World War II, soaring production and accident rates,

the origins of modern occupational and technical safety, and the toppling dominoes of occupational accidents

LEGEND
- Safety scientist/activist
- Safety problem
- Safety legislation/milestone
- Safety concept
- Safety slogan/metaphor

Before World War II, there were various management schools, including general and behavioral management. However, a new approach called quantitative management emerged, leveraging the power of mathematics and statistics. Initially used for military purposes, known as operational research, this approach was later applied to the private sector. It provided valuable data for quantifying risks and supporting management decisions, albeit limited by data availability and reliability, as well as the need to consider non-quantifiable factors in policy decisions.

During this period in the United States

While the psychological approach to accidents was losing popularity in Europe, the concept of an accident-prone personality remained popular, based on flawed early studies that lacked personality measures and relied on subjective interpretations. Instead of solely relying on worker education, it was found that creating fail-safe machines and installations is more effective in preventing accidents caused by worker mistakes.

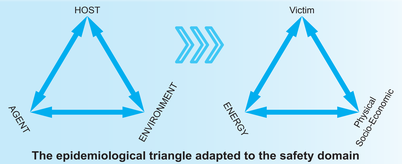
Safety for you for all; 1936 poster for the WPA Illinois safety division promoting safety. (Library of Congress, LC-USZC2-5556)

Work with care; 1936 poster encouraging safety in the workplace. (Library of Congress, LC-USZC2-1172)

"Just a scratch" But!, Poster for Illinois WPA Safety Division promoting the immediate treatment of on-the-job injuries. (Library of Congress, LC-USZC2-806)

Safety comes first; a poster promoting safety in the workplace shows a wheel with spokes and a locomotive. (Library of Congress, LC-USZC2-1139)

The epidemiological triangle's application to safety management problems gained traction during this period. Physicians who witnessed its success in controlling cholera promoted its use in accident prevention. This approach focused on understanding the interactions between the victim, host, and situational variables. Gordon (1949) introduced the epidemiological approach to safety which was later perfected by Haddon (1963). Focusing on the etiology of accidents and exposure to hazards proved to be more effective than the psychological approach. The assumption behind this model was that stopping one vector of the triangle could halt the spread of accidents.

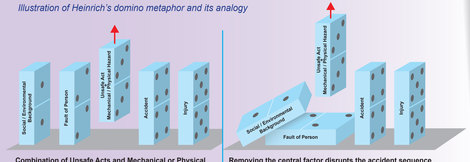


The epidemiological triangle adapted to the safety domain

Herbert William Heinrich (1886-1962), *a prominent figure in safety science, viewed accidents as a process with a clear separation between causes and consequences. He stands out for his ability to transform complex phenomenon to easily understandable ratios, such as the 4:1 proportionality rule for hidden costs of accidents and 88:10:2 for causes of accidents. He published the safety reference book "Industrial Accident prevention: A Scientific Approach", along with influential articles, metaphors, and numerical models. Although his book's titles touts a scientific approach, it is limited to application of statistical analysis rather than scientific research methodology or justification as he does not share the data supporting his insights. During the Second World War, he stressed the importance of preventing work accidents to avoid delays in weaponry production. Heinrich's contributions made safety more predictable, and he advocated for reducing accidents even during wartime. Even though he contributed to the war effort and served as the chairman of the Safety Division for the War Advisory Board in 1942, Heinrich continued to be an active author in the safety field throughout and after the war.*

The domino metaphor (1941) was one of Heinrich's notable contributions to explaining the proximate and immediate causes of accidents. According to his findings, 88% of accidents were due to workers' unsafe acts, 10% were due to unsafe conditions, and 2% were considered unpreventable. Heinrich suggested integrating psychology into safety practices to improve safety, as most errors resulted from supervision failures and human errors. The falling dominoes metaphor visualizes the accident process, where removing one domino can halt the sequence of events. Heinrich also believed that individuals with dubious hereditary or social backgrounds were more susceptible to accidents.

Illustration of Heinrich's domino metaphor and its analogy

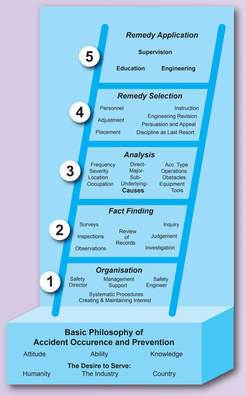


Combination of Unsafe Acts and Mechanical or Physical Hazards is the accident sequence's central factor

Removing the central factor disrupts the accident sequence

During the war years, Heinrich highlighted the crucial role of supervisors in promoting safety and production. He advocated for supervisors to have independent safety meetings and provided a framework for their supervisory tasks. Recognizing the potential benefits of statistical analysis in safety, Heinrich highlighted its importance in his paper on safety and insurance. He demonstrated how cooperation between causality and safety engineers could enhance safety interventions. Although Heinrich's call for statistical analysis in safety was ahead of its time and not mentioned in later papers, he remained open to probabilistic approaches.

