

Concerns Regarding One-Person Crewing (OPC) of Trains and Engines¹

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GAMST, Frederick C. (University of Massachusetts, Boston; fcgamst@aol.com)²

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Federal regulations have long protected American public health and safety regarding railroad operations. In the United States, for any rail operations involving one-person traincrews or remote control of a locomotive by a body-mounted radio transmitter, used separately or together, FRA investigation and rulemaking are needed for their regulation.³ As an aid to such FRA tasks, this paper discusses some of the safety issues regarding one-person crewing (OPC) of trains. Also as such aid, a complementary paper discusses some of the safety issues regarding the operation of a Remote Control Locomotive (RCL) (Gamst 2001).

OPC (when no other operating personnel are in the crew) of a train or engine has a range of variation, including the following: (A) an engineer in the cab (control compartment) of a locomotive with or without trailing rolling equipment; (B) as in Canada, a groundperson (i.e., switchman, brakeman, or conductor) qualified as an operator to switch railcars with an RCL via radio signals from a body-mounted, remote-control device (RCD); and (C) as on Deutsche Bahn, a Rangierlokf hrer (yard locomotive engineer) qualified to be on the ground to switch railcars with an RCL via radio signals from an RCD. OPC sometimes involves the use of a utility operating person, who temporarily appears on the scene when needed.⁴

Comparing two-person crewing in the U.S. with one-person crewing in overseas countries is ordinarily a comparison not of kinds of apples with apples but of avocados with ostrich eggs. For example, when I thought that the Wisconsin Central in its 1996 advocacy of one-person crewing in the US would bring in testimony from its Tranz Rail, New Zealand affiliate, I prepared in addition to "Human and Operational Factors in the Use of One-Person Train Crews" (Gamst 1996b), another report, "Railroad Operations in New Zealand Compared to Those in the United States (Gamst 1996a). In this New Zealand report, I noted regarding the toy trains there contrasted with the behemoths of the US: "In all, the dynamic New Zealanders have a diminutive railroad, usually running light, tiny trains with small cars. There is, in all reality, virtually nothing to compare between the rolling equipment and operations of the two nation's railroads, only everything to contrast" (Gamst 1996a:3)

To save time, some matters also applicable to the companion paper of the present one (FCG-TRB-01-2, Concerns Regarding Remote-Control Locomotive [RCL] Operations) will be presented only in the present paper. This paper reasons that a minimum traincrew of two persons, a locomotive engineer and a groundperson (ordinarily a conductor), is necessary for operational safety on American railroads.

1. The Ever-Present Potential for Catastrophe on America's Railroads.

1.1. The Nature of Rail Catastrophe:

- That the railroad industry is defined by potentially catastrophic operations for which safety is essential has long been without question.

America's railroad industry constitutes a widespread, potentially catastrophic worksite, with respect to its movement of trains and engines and the handling of rail cars (Adams 1879; Shaw 1978; Savage 1998). Regarding the harmful results of railroad catastrophe, the U.S. General Accounting office reports, "thousands of people are evacuated from their homes as a result of the hazardous materials that are released during train accidents" (GAO 1997:3). Between 1978 and 1995, about 261,000 persons were evacuated from their homes, nationwide, because of releases of rail-related hazardous materials. "Concerns remain about evacuations because the volume of chemical traffic increased by over one-third from 1976 to 1995," the GAO concludes (GAO 1997:4, 36).

As former *Railway Age* editor John Armstrong writes regarding the issue of safety on railroads: "there's always a 'knock on wood' realization that a combination of events and circumstances can lead to a wreck of proportions sufficient to tarnish the best of records" (1982:32).

The linear railroad worksite in America branches for 170,000 miles across forty-nine states, and pierces through the heart of most communities of any size. This railed worksite has freight trains, often with hazardous loads, moving through America's hometowns, urban neighborhoods, and ecologically sensitive environments.

1.2. The Crew Mitigating the Rail Catastrophe:

The potentially catastrophic work on railroads is directly performed by operating railroaders, who crew trains and engines. Such railroad employees include locomotive engineers, conductors, brakemen, and switchmen, who, when comprising a single crew, will collectively be called crewmembers in this presentation.

