinrich Dance forever and a day. So lets keep counting statistics that mean nothing, TRIFR rates that create pettiness and reporting and writing endless risk assessments, hazard records and JSAs that contribute nothing to tackling risk." "Sometimes the first moves are simply to change models, symbols and language. It is amazing what happens when those dumb symbols of cones, pyramids, matrices, boots, hard hats, gloves and glasses are substituted for humanising symbols."
Long, R. (2018) The Domino Delusion in Safety. Retrieved 19 December 2018 from https://safetyrisk.net/the-domino-delusion-in-safety/	1959	--	Dominos symbolism	Again wrong reference - mixes up 1980 and 1959 editions. "The trouble is, domino theory is just as unreal in safety as it is in history. Unfortunately, this theory is still taught in safety along with other simplistic behaviourist (triangles/pyramids) non-sense and attributed as real. Unfortunately too, this mythology/symbology once in a curriculum is nearly impossible to remove."

Appendix 6: Literature by other 'new view' authors

The table below gives a brief overview of the literature by 'new view' authors that has been reviewed for inclusion in this study. The first column indicates the document. The second column indicates whether Heinrich is referenced in the document, and what source. The third column indicates the page(s) Heinrich, or Heinrichian themes are discussed. The last two columns show what (theme) is discussed, including relevant quotes and some remarks on the material. Literature that does not mention Heinrich or Heinrichian themes is not taken further into the study - unless it does have other relevance.

Table 8: An overview of the literature by other 'new view' authors reviewed for inclusion in this study.

Title	Heinrich reference	Page	What	Remarks
Nippin Anand[207]				
Anand, N. (2015) Accident Investigations: Learning from failure or failure to learn? *Seaways*, March 2015: 24-25.	None	24	Dominos - one almost suspects that he mixes up Heinrich and Reason, and attributes some things to Reason that he shouldn't. But we're not discussing Reason here.	"James Reason, widely cited for the famous 'Domino effect' and 'Swiss cheese' models, identifies accidents as the outcome of unsafe practices such as rule violations and 'human error'. According to Reason, the investigation should begin by identifying unsafe practices."
Anand, N. (2015) Caught in numbers, lost in focus. *Seaways*, August 2015: 5-8.	1931	5-6	Triangle Besides, this article contains some interesting reflections around the function and functioning of HSEQ in organisations. Not related to Heinrich, however. Although it was a subject close to Heinrich's heart.	See discussion in Chapter 5.2.5.
Anand, N. (2018) Near miss reporting: a (mis)leading indicator of safety? *Standard Safety*, July 2018: 4-5.	1931	4-5	Triangle Science	See discussion in Chapter 5.4.6.

[207] Scopus does not return any hits for Anand (searched 5 July 2018). His website contains some more articles from similar publications and safetydifferently.com, but none contain references to Heinrich or Heinrichian themes.

Title	Heinrich reference	Page	What	Remarks
Todd Conklin[208]				
Conklin, T. (2007) Preventing Serious Accidents with the Human Performance Philosophy. *Nuclear Weapons Journal, Issue 1, 2007*: 17-18.	1931	17	Triangle	"The underlying assumption of Heinrich's theory is based on probability". - wouldn't quite say that… "He simply used a commonly held notion - some day our unsafe behaviour will catch up to us." - funny way of phrasing it "A safety program that follow's Heinrich's pyramid may drive reporting of inconsequential accidents underground because such a program is punitive." - where did the 'is' come from? Somewhat simplistic causality
		18	Reacting on weak signals	Suggests an "accident sphere" - now, that is creative! ☺ And much of what Todd suggests is what Heinrich actually wrote - in different words: "near misses are probably the best data that we receive on the reliability of safety systems. Accidents without consequences are a good thing." Interesting: "Contrary to Heinrich's law of averages, any mistake can lead to a severe injury or other disastrous consequence" - exactly what H. said ("the very first"), and contrary to Todd's later "what hurts you doesn't kill you"
Conklin, T. (2012) *Pre-Accident Investigations: An Introduction to Organizational Safety*. Boca Raton: CRC Press.	None			
Conklin, T. (2016) *Pre-Accident Investigations: Better Questions*. Boca Raton: CRC Press.	None			
Conklin, T. (2017) *Workplace Fatalities: Failure To Predict*. Santa Fe: PreAccident Media.	None[209]	41	Triangle, predictability, connects to Zero	"…elegance and predictability of the Pyramid" - what is the deal with predictability?

[208] Scopus does not return any hits for Conklin (searched 5 June 2018).

[209] However, Conklin does mention in the text (p.59) that he has gotten hold of a copy of the 1931 book.