In 1950, Heinrich created a practical framework for safe and efficient production, consolidating his accident prevention knowledge presented as the "safety ladder" metaphor. This framework analyzed accidents and aimed to improve prevention efforts. It became the industry standard for safety system development. The framework had five steps: organization, fact-finding, analysis, selection of the remedy, and application of the remedy. Heinrich's contribution provided one of the first and a clear representation of safety management systems. However, Heinrich's framework lacked scientific validation, unlike prior authors like DeBlois and Armstrong. Its underlying principles remained undisclosed, limiting its recognition in the scientific community.



Heinrich's safety ladder metaphor illustration

Heinrich's practical approach to safety emphasized simple solutions for safety practitioners. He introduced concepts such as hidden costs of accidents, the domino metaphor for accidents, and a framework for safe industrial production. However, the lack of detailed data and methodology in his publications makes the numerical values of his ratios debatable. Nevertheless, Heinrich's work significantly impacts safety instruction and practices even today.

In this period, president Franklin D. Roosevelt recognized the significance of the National Safety Council, the national occupational and road safety organization for the war effort in 1941: *"[M]obilize its nationwide resources in leading a concerted and intensified campaign against accidents, and to call upon every citizen, in a public or private capacity, to enlist in this campaign and do their part in preventing wastage of human and material resources of the nation through accidents" (Roosevelt, F.D., 1941).* Several reference books were published during this time, including multiple editions of Heinrich's "Industrial Accident Prevention" in 1931, 1941, and 1950. Additionally, Armstrong et al. published "Safety Organization" in 1945.

During this period in the United Kingdom

There were no major safety-related developments or incidents apart from the publication of Vernon's 1936 book, "Accidents and Their Prevention." Despite Vernon's background in chemistry, physiology, biology, and medicine, he took an interdisciplinary approach to safety. His research covered industrial and mine safety, transport sector safety, and home safety. Vernon supported his approach with extensive data from his research and the British Labour Inspectorate, revealing higher fatalities in the transport and domestic sectors compared to the industry. He also examined environmental factors such as temperature, fatigue, production speed, ventilation, and alcohol consumption. Vernon critiqued certain tests for accident proneness and emphasized the complexity of human factors compared to mechanical defects. He advocated for addressing safety through technical solutions and emphasized the importance of safety committees and inspections in the workplace. Vernon highlighted that legislation without inspection lacked effectiveness.

Horace Middleton Vernon (1870-1951) a pioneer of industrial health research.

During this period, the Netherlands

Contribution to safety research, while not as extensive as that of the USA and UK, has seen notable dissertations by Ter Borg (1939) and Herold (1945). Ter Borg's research involved using questionnaires to investigate accident factors at Hoogovens and other Dutch companies, providing support for the accident proneness theory. Additionally, Ter Borg emphasized the importance of addressing accident proneness in safety education for workers. Herold's study focused on miners in the southern region of the Netherlands, utilizing the aesteto-kinetic test battery developed by a British research group. While Herold did not establish a direct relationship between accidents and test results, he highlighted the potential to enhance accident prevention through company training. Dutch safety literature also emphasized safety education for workers and design-related safety aspects, echoing the well-known American slogan, "Safety Pays Off."

The Safety Museum was central to improving occupational safety in the Netherlands in the 1930s. The museum gathered detailed data on accidents per 1,000 workers by registering occupational accidents. This information was used to enhance safety posters, some tailored to specific machines or activities. The museum also pioneered the development of occupational health services focused on early tuberculosis detection. The Labour Inspectorate showed particular concern for accidents involving electricity. Although safety committees were not mandatory or widespread in the industry, the discussion about their importance resumed after the war, with varying opinions from employers and employees. The Dutch government supported these committees and services and suggested that a safety inspector or engineer manage them to ensure focus and effectiveness.

Occupational poster depicting proper semaphore signals for lifting equipment in different situations

The post-WWII occupational poster implies: The battered Netherlands recovers through labor

Dutch safety poster reads: Is your family sacred to you? Then work safely

Dutch safety poster promotes the use of respiratory protective equipment, it reads: Use a fresh-air mask

Dutch occupational safety poster warns of welder's flash: Weld safely

Post-WWII poster reads: The Netherlands is industrializing

Dutch safety poster promoting hygiene reads: Don't spit.

Text on the top reads: Unsafe punching with the stamping press, etc.!! and at the bottom: 546 accidents per year.

1930-1950

1800-1910 | 1910-1930 | **1930-1950** | 1950-1970 | 1970-1990 | 1990-2010 | 2010→

Based on the book *From Safety to Safety Science* (Swuste et al., 2022)