AC 2010-605: ENGINEERING AS LAW: INJURY EPIDEMIOLOGY AND CONSENSUS CODES

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Engineering as Law: Injury Epidemiology and Consensus Codes

Abstract

British Field Marshal John Slessor observed during World War II that the first social service a nation can provide for its people is to keep them alive.[1] As the recent experience of the Haiti earthquake has forcefully brought home to us, engineering safety codes and standards play a major role in this vital function of government.[2,3] From the point of view of keeping citizens alive, the development, incorporation into law, and enforcement of consensus safety codes for the built environment makes safety engineering the instrumental arm of injury epidemiology in industrial democracies. This important concept is not customarily taught as a component of engineering education, nor is it often used as a means of attracting students to the profession of engineering. I intend to discuss in this paper the educational advantages of incorporating such material into college curricula across disciplines, and the historical substance and value of the case study material available to educators.

Educational Objectives

At the college level, there are notoriously few crosswalks for students to or from engineering into other disciplines.[4,5,6,7] Building codes are rarely taught as a separate subject above the community college level, and when taught, are typically embedded as a unit in architecture and/or construction management courses.[8,9,10,11,12] Their role as environmental prophylaxis for unintentional injuries is rarely addressed, although the Haiti earthquake appears to be calling increased attention to this aspect of what engineers do. Moreover, there is little educational focus on the iterative process by which consensus codes are developed over time by engineering organizations, including those in developing nations, as a component of the rise and spread of democratic institutions that aspire to provide Field Marshal Slessor's "first social service."[13,14,15,16,17,18,19,20] Due process for the development of consensus codes is itself defined by an ANSI (American National Standards Institute) consensus standard, as follows:

> Due process means that any person (organization, company, government agency, individual, etc.) with a direct and material interest has a right to participate by: a) expressing a position and its basis, b) having that position considered, and c) having the right to appeal. Due process allows for equity and fair play.[21]

Safety engineering as the instrumental arm of injury epidemiology, including the code development process, was introduced to students in an upper-division research-methods course in medical history at a liberal arts college in the spring term of 2009. Students were introduced to these concepts through historical texts such as Sedgwick's *Principles of Sanitary Science* (1902),[22] and modern studies such as the World Health Organization's *Injury Chart Book: a Graphical Overview of the Global Burden of Injuries* (2002).[23] Gender and economic injury-risk factors were strongly emphasized, such as the very high current death rates from fire among South Asian women, and from alcohol poisoning among middle-aged Russian men.

The course was offered through the Women's Studies Department; seven of the ten students were Women's Studies majors and three were majoring in premedical biology. It was clear that few of these students had previously associated health concerns with engineering, or connected the regulation of the built environment with industrial democracies' larger goals for the health, welfare and self-realization of their citizens. The structure of the course was organized around the upward travel of responsibility for health and epidemiological issues from the body personal to the body politic. Much of the class discussion focused on quantification as a tool in the process of translating health policy into safety engineering. Who "counts"? Who is counting, and why? How is statistical information about human health and safety made operational as safety engineering in the built environment? How have all of these elements evolved over the course of Western history?

Injury epidemiology in this context may be understood as the exploration of the interface between engineering and medicine. While the primary literature is voluminous, the secondary literature that explicitly addresses the engineering/medicine nexus is relatively sparse, possibly because, historically, most studies of the social context and political implications of mortality and disability, especially those published before 1985, were primarily concerned with the prevention or treatment of communicable and chronic diseases, which were framed in the intersection of medicine and science, not engineering.[24,25] This is unsurprising in light of Omran's hypothesis regarding the "epidemiologic transition" from communicable diseases as nations develop. Omran asserts that

> An epidemiologic transition has paralleled the demographic and technologic transitions in the now developed countries of the world and is still underway in less-

developed societies. Ample evidence may be cited to document this transition in which degenerative and man-made diseases displace pandemics of infection as the primary causes of morbidity and mortality.[26,27]

After 1985, research on injury epidemiology gained traction rapidly as the importance of the field to medicine and policymaking in the developing world began to be more widely recognized.[28,29,30,31,32,33] The literature of the safety-engineering interface with public health, other than that noted above, generally falls into one or more of the following types.

- Injury epidemiology studies by official authorities, either governmental or non-governmental, such as Congressional and parliamentary bodies, the World Health Organization, the U.S. Centers for Disease Control, and the National Institute of Standards and Technology.[34,35,36,37,38,39,40,41,42]

- Risk evaluations and code manuals produced by or for the insurance industry.[43,44,45,46,47]

- Safety engineering and scientific studies, including publications and proceedings of state, national and international organizations concerned with the development of consensus standards and codes.[48,49,50]

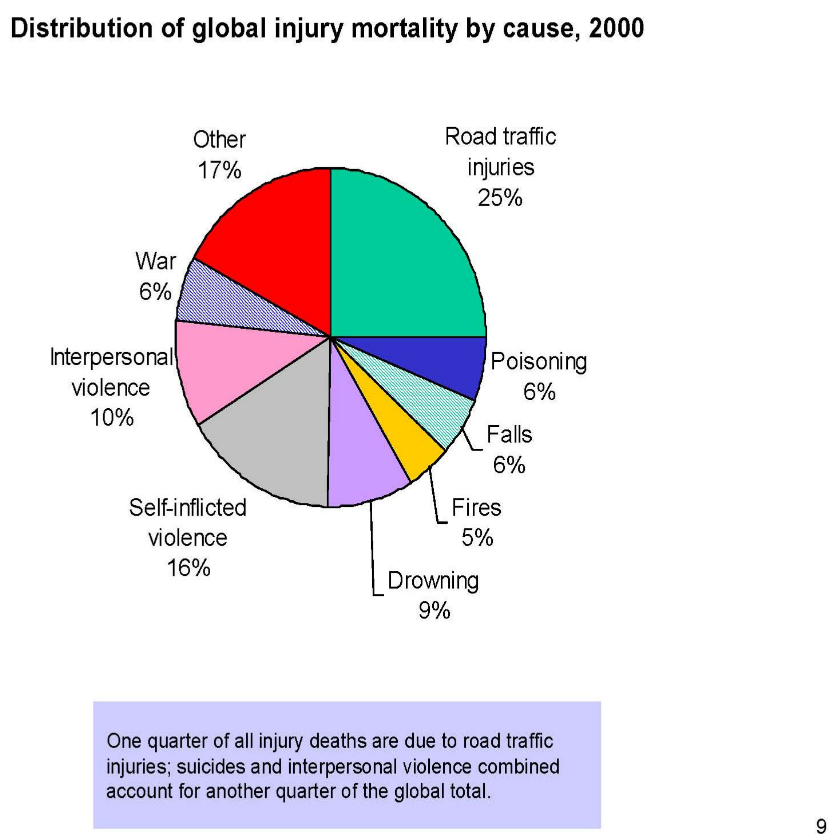
- The codes and standards themselves, both model codes such as the National Fire Protection Association's (NFPA) *Life Safety Code*, and those enacted by national, state and local governments.[51,52,53,54,55,56,57,58]