Title	Heinrich reference	Page	What	Remarks
				"Believing in the Pyramid would make it possible to have zero anomalies" - why, how, and did Heinrich claim this?
		51	Triangle suggests that everything is preventable	"…with ideas like Heinrich's pyramid, the notion every accident is preventable." - Does it? While one may argue that Heinrich concluded that most accidents were preventable (of his accident) he shows a lot of nuance in several of his papers.
		58	Triangle	"goofy pyramid" (5x !!)
				"[Heinrich's] assumption that frequency and severity were linked…" - can we actually say that this was Heinrich's assumption? In a way probably. But was it the central message? Probably not.
				"…pyramid is reducing your operational data not increasing operational knowledge." - quite contrary what Heinrich says!
		60		Explanations of why Heinrich's ideas caught on. Acknowledges: "In my opinion Heinrich's heart was in the right place…"
		61	88%	"…perhaps his most impact-fully wrong idea…" - agree But nuances: "To be fair, Heinrich did go on to tell employers that the managing of workplace hazards was more effective than managing worker decisions and behaviours…", adding the most likely correct "…but after the grand statement that almost all of the problem (88%) was of the worker's doing, you can't really

Title	Heinrich reference	Page	What	Remarks
				blame management for going after worker behaviour."[210]
		61 62	Science	Missing data Datasets that are simply not capable of being repeated - should they? is it necessary?
Conklin, T. (2017) Heinrich Was Wrong - Admit It - and Move On… Retrieved 19 May 2018 from https://preaccidentpodcast.podbean.com/e/papod-143-heinrich-was-wrong-admit-it-and-move-on/[211]	None	--	Triangle	Website abstract: "Sometime around 1938, Mr. Heinrich made a triangle - and the rest of the world fell in love with it. We should stop. It is wrong and we all know it. We must stop selling this magical thinking as real." - discredits / sloppy about the year
Conklin, T. (2018) PAPod 201 - Todd Revisits the Triangle - that damn triangle - to try to understand why we can't manage fatalities better… Retrieved 27 November 2018 from https://preaccidentpodcast.podbean.com/e/papod-201-todd-revisits-the-triangle-that-damn-triangle-to-try-to-understand-why-we-cant-manage-fatalities-better/		--	Triangle	Does add little to the previous podcast on the subject, but elaborates on the thought of "Are the things that hurt people the same things that kill people in your organisation". This is worthy a long discussion in a study of the triangle (not here!) "The biggest challenge for fatality prevention is that stupid pyramid and how it shaped an entire generation of leaders in organisations globally to believe that their job is to take care of the small things." "the belief that the pyramid is right is killing people, and that's what worries me the most"

[210] Especially when coupled to the focus on direct causes.

[211] This is the only podcast that is found when searching for Heinrich on preaccidentpodcast.podbean.com, and then there is one about the triangle mentioned below. (search 27 November 2018)

Title	Heinrich reference	Page	What	Remarks
Ron Gantt[212]				
Gantt, P. & Gantt, R. (2012) Disaster Psychology: Dispelling the Myths of Panic. *Professional Safety*, 57 (8): 42-49.	None			
O'Connell, M. & Gantt, R. (2013) Moving Selection to the Top of the Hierarchy. *Occupational Health & Safety*, 82 (7): 48-52. Retrieved 16 June 2018 from https://ohsonline.com/Articles/2013/07/01/Moving-Selection-to-the-Top-of-the-Hierarchy.aspx.	None			Deals with selection and (also) accident-proneness. Relatively 'old view', in a way.
Gantt, R. (2013) HazMat Transportation Navigating Training Requirements. *Professional Safety*, 58 (6): 68-75.	None			
Gantt, R. & Shorrock, S. (2016) Human factors and ergonomics in the media. In S. Shorrock & C. Williams (Eds.), Human factors and ergonomics in practice: Improving system performance and well-being in the real world. Boca Raton, FL: CRC Press.	None			
Gantt, R. (2017) Unsafe Behaviour: Rethinking the Concept. *Professional Safety*, May 2017: 50-56.	1931	50	88%, unsafe acts	One of the better citations, mentions that we are dealing with *proximate* causes.
				For perfectionists - given the choice of words, 1941 would have been a better reference[213].
Scott Gesinger				
Gesinger, S. (2018) *The Fearless World of Professional Safety in the 21st Century*. Milton Park: Routledge.	1931	1-2	'Heinrich's Law' (triangle) Worker's behaviour causes…	
		2	dated	"Heinrich's Law is nearly a century old…"

[212] Scopus does not give additional hits for Gantt.

[213] While Heinrich does not use the term 'acts of God' in relation to the 'origin of accidents' figure (he calls the 2% just unpreventable), he does actually use this phrase in the 1941 edition of *Industrial Accident Prevention* on p.106.