Work by these crewmembers is safety critical and involves mental and manual responsibilities and tasks for the mastering and safeguarding of movements of rolling equipment on track. The movements, although indeed potentially catastrophic, are only rarely disastrous because of these crewmembers' proper performing of tasks and fulfilling of responsibilities on the job. At its core, such safety-critical performing and fulfilling is *coordinated*, that is, functioning interdependently and harmoniously regarding members of a crew.

Preventing unacceptable catastrophic risk, this performance and fulfillment has long included the coordinated activities of an, at minimum, two-person train crew or yard crew. The minimum two-person crew must continue for maintenance and enhancement of railroad operating safety, thereby protecting the public health and safety.

A brief overview of the cognitive and motor tasks of the two-person crew in the high-risk railroad industry is as follows. The locomotive engineer performs exacting, rule-bound worktasks and has intricate skills of a kind not extant for any other kind of railroad employee. As the engineer's teammate, among other responsibilities, the conductor performs flag protection, switching of cars (sometimes in chess-like moves), manual and visual safety inspections of his train, and back-up safety monitoring of the engineer. Regarding the cumulative affect of the many tasks and responsibilities in a conductor's work, Mark Sanders concludes, "the total difficulty of the job is greater than the average difficulty of the individual tasks" (1974:186). The engineer must be vigilant while making changing judgments regarding the constantly altering information from both his train and its status indicators and additionally from both the physical and the operating environments through which he pilots his movement. The conductor must also be vigilant in making judgments regarding the ever-changing information from both the physical and the operating environment in which he supervises his train's "operation and administration" and its employees.

"Work for [railroaders] requires a keen sense of responsibility and a marked capacity for error-free, logical thinking not found for workers in most other industries" (Gamst 1990:6). Railroad operations will always involve decisions to cope with dangerous situations that cannot be reasonably anticipated in advance. Often the crewmembers' decision making, "is logically deductive where they reason, from a known general principle, to a specific conclusion: 'Given that we must either have authority or protection to occupy the main track with these cars and the former expires five minutes from now, you'd better start walking down the line to provide the latter'" (Gamst 1990:6). Such decision making is most safely done by a minimum team of two cross-monitoring crewmembers.

James Beniger notes that, for safety, because railroad officers could not directly monitor a mobile traincrew they placed a conductor on each train, to control its movement and employees. Beniger says conductors "are possibly the first persons in history to be used as programmable, distribution decision makers in the control of fast-moving flows through a system where scale and speeds precluded control by more centralized structures" (1986:228). Since the late 1830s, the railroad operating rules place the conductor in command of a train, with the conductor and engineer jointly/equally responsible for safety, that is, they cross-monitor one another for freedom from operational hazard.

In North American railroading, then, cross-monitoring in train operations has always been done by a conductor-engineer team, and for good safety reason. Today, the conductor remains empowered by the operating rules, on almost all railroads, to have, "All persons employed on the train ... obey [his/her] instructions." But, "If any doubts arise concerning the authority for proceeding or safety, the conductor must consult with the engineer who will be equally responsible for the safety and proper handling of the train" (Rule 1.47.A.1, GCOR 2000:1-11). Thus the necessity of the coordinated responsibility for safety by a crew of an engineer and a conductor is recognized in a code distilled from 170 years of operating experience on innumerable railroads.

For compelling safety reasons, developed across more than a century and a half, GCOR's Rule 6.10 directs the coordinated crewmembers as follows: "The conductor must remind the engineer that the train is approaching an area restricted by: • Limits of authority/ • Track warrant or/ • Track bulletin. . . . If the engineer fails to comply with the restriction, the conductor must stop the train" (GCOR 2000:6-4). The coordinated safety responsibility of the conductor and engineer does not necessitate that the conductor always ride in the engine's control compartment,

which is a control center and office (1975a, 1975b)). For example, the conductor ordinarily cannot do so on a passenger train and might not do so on the rare freight train having a caboose. But Rule 1.30 directs: "When riding on the head end, the conductor will ride in the control compartment" (GCOR 2000:1-7). This rule affirms, however, the safety prudence of the conductor crewmember reinforcing the vigilance of the engineer as much as practicable. To downsize this team-based reinforcement is to downsize operational safety.

By reinforcing the operational vigilance of each other, as a team the engineer and conductor protect from personal danger: the self, any other personnel on the train or engine, personnel on other trains, engines, and other on-track equipment, other railroad employees along the track, persons on passenger trains, and the public along the right-of-way. Also, the engineer and conductor protect from property damage: the engine and its cars; the lading of these cars; other engines and cars; railroad structures such as track, wayside signaling, buildings, bridges, and tunnels; and nonrailroad property along the right-of-way. In the few times when the coordinated vigilance of operating crewmembers was not maintained, the result has made the headlines (Gamst 1975b:43-44).