- Scientific, engineering and popular studies of life safety, often in a political context, typically addressing a single issue such as boiler, traffic, carbon monoxide, structural fire or aviation safety.[59,60,61,62,63,64]

In the 2006 volume of *Disease Control Priorities in Developing Countries*, the Haddon matrix of injury risk factors, formerly used only for studying the engineering/medicine/policy intervention interface for traffic accidents, was applied across the board to unintentional injuries.[65]

Leif Svanström and other international experts on injury prevention argue that life safety is a community value that requires consistent participatory education to create a "culture of safety" in which social factors operate positively against preventable injury.[66,67,68] The principal purpose of consensus life safety codes and standards is the prevention of death and injury to humans occupying the built environment. While these codes and standards, based of necessity on the historical experience of participants in the consensus process, are backward-looking in form, they are anticipatory in intent. Their objective is to apply the lessons of history to future development of the built environment, and occasionally to require modification of existing structures to reduce what are perceived as particularly urgent threats to life safety.[69] The adoption and enforcement of health and safety codes and standards, including federal, state and municipal building codes, has resulted in significant decreases in injury death rates per hundred thousand population in the United States and Western Europe since 1900.

Figure 1 Distribution of global injury mortality by cause, from World Health Organization, *Injury Chart Book (Geneva 2002).*



The National Center for Injury Prevention and Control of the Centers for Diseasea Control and Prevention (CDC) reports that unintentional injury is the number one leading cause of death in the United States for individuals between the ages of 1 and 44 years.[70] For all ages, unintentional injury ranks 5th in causes of death. Among the 25 developed nations reporting to the International Association for the Study of Insurance Economics, the U.S. has the sixth highest fire death rate, and there are inequities in this risk: African-Americans are three times as likely to die in residential fires as whites.[71,72] Worldwide, fire-related burns accounted for 5% of the mortalities from injury in 2000, only 1% less than injuries attributable to war; 95% of these deaths occurred in low and middle-income nations.[73]

The U.S. lags behind other developed nations in the reduction of traffic fatalities. The European Union has a rate of 7 traffic deaths per 100,000 population and continues its efforts to reduce injury and mortality on European roads; in the United States, even after decades of safety efforts, the 2004 rate was 14.59 per 100,000.[74,75,76] This represented a significant improvement, however over the U.S. rate in 1966, which had been 25.89 per 100,000.[77,78] To evaluate this improvement by a different metric, the number of fatalities per motor vehicle, the United States achieved a decrease from 53.18 fatalities per 100,000 registered motor vehicles to 18 in 2004. Clearly, however, we still have a long way to go to achieve the kind of culture of traffic safety that prevails in the European Union. I shall have more to say of this in a later section on case studies and success stories.

Life safety codes and standards are significant not only to the health of the U.S. population but to our interactions with the global economy. In 2002, the World Health Organization (WHO) reported that more than 5 million persons worldwide die annually from injuries, accounting for "9% of the world's deaths in 2000 and 12% of the world's burden of disease ... More than 90% of the world's deaths from injuries occur in low- and middle-income countries."[79] The worldwide mortality rate from injuries is 83.7 per 100,000 population, with road traffic accidents responsible for a quarter of these deaths. Most of the nations with injury mortality rates below 70 per hundred thousand are the prosperous industrial democracies of Europe, North America and the Western Pacific (Australia and New Zealand). The exception is

China, which is, however, currently undergoing an increase in injury deaths as it industrializes and increases its automobility, with the rate at 66 per hundred thousand and climbing in 1997, accounting for 11% of all deaths in China.[80,81,82]

The Russian Federation, however, leads the world in injury mortality with rates above 120 per hundred thousand population, a higher rate even than that of sub-Saharan Africa. Russian life expectancies at birth have been in a decline since 1965, and fell precipitately, especially for men, in the 1990s, with injuries contributing significantly to this trend.[83,84,85,86]

Stanfield, Smith and McGreevey, writing of injury epidemiology in the 1996 edition of *Disease Control Priorities in Developing Countries,* observed that:

> Studies have confirmed that safety is considered a normal good, the demand for which rises with income (Peltzman 1975). The development of a complex institutional structure (including legislation, enforcement, insurance and litigation services, and complex capital markets) helps to reduce the incidence of injury by forcing implementation of safety measures.[87,88]

What Stanfield *et al.* are describing here is the historical evolution of a culture of safety; what is missing from their analysis is the role of international codes and standards in helping to create what the World Health Organization called in 1989 a "national policy and plan of action to create and sustain safe communities."[89,90] Industrial democracies that have already taken this step have done so with the aid of such codes and standards, and there is every likelihood that such norms as building fire safety codes, uniform traffic laws, aviation safety regulations, and routine monitoring of indoor and outdoor carbon monoxide will play a role in the reduction of injury and mortality in the developing world as well.

Historical Case Studies and Success Stories

A rich literature of historical case studies is available to educators in almost any discipline, including not only those of engineering but also political science, history, economics, law and medicine. Until the 19th century, government use of engineering to keep people alive was minimal,[91] but the highly visible success of sanitary engineering by the end of the 19th century, the great promise of fire safety engineering by the 1890s, and boiler safety engineering by 1920, for this purpose drove both public and private efforts to codify safety rules in the form of consensus codes. The Federal government was involved in the development of model safety codes like the National Electrical Code by 1904, for example, for adoption as law by states and localities.[92]

One of the first environmental risks to be the target of government regulatory efforts, fire death rates remained high in industrial democracies until systematic efforts from the late 19th century forward to create a culture of fire safety began to bear fruit in the 20th century. Theater fire safety was among the first risks to be addressed by the international community of fire safety professionals in 1881 after the Ring Theatre fire in Vienna killed more than 450 persons.[93,94,95,96,97] In December 1903, the Iroquois Theatre fire in Chicago, with 602 fatalities of which 40% were children, added further impetus to U.S. and international fire prevention efforts; the Iroquois remains the most deadly single-structure fire disaster in American history.[98,99,100,101,102,103,104]