Title	Heinrich reference	Page	What	Remarks
		58		"…programs dedicating time to teach safety students about Heinrich as if his concepts are still valid…" - or rather explain properly? with their limitations? See Townsend's argument! "…it is time for the old ideas to be swept into history…" "…Heinrich's work, while pioneering and important for its time, is not valid for today's environment."
		2	science	"…and was based on data that was collected in a manner most modern researchers would reject." - draws on Manuele
		2 23-24	Influence on safety profession	"…Heinrich was essential in the evolution of the profession…"
		22-26		"Ptolemy, Freud and Heinrich walked into a bar" - Great title for a chapter.
		23	Triangle	Basically the same argument as Conklin: paper cuts do not kill. DWH had excellent safety record. Etc. Confounds argument.
		23-24 24	88%	Polemic ('it's your own fault') followed by nuance. The Challenger argument does lack that nuance and makes a most likely ungrounded attribution.
		54	88%	Opposes Heinrich and Deming, not realising that the two discuss different 'levels' of causes
		55	Triangle	Misses the main point.
		55	Machine guarding	Acknowledges that Heinrich did more than blame the worker
		56	Opposes PDSA and Heinrich	Actually, one might argue that Heinrich's 'scientific accident-prevention principles' cover part of the PDSA cycle (especially if coupled through the 'follow-through' - 1931a, Chapter 5)

Title	Heinrich reference	Page	What	Remarks
David Hummerdal[214]				
Hummerdal, D. (2013) From The Road Less Travelled. Retrieved 22 May 2018 from http://www.safetydifferently.com/from-the-road-less-travelled/	None	--	'role of workers'	Opens with "Analysis showed that 82-94% of our accidents and incidents were caused by 'unsafe acts'" but (surprisingly) does not relate this to Heinrich.
			Triangle	"13,000 stories about situations in which people either struggled with safety, or had stepped up to save the day!? And this in a company with one of the best accident records in the industry. Numbers fascinating enough to cast serious doubts on Heinrich's accident pyramid."
Craig Marriott[215]				
Marriott, C. (2018) *Challenging the Safety Quo*. Milton Park: Routledge.	1931	23-30 26 26	Triangle	Very nuanced discussion of origins, interpretations and misunderstandings. The latter create the "triangular fallacy": "In the triangular fallacy, the confusion arises because the triangle is viewed as a whole and not as a collation of discrete events." "While an individual event may have causal links to other individual events above or below it in the triangle, as a whole this is not the case." "It should be quite apparent that the triangle will be a different shape for different industries."
		23	Dated	"It is indicative of the development of safety thinking that a model developed almost a century ago remains an active, and indeed heavily relied upon, part of our current approach to safety management"

[214] Scopus gives two more hits, both mentioned in appendix 3 since Dekker is one of the co-authors - and both not relevant for this study. (Searched 4 June 2018: https://www-scopus-com.ludwig.lub.lu.se/authid/detail.uri?authorId=44061446300)

[215] Scopus does not give additional hits for Marriott. His website does not contain further references to Heinrich (https://safetyquo.com/?s=Heinrich, Searched 19 June 2018).

Title	Heinrich reference	Page	What	Remarks
		24	Heinrich's contribution	Acknowledges: "This was groundbreaking at the time and a great step forward in thinking, effectively forming the basis for modern leading indicator programmes."
	None	65	Triangle	Only in passing, no discussion, yet in a disapproving way "unfortunately"
	No real reference in this chapter	81-82	Man failure 88%	Also here a nuanced discussion and conclusion: "At its core, the 88 per cent quote is no more useful than saying, 'Most of our activities involve people'."
Jean Pariès[216]				
Pariès, J. (2007) Complexity, Emergence, Resilience… In *Resilience engineering: Concepts and precepts*, Hollnagel, E., Woods, D. D., & Leveson, N. (eds.) Aldershot: Ashgate Publishing, Ltd.	1931	53???	Dominos	Wrong year referenced
Pariès, J. (2018) Safety Cultures in the Safety Management Landscape. In *Safety Cultures, Safety Models: Taking Stock and Moving Forward*, Gilbert, C., Journé, B., Laroche, H. & Bieder, C. (eds.) Cham: Springer.	1931	142	Triangle	"assertion of a constant ratio between unsafe behavior, minor injuries, and fatal accidents" "it has been refuted by many researchers" - do the references actually refute? - mentions for example the SIF study, which refutes (ish) a 'total' triangle, but narrows it down (yet, not enough) "…safety strategies about severe accidents based on the Bird pyramid are at least partially flawed and inefficient, whatever their intuitive attractiveness and commercial success."