Given the ever-present potential for railroad catastrophes, we need to know that eliminating the second member of the conductor-engineer team does not engender unacceptable safety risks to all of the just-enumerated kinds of persons and property.

2. Safety, All-Important in Railroad Operations.

Railroad operating work involves the highly coordinated movement of trains and engines including the switching of rolling equipment. Moreover the work uses heavy machinery, is outdoors, sometimes in inclement weather, often in difficult isolated territory far from medical and other help. This work is by its nature exceedingly mobile, extremely dispersed geographically, and not capable of direct managerial supervision. The safety criticality of this work has always been a truism, continuing into the present (Adams 1879).⁵

- Safety limits on the individual behavior of not-directly supervised crewmembers must be insured. Such limits are best insured by the cross-monitoring afforded by the conductor-engineer team in the application of the myriad operating and other rules.

The safety-critical nature of the highly responsible operating work is explained by former *Railway Age* editor John Armstrong: "Perhaps the single most important fact affecting the railroad organization, particularly in the transportation department, is that *most of its employees must carry out their work away from their supervisor*; yet the railroad is a system whose parts must all work together in precise timing." (1998:279). "This high level of individual responsibility has made railroading a proud profession, and it has also meant that the limits of individual initiative in carrying out tasks must be established by written rules," concludes Armstrong (1998:279).

By the turn of the nineteenth century, it was recognized by specialists on railroad operations that essential to safety was a thorough knowledge and practice by involved employees of the multi-function operating rules (Forman 1904:5; Dalby 1904:9; Jacobs 1939; Gamst 1980, 1983, 1986, 1989). Peter Josseland, a more recent such specialist, encapsulates operational safety succinctly when he says, "There is no industry where little mistakes can have such far-reaching and disastrous results" (1957:ix). A major work on railroad safety of the 1960s by the Railroad Retirement Board concludes: "An error in a[n] . . . order or a misunderstanding of an operating rule can result in a costly delay, but it can also result in a costly collision" (USRRB 1962:2-57). The safety pressures of railroad work are often time sensitive, adding another dimension to the ordinary concerns of industrial safety (Gamst 1993).

- The skills of the interacting members of an operating crew are, without question, extraordinarily safety-critical.

With growing federal involvement in railroad operating safety, during the 1970s, researchers increasingly reported upon the great responsibilities, complexity, and safety criticality of railroad worktasks and their governing rules. For example, a major research project on the locomotive cab concluded: "that the role of the train crew in freight operations may be characterized as complex and entailing a high level of responsibility" (Robinson, Piccione, and Lamers 1976:7-8). Another study, analyzing the work of the locomotive engineer, found: "Concerning safety of operations, these [data] reveal that approximately 65% of these tasks, if improperly performed, may lead to potentially hazardous situations" (McDonnell Douglas 1972:14). Speaking of the locomotive engineer's cognitive and motor skills in train handling and in general operations, researchers of railroading A. Hale and H. H. Jacobs say: "Fundamentally, the engineer is a sophisticated information processor and controller of a very complex, and often difficult to maintain, man-machine system" (1975:11).

- In an operating situation, as compared to a one-person crew, having a two-person crew assures more accurate choices of and informed reaction to the safety-critical rules.

A train crewmember's judgment is used in selection of the rule principles that apply in a particular operating situation. As operating-rule specialist C. S. Matthews explains: "It is not practical to give in a book of rules detailed information of train operation, because to go into detail would make it necessary to cover every condition; otherwise anything omitted from the detailed explanation would not be considered as provided for. It is for this reason that the rules state a principle of operation. . ." (1943, 1:2-3).