These measures have involved some health-issue tradeoffs, such as the use of asbestos to prevent fire.[105] As noted earlier, the overall fire mortality rate per 100,000 population in the US since 1900 is a significant success story. In 1921, an estimated 15,000 persons died from the effects of fire in the United States; in 1998, only about 5300 did so, a reduction in the death rate in 77 years from about ten per 100,000 population to one, a 90% decrease.[106,107] In Europe, the rate has fallen even more.[108,109]

The Industrial Revolution of the late 18th and early 19th century brought power boilers into wide use throughout the Western world, with their attendant dangers of fire and explosion. International efforts to define and enforce standards of safety for boilers began in the 1820s and began to show significant results in accident mortality reduction in the United States and Europe by the late 19th century.[110,111,112,113,114,115] Steam boiler safety is an example of a highly successful international effort among industrial nations to use codes, standards and inspections to reduce injury and mortality from accidents.[116,117,118,119,120,121] The transfer of both the technology and the safety infrastructure to what was then the developing world was fairly successful in many cases as well.[122,123,124,125,126,127,128,129,130] Because boiler and pressure vessel safety is a technological and industrialization issue, it is possible that the historical success of efforts to create an international culture of boiler safety may have lessons for traffic and aviation safety in the developing world.

Traffic accidents, as noted earlier, account for a significant percentage of the global burden of injuries.[131] Even in the developed world, cultures of safety in automobility have taken many decades to create. The Uniform Motor Vehicle Code, for example, was first proposed in the United States in 1926, but it took nearly a half century of highway fatalities to convince policymakers—and motorists—that consistently-drafted and rationally-enforced motor vehicle laws were a benefit to the nation, with the potential, eventually achieved, to save tens of thousands every year from death and injury.[132] More than four decades elapsed between the original drafting of the Code and its eventual adoption by all 50 states in the late 1960s.[133,134,135,136,137]

The United States' culture of traffic safety is not as successful as that of the European Union, but we are well ahead of, for example, Ethiopia and Nigeria, which as of 1978 had mortality rates per motor vehicle fifty times that of the U.S.[138] Traffic deaths in the developing world began to rise in the 1960s, as automobility spread into regions with little or no legal, social or economic infrastructure to mitigate its dangers.[139,140] In 2000, road traffic injuries accounted for a quarter of global injury mortality, killing 1.26 million persons worldwide, of whom three out of four were male, and half were young adults. According to the World Health Organization, in 2002, "90% of all road traffic injury deaths occurred in the low- and middle-income countries," with China and the Indian subcontinent showing the highest death rates. Parts of South Asia have traffic fatality rates in excess of 34 per 100,000 population.[141]

The risk of carbon monoxide poisoning is another example of an environmental injury potential with an incompletely formed culture of safety. The world's most frequently-encountered poison, carbon monoxide is the product of incomplete combustion, and is thus a "normal risk" (in Robert Perrow's sense of "normal accidents") in the context of the human use of fire.[142,143] It was not perceived as a widespread risk to life, however, until technological change in the 18th and 19th centuries brought humans into close proximity with the gas in enclosed spaces with inadequate ventilation.[144,145,146] When the architect A. J. Downing wrote in 1850 of the hazards of coal stoves, he called carbon monoxide "the favorite poison of America;" more than a century and a half later, physiologist David Penney called it "the most commonly encountered and pervasive poison in our environment," adding that "It is responsible for more recent deaths than any other single poison."[147,148]

More than five thousand accidental deaths from carbon monoxide occurred in the United States between 1988 and 1996, and suicides by this means are more than four times the number of unintentional deaths, with the total U.S. mortality rate for both approximating 1 per 100,000 population in 1996. Carbon monoxide is an example of a risk with a still-evolving safety culture; the risks are well understood, but prevention of injury and mortality has proved challenging even in the Western industrial democracies.[149,150,151,152,153] As for the developing world, Manish A. Desai, Sumi Mehta and Kirk R. Smith reported in 2004 that "Worldwide, approximately 50% of all households and 90% of rural households utilize solid fuels for cooking or heating," with consequent risks from carbon monoxide and other indoor air pollutants that account for 2.6% of the world's burden of ill-health.[154]

Aviation safety efforts since the 1920s have been highly successful in industrial democracies, but the sociopolitical and infrastructure requirements and economic challenges of maintaining high safety standards have prevented some nations from putting effective systems into operation. The building of a culture of safety in civil and commercial aviation began in the

1920s in the United States, paralleling and sharing some protocols with the International Committee for the Safety of Life at Sea (SOLAS), established after the sinking of the *Titanic* in 1912.[155,156] Worldwide, aviation safety in industrial democracies has shown a consistent pattern of improvement in accident reduction and loss of life per passenger mile since the 1930s, when the rise of regularly-scheduled air passenger service first brought the issue to public attention.[157,158,159,160,161]

Today, the poorest recent records of aviation safety are on the continent of Africa, which in 2005 accounted for 37% of all fatal multi-engine airliner accidents but only 3% of all world aircraft departures.[162] In 2005, there were 35 such accidents with about 1100 total fatalities.[163] While aviation accidents do not account for a significant percentage of the overall global burden of injury fatalities, the disproportionate share of such accidents accounted for by the developing world clearly marks it as a problem deserving further study. In nations where civil and commercial aviation are known to be unsafe propositions, investment, tourism, and trade will suffer the economic consequences of perceived risks, contributing to unemployment and poverty.

The success of constantly-evolving engineering consensus codes in keeping people alive is evident in studies such as Alan Lopez' *Global Burden of Disease and Risk Factors* (2006), which shows the massive drop, over time, in industrial democracies, in preventable injury deaths from environmental causes such as fire and drowning.[164]

Another success story is the reduction of injuries in workplaces. In 1913, the Bureau of Labor Statistics recorded about 23,000 American worker deaths in industrial accidents;[111] in

1995, only 5314 such deaths occurred; in just over eight decades the death rate per 100,000 workers fell from 61 to less than 5.[165,166]

These savings of lives, and the reduction of disabling injuries from the same causes, are paralleled in industrial democracies in Europe and Canada and, more recently, in some developing nations, that have established methods of consensus-building among the professional communities of life safety to devise and enforce codes and standards, not only of safety, but also of the testing of materials, devices and assemblies for their safety potential. These nations have also evolved methods of integrating these codes and standards into the laws of the land at all levels of government from local to national, much as these same nations have developed epidemiological regulations that protect their populations from disease.