[216] Scopus returns 12 more documents for Pariès, none of which references Heinrich (Searched 5 June 2018: https://www-scopus-com.ludwig.lub.lu.se/authid/detail.uri?authorId=6603967136)

Title	Heinrich reference	Page	What	Remarks
David Provan[217]				
Provan, D.J., Dekker, S.W.A., Rae, A.J. (2017) Bureaucracy, influence and beliefs: A literature review of the factors shaping the role of a safety professional. *Safety Science*, 98: 98-112.	None	108	Triangle 'role of workers'	"For example, the Heinrich Accident Triangle is still used in the professional domain, even though it has repeatedly been disproven academically (Swuste et al., 2014[218]). Safety professionals believe that workers and line management are the problem and safety improvement interventions should be targeted at these individuals, through compliance with systems, behavioral programs, and safety training." - Not a direct discussion of Heinrich
Weber, D.E., MacGregor, S.C., Provan, D.J. & Rae, A. (2018) "We can stop work, but then nothing gets done." Factors that support and hinder a workforce to discontinue work for safety. *Safety Science*, 108: 149–160.	None			
Provan, D.J., Dekker, S.W.A. & Rae, A.J. (2018) Benefactor or burden: Exploring the professional identity of safety professionals. *Journal of Safety Research*. In Press, Uncorrected Proof.	None			
Steven Shorrock				
Hollnagel, E., Leonhardt, J., Licu, T. & Shorrock, S. (2013) *From Safety-I to Safety-II: A White Paper*. Luxembourgh: Eurocontrol.	1931	5	Linearity, Dominos	- discussed in the Hollnagel section
Shorrock, S. (2013) Why do we resist new thinking about safety and systems? Retrieved 21 October 2018 from: https://humanisticsystems.com/2013/04/12/why-do-we-resist-new-thinking-about-safety-and-systems/	None, but mentioned	--	Mocks the triangle	Caption: "Little Johnny came to regret asking awkward questions about Heinrich's pyramid."

[217] Scopus does not give additional material by David Provan (Searched 18 June 2018).
[218] I wonder whether this is the best reference to make this point…

Title	Heinrich reference	Page	What	Remarks
Shorrock, S. & Williams, C. (2016) *Human factors and ergonomics in practice: Improving system performance and well-being in the real world*. Boca Raton, FL: CRC Press.	None			
Andrew Townsend[219]				
Townsend, A. (2013) History of Health and Safety. Retrieved 22 May 2018 from http://www.safetydifferently.com/history-of-health-and-safety/	None	--	Science	"…few in safety stand back from their involvement in the here and now to recognise that things are changing. If they did, they might be alarmed. They would see that the original theories of Heinrich and Bird do not match modern standards of research."
Townsend, A.S. (2014) *Safety Can't Be Measured: An Evidence-based Approach to Improving Risk Reduction*. Farnham: Gower Publishing.	1931	77 78	Triangle	"an early theory how to reduce accidents" "Heinrich proposed that accidents of different severities happened in fixed ratios" - does H. say "fixed"? "The principle that Heinrich and Bird used was that a reduction of the number of low severity events at the bottom… would result in a proportionate reduction in more severe events at the top" - Does Heinrich say that?
		80	Science	Source data of Heinrich's triangle, unproven theoretical concept, but focuses on the numerical part
		157	Science	"By modern standards the original researches of Heinrich and Bird are fundamentally flawed. There have not been validation studies to test the limits of applicability of the principle of the accident triangle."
		157	Linear accident models (refers to SCM instead of dominos, however)	Stresses the fact that things have to be taught *including* their limits of applicability.

[219] Scopus does not give additional hits for Townsend. Of Townsend's five contributions to safetydifferently.com, only the one above mentions Heinrich (Searched 22 May 2018: http://www.safetydifferently.com/author/andrewtownsend/).

Appendix 7: Where do 'new view' authors discuss Heinrich?

Sorting the various publications into source types, it is interesting to see that a major part of the 'new view' critique of Heinrich is delivered outside of academic rigour, quite often in popular books for practitioners or through blogs. Long's volume of blogs skews the picture somewhat.

Table 9: Sources where 'new view' authors discuss Heinrich (based on appendix 3-6)

	Book (chapter)	**Academic paper**	**Conference paper**	**White paper / prof. mag.**	**Blog / podcast**	**Total**
Dekker	5	3 + 2	0	1	2	**13**
Hollnagel	10	7	2	2	0	**21**
Long	2	0	0	0	37	**39**
Anand	0	0	0	3	0	**3**
Conklin	1	0	0	1	2	**4**
Gantt	0	1	0	0	0	**1**
Gesinger	1	0	0	0	0	**1**
Hummerdal	0	0	0	0	1	**1**
Marriott	1	0	0	0	0	**1**
Pariès	2	0	0	0	0	**2**
Provan	0	1	0	0	0	**1**
Shorrock	0	0	0	0	1	**1**
Townsend	1	0	0	0	1	**2**
Total	**23**	**14**	**2**	**7**	**44**	**90**