Conversely, governments which spring from societies that do not have traditions of democracy, with its irreducible concern for the individual, have fared poorly in the development and adoption of life safety codes and standards; many of these nations have poor epidemiological records as well. In the case of accidental deaths and injuries from fire and industrial causes, safety engineers have noted that structures and facilities are made, in many parts of the world, to visually resemble their code-compliant counterparts, but fail the tests of fire and collapse, often with substantial loss of life, as in the case of a Paraguayan grocery store fire in August 2004, and Chinese schools in the 2008 earthquake.[167]

Failure to enforce codes and standards also plays a role; in the Former Soviet Union (FSU) nations, for example, there have been three commercial airliner accidents with triple-digit mortality since January 2006. Aviation safety experts in the United States believe that failure to inspect and maintain aircraft is the principal factor in this deplorable accident record.[168,169,170]

Educational Prospects

It is difficult to overstate the importance of the profession of engineering, and its consensus codemaking process, to reducing the global burden of preventable injury from fire, traffic and aviation accidents, falls, drowning and carbon-monoxide poisoning, to say nothing of its historical and current role in preventing waterborne, foodborne, and insect-vectored disease. Safety engineering is perceived by some as unglamorous, but it clearly saves lives and prevents injury more effectively and efficiently than almost any other form of public health intervention.[171] As such, it merits systematic inclusion in education outside the disciplines of engineering, and more educational attention within in it. Students choosing majors or graduate programs need to be aware that a career in engineering, like a career in medicine or public health, can contribute significantly to reducing the global burden of disease and injury.

My medical historiography students learned that the body personal enters the province of the engineer not only in the form of medical technology but in the built environment that, in industrial democracies, is engineered to protect the body politic. Engineers as well as doctors and health policy professionals have a significant role to play in democracies' primary social service of keeping its citizens alive.

Bibliography

[1] Foster, Richard S., and Francis P. Hoeber, "Limited mobilization: a strategy for preparedness and deterrence in the Eighties," *Orbis* 24 (1980: 451.

[2]Fierro, Eduardo. "Preliminary reconnaissance presentation about Haiti earthquake," at Pacific Earthquake Engineering Research Center, University of California at Berkeley, 27 January 2010, available at http://peer.berkeley.edu/publications/haiti_2010/related_events_haiti.html, accessed 8 March 2010.

[3] Bajak, Frank (Associated Press). "Chile was ready for quake, Haiti wasn't." *Seattle Post-Intelligencer* (27 Feb 2010), available at http://www.seattlepi.com/national/1102ap_cb_tale_of_two_quakes.html, accessed 5 March 2010.

[4] Chinowsky, P. S., and J. Robinson. "Facilitating interdisciplinary design education through case histories." *Proceedings, Frontiers in Education 1995 25th Annual Conference: Engineering Education* 2, no. 4a3 (1995): 6-9.

[5] Berezin, A. A. "Interdisciplinary integration in engineering education." *IECON '01: 27th Annual Conference of the IEEE Industrial Electronics Society* 3 (2001): 1740-45.

[6] Martinez, D., and K. H. Smith. "An engineering and education interdisciplinary learning experience." *33rd Annual Frontiers in Education (IEEE Cat No 03CH37847C)* 2, no. F1A (2003).

[7] Rojas, E. M., and C. S. Dossick. "Developing a state-of-the-art facility to support construction research and education: a case study." *Journal of Professional Issues in Engineering Education and Practice* 134, no. 1 (2008): 67-74.

[8] Jarosz, Matthew. "ARC 760: History of building technology [syllabus]." Milwaukee WI: University of Wisconsin at Milwaukee. School of Architecture and Urban Planning. Department

of Architecture, 2009, available at http://soa.utexas.edu/faculty/moore/syllabi/syllabus_hbt.pdf, accessed 6 March 2010.

[9] Moore, Steven. "ARC 386M: History of building technology [syllabus]." Austin TX: School of Architecture, University of Texas at Austin, 2009, available at http://soa.utexas.edu/faculty/moore/syllabi/syllabus_hbt.pdf, accessed 6 March 2010.

[10] Makarechi, Yar. "CM 3500-001 Building codes [syllabus]." Marietta GA: Southern Polytechnic State University. Department of Construction Management, 2010, available at http://www.spsu.edu/cnst/CNSTWEB/Course%20Schedules/Spring%202010/Dr.Yar/CNST3500_001SyllabusSpring2010.pdf, accessed 6 March 2010.

[11] Westwood College. School of Business, Denver CO. "Construction management." http://www.westwood.edu/programs/school-of-business/construction-management/ [webpage], 2010, accessed 6 March 2010.

[12] Middle Tennessee State University. Engineering Technology Department, Murfreesboro TN. "Commercial construction management," http://www.mtsu.edu/commconstruction/index.shtml, [webpage], 2010, accessed 6 March 2010.

[13] Building Officials and Code Administrators International (BOCA), "Democratic National Code Revision," *The BOCA National Mechanical Code*, 7th ed. (Country Club Hills, Ill.: BOCA, 1990), inside front cover.

[14] Stone, W. C., F. Y. Yokel, M. Celebi, T. Hanks, and E. V. Lyendecker. *Engineering aspects of the September 19, 1985 Mexico earthquake*. Washington DC: National Bureau of Standards, 1987.

[15] Srivastava, H. N. "The Mexican earthquake of 1985 vis-a-vis great Indian earthquakes: field and seismological aspects." *Mausam* 39, no. 2 (1988): 149-58.

[16] Jain, A. K. "Inelastic response of reinforced concrete frames subjected to the 1985 Mexico earthquake." *Computers and Structures* 34, no. 3 (1990): 445-54.

[17] de Buen, P. R. "SEADSE: an expert system for tutorial of seismic design." *Applications of Artificial Intelligence in Engineering: Proceedings of AIENG 92* 7 (1992): 345-55.

[18] Klingner, R. E. "Behavior of masonry in the Northridge (US) and Tecomán-Colima (Mexico) earthquakes: Lessons learned, and changes in US design provisions." *Construction & Building Materials* 20, no. 4 (2006): 209-19.

[19] Tena-Colunga, A., U. Mena-Hernandez, L. E. Perez-Roche, J. Aviles, M. Ordaz, and J. I. Vilar. "Updated seismic design guidelines for model building codes of Mexico." *Earthquake Spectra* 25, no. 4 (2009): 869-98.

[20] Ovalle, David. "Mexico's earthquake recovery could be a model for Haiti." *Miami Herald*, 17 Februrary 2010, available at http://www.miamiherald.com/2010/02/16/1483851/mexicos-quake-recovery-could-be.html, accessed 8 March 2010.

[21] American National Standards Institute (ANSI), *ANSI Essential Requirements: Due Process Requirements for American National Standards*," ANSI, 2008, at www.ansi.org, accessed 8 March 2010.

[22] Sedgwick, W. T. *Principles of sanitary science and the public health with special reference to the causation and prevention of infectious diseases*. New York and London: Macmillan Company, 1902.

[23] WHO (World Health Organization). Injuries and Violence Prevention Dept. 2002. *The injury chart book: a graphical overview of the global burden of injuries*. Geneva: Dept. of Injuries and Violence Prevention, Noncommunicable Diseases and Mental Health Cluster, World Health Organization.

[24] Elder, John P. 2001. *Behavior change & public health in the developing world*. Thousand Oaks, Calif.: Sage Publications.

[25] Knight, Joseph A. 2004. *A crisis call for new preventive medicine: emerging effects of lifestyle on morbidity and mortality*. River Edge, NJ: World Scientific Pub.

[26] Omran, A. R. 1971. "The epidemiologic transition: a theory of the epidemiology of population change," *Milbank Memorial Fund Quarterly* 49:509-538.

[27] Hobson, William. 1963. *World health and history*. Bristol: J. Wright.

[28] Wintemute, G. J., S. P. Baker, D. Mohan, S. P. Teret, and C. J. Romer, eds. 1985. *Principles for injury prevention in developing countries: proceedings of an international course [held in] Baltimore, Md., 5-17 June 1983*. Geneva, Switzerland: World Health Organization.

[29] Langley, J. D. 1988. "The need to discontinue the use of the term 'Accident' when referring to unintentional injury events," *Accident Analysis and Prevention* 20:1-8.

[30] Odero, W. O, P. Garner, and A. B. Zwi. 1997. "Road traffic injuries in developing countries: a comprehensive review of epidemiological studies," *Tropical Medicine and International Health* 2 (5):445-460.

[31] Peden, M. M., and World Health Organization. 2004. *World report on road traffic injury prevention*. Geneva: World Health Organization.

[32] Lopez, Alan D. 2006. *Global burden of disease and risk factors*. New York, NY and Washington, DC: Oxford University Press and World Bank.

[33] Norton, Robyn, Adnan A. Hyder, David Bishai, and Margie Peden. 2006. "Unintentional injuries," in *Disease control priorities in developing countries*, edited by D. T. Jamison. New York, NY and Washington, DC: Oxford University Press and World Bank, pp.737-753.

[34] Franklin Institute (Philadelphia Pa.). Committee on the Explosions of Steam Boilers. 1836. “Report of the Committee of the Franklin Institute of the State of Pennsylvania for the promotion of the mechanic arts, on the explosions of steam boilers, part II, containing the General report of the Committee,” *Journal of the Franklin Institute* 18 (4):217-232.

[35] BFPC (British Fire Prevention Committee). 1899. *The safety of theatre audiences and the stage personnel against danger from fire and panic: a paper*. Edited by W. P. Gerhard, *Publications of the British Fire Prevention Committee no. 41*. London: British Fire Prevention Committee.

[36] Whitelaw, John L. 1962. *A selected bibliography, highway traffic safety with annotations (1956-1960)*. Washington: Division of Accident Prevention Public Health Service U.S. Dept. of Health Education and Welfare.

[37] Lee, K. N., Y. O. Choi, C. H. Kim, and D. R. Yun. 1971. “An epidemiological study on the incidence of carbon monoxide poisoning in Korea,” *Journal of the Korean Preventive Medicine Society* 4:95-106.

[38] OECD (Organisation for Economic Co-operation and Development). Scientific Expert Group on Traffic Safety of Children. 1983. *Traffic safety of children: report*. Paris, France and Washington, DC: OECD.

[39] Anderson, David. 1997. *The Russian mortality crisis: causes, policy responses, lessons*. International Union for the Scientific Study of Population Policy and Research Paper No. 11.

[40] WHO, *Injury chart book*, 2002.

[41] Desai, Manish A., Sumi Mehta, and Kirk R. Smith. 2004. *Indoor smoke from solid fuels: assessing the environmental burden of disease at national and local levels*, *Environmental*

burden of disease series, no. 4. Geneva, Switzerland: Protection of the Human Environment, World Health Organization.

[42] NIST (National Institute of Standards and Technology). 2005. *Final report on the collapse of the World Trade Center towers*, *NIST NCSTAR-1*. Gaithersburg, Md.: U.S. Dept. of Commerce, Technology Administration.

[43] Walford, Cornelius. 1877. “Fires and fire insurance considered under their historical, financial, statistical, and national aspects,” *Journal of the Statistical Society of London* 40 (3):347-432.

[44] Aero Insurance Underwriters. Engineering dept. 1945. *Airplane operations and maintenance manual*. New York: AIU.

[45] NBFU (National Board of Fire Underwriters). 1919. *Regulations of the National Board of Fire Underwriters governing the production, storage, and handling of nitro-cellulose motion picture films.* New York.

[46] Robertson, Leon S. 1983. *Injuries--causes, control strategies, and public policy*. Lexington, Mass.: LexingtonBooks.

[47] World Fire Statistics Centre and International Association for the Study of Insurance Economics. General Secretariat. *World fire statistics: information bulletin of the World Fire Statistics Centre*. Geneva: Geneva Association, v.22 October 2006.

[48] BFPC (British Fire Prevention Committee). 1904 *The standards of fire resistance … as adopted to serve as universal standards at the International Fire Prevention Congress, London, 1903, with translations into German and French, together with special tables of measurements, weights and temperatures converted into their metric equivalents*. *Publications of the British Fire Prevention Committee no.82*. London: The Committee.

[49] Montreal International Civil Aviation Organization. 1944. *International standards and recommended practices. Annex 3: Meteorological service for international air navigation*. Montreal.

[50] NFPA (National Fire Prevention Association). 1991. *Fire Protection Handbook*, chapter 1 on history of fire prevention codes and standards. Quincy MA: NFPA.

[51] United States. 1879. *Laws governing the steamboat inspection service*. Washington: Government Printing Office.

[52] Massachusetts. Board of Boiler Rules. 1908. *Rules formulated by the Board of Boiler Rules*. Boston.

[53] Clarkson, Coker Fifield. 1918. *International aircraft standards*: New York.

[54] Rühl, Adolf, and Otto Ulrichs. 1929. *Bestimmungen über Anlegung und Betrieb der Dampfkessel: Nachtrag zur fünften Auflage unter besonderer Berücksichtigung der Werkstoff und Bauvorschriften*, *Die überwachungspflichtigen Anlagen in Preussen 2*. Berlin: C. Heymann.

[55] Cincinnati (Ohio) City Council. 1933. *Building code of the City of Cincinnati, effective April 1, 1933.* Cincinnati, Ohio: Council of the City of Cincinnati.

[56] *New Zealand Standard Specification: By-Law for Precautions against Fire and Panic in Buildings for Public Meetings.* Auckland: February 1951.

[57] ICBO (International Conference of Building Officials). 1958. *Uniform building code*. Pasadena, Calif.: International Conference of Building Officials.

[58] NFPA (National Fire Protection Association). 2000. *Life safety code: code for safety to life from fire in buildings and structures*. 2000 ed. Quincy, MA: National Fire Protection Association.

[59] Howland, S. A. 1840. *Steamboat disasters and railroad accidents in the United States*. 2d ed. Worcester [Mass.]: Dorr, Howland & Co.

[60] Coburn, Ronald F. 1970. Biological effects of carbon monoxide*, Annals of the New York Academy of Sciences,* v. 174, art. 1. New York: NYAS.

[61] "Construction and arrangement of theatres," 1882. *American Architecture and Building News* v.11:138-140 and 162-164.

[62] Irwin, Alan. 1985. *Risk and the control of technology: public policies for road traffic safety in Britain and the United States*. Dover, N.H.: Manchester University Press.

[63] Blomquist, Glenn C. 1988. *The regulation of motor vehicle and traffic safety*. Boston: Kluwer Academic Publishers.

[64] Wang, S., G. B. Chi, S. X. Jing, S. M. Dong, C. P. Wu, and L. P. Li. 2003. "Trends in road traffic crashes and associated injury and fatality in the People's Republic of China," *Injury Control and Safety Promotion* 10 (1-2):83-87.

[65] Jamison, Dean T., and World Bank. *Disease control priorities in developing countries*. 1st and 2nd eds. New York, NY and Washington, DC: Oxford University Press and World Bank, 1993 and 2006.

[66] International Labour Organization. "World Day for Safety and Health at Work 2005: a background paper." Geneva, Switzerland: International Labour Office, 2005.

[67] Svanström, Leif Laflamme Lucie Schelp Lothar. 1999. *Safety promotion research: a public health approach to accident and injury prevention*. Stockholm: Karolinska Institutet, Dept. of Public Health Sciences, Division of Social Medicine.

[68] Teret, S. P., and M. Jacobs. 1989. "Prevention and torts: the role of litigation in injury control," *Law, Medicine and Health Care* 17:17-22.

[69] Brannigan, Vincent M. 1981. "Record of appellate courts on retrospective firesafety codes," *Fire Journal* v.75 (6):pp.62-72.

[70] United States. Dept. of Health and Human Services. *Healthy people 2010*. Washington, DC: U.S. Dept. of Health and Human Services, U.S. G.P.O. Supt. of Docs., 2000.

[71] Hall, John R. Jr. *Fire in the U.S. and the United Kingdom*. Quincy MA: National Fire Protection Association, 2005.

[72] World Fire Statistics Centre and International Association for the Study of Insurance Economics. General Secretariat. *World fire statistics: information bulletin of the World Fire Statistics Centre*. Geneva: Geneva Association, v.22 October 2006.

[73] WHO, *Injury chart book,* 2002.

[74] European Road Safety Action Programme. 2003. *Saving 20,000 lives on our roads: a shared responsibility*. Luxembourg: Office for Official Publications of the European Communities.

[75] Irwin, Alan. 1985. *Risk and the control of technology: public policies for road traffic safety in Britain and the United States*. Dover, N.H.: Manchester University Press.

[76] Omran, "Epidemiologic transition," 1971.

[77] Peltzman, S. 1975. "The effects of automobile safety regulation," *Journal of Political Economy* 83 (4):677-725.

[78] Ribicoff, Abraham A. 1966. "Traffic safety," *Vital Speeches of the Day* 33:104-106.

[79] WHO, *Injury chart book*, 2002.

[80] Lopez, Alan D. 2006. *Global burden of disease and risk factors*. New York, NY and Washington, DC: Oxford University Press and World Bank.

[81] Wang, S., G. B. Chi, S. X. Jing, S. M. Dong, C. P. Wu, and L. P. Li. 2003. "Trends in road trafffic crashes and associated injury and fatality in the People's Republic of China," *Injury Control and Safety Promotion* 10 (1-2):83-87.

[82] Zhao, Zhongtang, and Leif Svanström. 2003. "Injury status and perspectives on developing community safety promotion in China," *Health Promotion International* 18 (3):247-253.

[83] Anderson, David. 1997. *The Russian mortality crisis: causes, policy responses, lessons*. International Union for the Scientific Study of Population Policy and Research Paper No. 11.

[84] Gavrilova, Natalia S., Victoria G. Semyonova, Galina N. Evdokushkina, and Leonid A. Gavrilov. 2000. "The response of violent mortality to economic crisis in Russia," *Population Research and Policy Review* 19 (5):397-419.

[85] Kennedy, B. P., I. Kawachi, and E. Brainerd. 2005. "The Russian Federation - demography - high adult mortality rate said to reflect a society that 'Doesn't value human life': the role of social capital in the Russian mortality crisis," *Current Digest of the post-Soviet press* 57 (48):10.

[86] Revich, B. 2006. "Toward the assessment of the Russian population mortality risk factors and the feasibility of their reduction: Comments on the World Bank Report 'Dying Too Young'," *Studies on Russian Economic Development 17, no* 6:643-654.

[87] Jamison and World Bank. *Disease control priorities in developing countries,* 1993 and 2006.

[88] Peltzman, "Effects of automobile safety regulation," 1975.

[89] WHO (World Health Organization). *Manifesto for safe communities: Safety--a universal concern and responsibility for all; resolution adopted September 20. 1989*. First World Conference on Accident and Injury Prevention, Stockholm.

[90] WHO (World Health Organization). 1989. *Research development for accident and injury prevention*, *IPR/Apr 216 m31R, 8923e*. Geneva: WHO.

[91] The Romans were, of course, a notable counterexample. See

[92] Croft, Terrell. *Wiring for light and power; a detailed and fully illustrated commentary on the more important portions of the National Electrical Code*. New York: McGraw-Hill, 1917.

[93] Construction and arrangement of theatres," 1882. *American Architecture and Building News* v.11:138-140 and 162-164.

[94] Citizens' Association of Chicago. Committee on Theatres and Public Halls. 1887. *Report of the Committee on Theatres and Public Halls to the Executive Committee of the Citizens' Association of Chicago.* Chicago: The Association.

[95] Sachs, Edwin O. 1897. *Modern opera houses and theatres*. Vol. 3. London: B. T. Batsford.

[96] Birkmire, Wm H. 1903. *The planning and construction of American theatres*. New York: J. Wiley & Sons.

[97] Maines, Rachel. 2005. *Asbestos and fire: technological trade-offs and the body at risk*. New Brunswick, N.J.: Rutgers University Press.

[98] Excludes explosions and building collapses like that of the World Trade Center towers in 2001.

[99] Westphalen [Prussian Fire commissioner]. 1906. "Experimental theater conflagrations," *Scientific American Supplement* 62:25873-4.

[100] Freeman, John Ripley. 1906. *On the safeguarding of life in theaters, being a study from the standpoint of an engineer*. U.S.: s.n.

[101] New Jersey. Bureau of General and Structural Inspection. 1928. *Building code for the construction of theatres, opera houses, grandstands and buildings used for motion picture purposes and other public entertainment* Trenton, N.J.: The Bureau.

[102] Mitchell, Nolan D. 1933. *Tests of theatre-proscenium curtains: asbestos and steel*. Wash.: U.S. Department of Commerce. Bureau of Standards.

[103] Brandt, Nat. 2003. *Chicago death trap: the Iroquois Theatre fire of 1903*. Carbondale: Southern Illinois University Press.

[104] Hatch, Anthony P. 2003. *Tinder box: the Iroquois Theatre disaster, 1903*. Chicago: Academy Chicago Publishers.

[105] Maines, Rachel. 2005. *Asbestos and fire: technological trade-offs and the body at risk*. New Brunswick, N.J.: Rutgers University Press.

[106] NFPA (National Fire Prevention Association). 1991. *Fire Protection Handbook*, chapter 1 on history of fire prevention codes and standards. Quincy MA: NFPA.

[107] NFPA (National Fire Protection Association). 2000. *Life safety code: code for safety to life from fire in buildings and structures*. 2000 ed. Quincy, MA: National Fire Protection Association.

[108] Hall, John R. Jr. *Fire in the U.S. and the United Kingdom*. Quincy MA: National Fire Protection Association, 2005.

[109] World Fire Statistics Centre and International Association for the Study of Insurance Economics. General Secretariat. *World fire statistics: information bulletin of the World Fire Statistics Centre*. Geneva: Geneva Association, v.22 October 2006.

[110] Greene, Arthur. 1953. *History of the ASME boiler code*. New York: American Society of Mechanical Engineers.

[111] Burke, J. G. "Bursting boilers and the Federal power," *Technology and Culture* 1966, v.7 no.1, pp.1-23.

[112] Sinclair, Bruce. 1966. *Early research at the Franklin Institute; the investigation into the causes of steam boiler explosions 1830-1837*. Philadelphia: Franklin Institute.

[113] Ferguson, Eugene S. 1987. "Risk and the American engineering profession: the ASME Boiler Code and American industrial safety standards," in *The Social and cultural construction of risk: essays on risk selection and perception*, edited by B. B. Johnson and V. T. Covello. Dordrecht, Boston and Norwell, MA: D. Reidel Pub. Co. and Kluwer Academic Publishers, p.304.

[114] Cross, Wilbur. 1990. *The code: an authorized history of the ASME Boiler and Pressure Vessel Code*. New York, NY: American Society of Mechanical Engineers.

[115] Maust, Peter. 2000. "'Congress could do nothing better': promoting steamboat safety in antebellum America," *Quarterly of the National Archives and Records Administration* v.32 (2):101-113.

[116] Franklin Institute (Philadelphia Pa.). Committee on the Explosions of Steam Boilers. 1836. "Report of the Committee of the Franklin Institute of the State of Pennsylvania for the promotion of the mechanic arts, on the explosions of steam boilers, part II, containing the General report of the Committee," *Journal of the Franklin Institute* 18 (4):217-232.

[117] Ashcroft, John. 1868. *The laws in relation to the inspection of steam boilers*. New York: J. Ashcroft.

[118] England. *The Boiler Explosions Act, 1882, 45 & 46 Vict. cap. 22. With appendix, index, etc*: pp. vii. 164. Simpkin, Marshall & Co.: London.

[119] Sweden. Kommerskollegium. 1902. *Underdånigt utlåtande angående kontroll å ångpannor*. Stockholm: I. Marcus [boiler inspection in Sweden].

[120] Italy. Ispettorato Generale dell' Industria e del Commercio. 1911. *Caldaie e recipienti a vapore sottoposti alla sorveglianza del Ministero di agricoltura*. Roma: Tip. nazionale di G. Bertero e. c.

[121] Manitoba. Bureau of Labor. 1918. *Canadian inter-provincial regulations for the construction and inspection of steam boilers, tanks and appurtenances*. Winnipeg.

[122] Bosnia and Herzegovina. 1897. *Verordnungen betreffend die erprobung, periodische untersuchung und construction etc. der dampfkessel, sowie die bestellung der prüfungs-commissäre*. Sarajevo: Landesdruckerei.

[123] Egypt. Wiz'arat al-Ashgh'al al-'Um'um'iyah. 1910. *Législation relative aux machines à vapeur*. Le Caire: Impr. nationale.

[124] Bulgaria. Ministerstvo na turgovi iata promishlenostta i truda. 1920. *Zakonopolozheni ia za kontrola na parnit i e kotli* [boiler inspection law].

[125] Burma and India. 1924. *The Burma boiler manual, containing the Indian boilers act, 1923; the Indian boiler regulations, 1924, together with notifications and rules thereunder*. Rangoon: Supdt Govt. Printing and Stationery, Burma.

[126] Hawaiian Sugar Planters' Association. Bureau of Boiler Inspection. 1928. *Annual report of the Bureau of Boiler Inspection*. Honolulu: Honululu star-bulletin.

[127] México. 1929. *Decreto que modifica el reglamento de inspección de calderas de vapor*. México.

[128] Sinev, Petr Ivanovich. 1929. *Voprosy tekhniki bezopasnotsi kotel nogo khoz i a istva* [boiler inspection in Russia].

[129] Costa Rica. 1956. *Reglamento de calderas*. San José: Ministerio de Trabajo y Previsión Social.

[130] United Nations. Economic Commission for Asia and the Far East. Sub-Committee on Energy Resources and Electric Power. 1971. *Boiler codes in the ECAFE region: suggested guidelines for the operation, care and inspection of boilers*, *Energy resources development series no. 10*. New York: United Nations.

[131] Haight, F. A. 1980. "Traffic safety in developing countries," *Journal of Safety Research* 12:50-58.

[132] Newlin, Gurney Elwood. 1926. *Uniform motor vehicle code, including Uniform motor vehicle registration act, Uniform motor vehicle certificate of title and anti-theft act, Uniform motor vehicle operator's and chauffeur's license act, and Uniform act regulating the operation of vehicles on highways*. American Bar Association.

[133] Blomquist, Glenn C. 1988. *The regulation of motor vehicle and traffic safety*. Boston: Kluwer Academic Publishers.

[134] Ribicoff, Abraham A. 1966. "Traffic safety," *Vital Speeches of the Day* 33:104-106.

[135] Peltzman, S. 1975. "The effects of automobile safety regulation," *Journal of Political Economy* 83 (4):677-725.

[136] United States. National Highway Traffic Safety Administration. *Traffic safety facts 2005* [PDF format]. National Center for Statistics & Analysis 2006 [Accessed on 28 Dec 2006. Available from http://purl.access.gpo.gov/GPO/LPS28877.

[137] Whitelaw, John L. 1962. *A selected bibliography, highway traffic safety with annotations (1956-1960)*. Washington: Division of Accident Prevention Public Health Service U.S. Dept. of Health Education and Welfare.

[138] Jacobs, G. B., and I. Sayer. 1983. "Road accidents in developing countries," *Accident Analysis and Prevention* 15:337-353.

[139] Haight, F. A. 1980. “Traffic safety in developing countries,” *Journal of Safety Research*12:50-58.

[140] Ofosu, J. B., A. M. Abouammoh, and A. Bener. 1988. “A study of road traffic accidents in Saudi Arabia,” *Accident Analysis and Prevention* 20:95-101.

[141] WHO, *Injury chart book,* 2002.

[142] Harrison, H. 1954. “Firemaking, fuel and lighting,” in *A history of technology*, edited by C. J. Singer, R. Raper. Oxford: Clarendon Press: 231.

[143] Perrow, Charles. 1984. *Normal accidents: living with high-risk technologies*. New York: Basic Books.

[144] Bache, William. *An inaugural experimental dissertation; being an endeavor to ascertain the morbid effects of carbonic acid gas, or fixed air, on healthy animals, and the manner in which they are produced …, 19th day of May, 1794; for the degree of Doctor of Medicine*, Early American imprints. First series no. 26598. Philadelphia: Printed by T. Dobson at the stone house no. 41 South Second-Street, 1794.

[145] C [author not further identified]. "Remarks on the combustion of charcoal in close rooms, and its deleterious effects." *Journal of the Franklin Institute* XXV, no. 4 (1840): 217-19.

[146] “Poisoning by charcoal fumes.” 1871. *Harper's New Monthly Magazine* 43 (256):627.

[147] Downing, A. J. “The favorite poison of America,” 1869. *Rural essays*. New York: G.A. Leavitt, originally published 1850.

[148] Penney, David G. 1996. *Carbon monoxide*. Boca Raton: CRC Press.

[149] Jones, G. W., L. B. Berger, and W. F. Holbrook. 1923. “Carbon Monoxide Hazards from House Heaters Burning Natural Gas,” in *Technical Paper 337*. Washington DC: U. S. Department of the Interior. Bureau of Mines.

[150] Roth, Jack. “Gas fumes kill 10 in a 3-room flat; owner is blamed,” *New York Times,* 8 November 1954: 1.

[151] Ledingham, Iain McAllan, and Henri Bour. 1967. *Carbon monoxide poisoning*, *Progress in brain research v. 24*. Amsterdam and New York: Elsevier Pub. Co.

[152] United Nations Environment Programme and World Health Organization. 1979. *Carbon monoxide*, *Environmental health criteria 13*. Geneva: World Health Organization.

[153] De Fre, R., P. Bruynseraede, and J. G. Kretzschmar. 1994. “Air pollution measurements in traffic tunnels,” *Environ Health Perspect* 102 Suppl 4:31-7.

[154] Desai, Manish A., Sumi Mehta, and Kirk R. Smith. 2004. *Indoor smoke from solid fuels: assessing the environmental burden of disease at national and local levels*, *Environmental burden of disease series, no. 4*. Geneva, Switzerland: Protection of the Human Environment, World Health Organization.

[155] *Aircraft sessions; First National Aeronautical Safety Conference*. 1928. Chicago: National Safety Council.

[156] Lederer, Jerome. James Jackson Cabot professorship of air traffic regulation and air transportation. 1939. *Safety in the operation of air transportation*. Northfield, Vt.: Norwich University.

[157] Whitnah, Donald Robert. 1967. *Safer skyways; Federal control of aviation, 1926-1966*. Ames: Iowa State University Press.

[158] Komons, Nick A. 1984. *The Cutting air crash: a case study in early federal aviation policy*. 2nd ed. Washington: Federal Aviation Administration.

[159] Komons, Nick A., and United States. Federal Aviation Administration. 1978. *Bonfires to beacons: federal civil aviation policy under the Air Commerce Act 1926-1938*. Washington: U.S. Dept. of Transportation Federal Aviation Administration.

[160] Bilstein, Roger E. 1994. *Flight in America: from the Wrights to the astronauts*. Rev. ed. Baltimore: Johns Hopkins University Press.

[161] Pisano, Domenick. 1991/1992. “The crash that killed Knute Rockne,” *Air & Space* 6 (5):88-93.

[162] Aviation Safety Network and Harro Ranter. 2003. *Airliner accident statistics 2002: statistical summary of fatal multi-engine airliner accidents in 2002*, available at http://aviation-safety.net/, accessed 1 January 2007.

[163] Aviation Safety Network and Harro Ranter. 2006. *Airliner accident statistics 2005: statistical summary of fatal multi-engine airliner accidents in 2005*, available at http://aviation-safety.net/, accessed 26 Dec 2006.

[164] Lopez, Alan D. 2006. *Global burden of disease and risk factors*. New York, NY and Washington, DC: Oxford University Press and World Bank.

[165] United States**.** *Bulletin of the United States Bureau of Labor Statistics***,** 1913.

[166] Ehrenhalt, Samuel M. *Zeroing in on the who's, why's and where's of work injuries and fatalities : new tools for improving worker safety*. New York: New York State Dept. of Labor, 1995.

[167] Alvarez, Eduardo, and Jaime A. Moncada. "Tragic fire in Paraguay." *NFPA Journal* (2004): 24.

[168] Aviation Safety Network and Harro Ranter. 2003. *Airliner accident statistics 2002: statistical summary of fatal multi-engine airliner accidents in 2002*, available at http://aviation-safety.net/, accessed 1 January 2007.

[169] Aviation Safety Network and Harro Ranter. 2006. *Airliner accident statistics 2005: statistical summary of fatal multi-engine airliner accidents in 2005*, available at http://aviation-safety.net/, accessed 26 Dec 2006.

[170] World Bank. 2005. *Dying too young: addressing premature mortality and ill health due to non-communicable diseases and injuries in the Russian Federation*. Washington DC: World Bank 2005, available from http://siteresources.worldbank.org/INTECA/Resources/DTY-Final.pdf, accessed 10 March 2010.

[171] Hemenway, David. *While we were sleeping: success stories in injury and violence prevention*. Berkeley: University of California Press, 2009.