Reaction to the railroad operating rules, then, involves more than assessing a *single* safety-critical principle for a particular operating situation. Most operating rules are written for an at-the-moment-of-situation assessing of the appropriateness and *range of interrelations* of their applications. Such assessment must be constantly altered as the operating conditions change. That several of the many interrelated rules must be, first, selected to form what could be called a rule set and, then, applied to an operating situation is without question. The late "dean" of operating rules and practices, Peter Josserand, explains, a railroader cannot understand or apply rules in isolation or out of context from other rules in the code of operating rules. For every railroad, "each set of rules has one thing in common: THEY DOVETAIL SO AS TO PROVIDE FOR A SAFE OPERATION" (Josserand 1957:81). Thus operating rules are, in a word, systemic. Accordingly, "choices involving virtually any of the operating rules and regulations in differing combinations are the basis for safety-critical action and reaction by employees" (Gamst 1990:15). A traincrew makes choices about which of the several rules should or should not be used and in what sequence they should be initiated.

- Informed embodiment of the operating rules among not-directly supervised crewmembers is best reinforced by the cross-monitoring afforded by the conductor-engineer team.

The Railroad Accident Reports of the National Transportation Safety Board show again and again that, for railroading, a thorough knowledge of the operating rules and their informed embodiment in work practices is absolutely necessary (e.g., NTSB 1973, 1976, 1978, 1988, 1990, 1995, and 1999).

3. Do America's Railroads Have Too Few Employees for Safety?

Since deregulation in 1980, and exposure to the unbridled force of the market, the U.S. Class-I railroads have reduced employment by about 60 percent and increased productivity of employees, as measured in freight ton-miles, by nearly 300 percent.

- A question: Is the further reduction of the train crew from two to one member a reduction too far in the interest of safety? (In 1985, the freight train crew had five or six members.)

Given the safety-critical nature of railroaders' work and the greatly diminished numbers of railroaders handling ever-increasing amounts of traffic a question arises. Are there too few railroad employees for the challenges and maintenance of operations in this new millennium? Several specialists in railroad operations and its labor relations, who are not connected to organized labor, think so. They say that the railroads may be cutting back too much on the number of their employees. Under the heading "Have railroad people been stretched too far?" rail pundit Don Phillips asks, In this downsizing era, are there enough experienced managers in the field, car-knockers, signal maintainers, do dispatchers cover too much territory, and are there enough train crews to protect the service yet get enough rest? Phillips concludes: "Railroads clearly are trying to squeeze more and more from their people. . . . But is railroading approaching the point that it'll go too far? Has it already gone too far?" (1996:19-20). In an article titled "Re-engineering' may need rethinking," the late, esteemed *Railway Age* editor Gus Welty asks if the re-engineering and downsizing on railroads have gone beyond cutting out the employee fat to removing large amounts of muscle and bone. The veteran railroad pundit answered his question with, "I suspect so. . ." (1996:12).

Regarding further employment reductions on railroads the FRA says: "the low-hanging fruit is largely gone. Managers and employees are increasingly asked to do more with less, a process that has outside limits" (FRA 2000:12). The impossibility rests in the outside practical and safety limitations on further reductions in forces for the railroads, necessarily operating in an environment open to the public and beset with the common mishaps of the intricately intertwined myriad of operational circumstances.

4. Safety for Any Solo Crewperson.

Rail management's financial need to reduce its number of employees economically⁶ compels operations with a one-person train or engine crew. Safety needs should be paramount, however. What are some of the safety issues regarding the one-person crew?

- With one-person operation in the remote areas frequently traversed by freight trains, the solo engineer could have a sudden incapacitating illness or injury, and no other person might know of such a personally dangerous situation for a life-critical time.
- If the one-person crewmember falls or is hit by or runs into equipment and becomes incapacitated, how is his safety insured and in what life-critical time frame?
- A matter of personal safety exists for one-person operation in the sometimes dangerous urban areas traversed by freight trains and engines; the solo engineer could be attacked by thugs while on the ground, and no other human might know of such a personally dangerous situation for a life-critical time.
- If the critical time frame designated by the railroad for sending of help is, say, 30 minutes or 60 minutes during which no communication had been received from the one-person crewmember, how does such duration insure arrival of help in time for personal safety? If the one-person crewmember is in a remote rural area requiring some time to reach, how is this location-specific variable factored into the response time? The second crewmember would be "right there on the spot."
- To whom would the *continuous alertness* and wellbeing of the one-person crewmember be communicated, and by what infallible means? Will this person be a train dispatcher already heavily occupied with time-sensitive tasks?
- While considering the personal safety of the one-person crewmember, another person's safety should be mentioned, that of the motorist or pedestrian hit, for whatever reason in whatever location, by a rail movement. It is often the experienced ground person such as a conductor who renders immediate assistance to the injured, while the engineer in the cab radios for medical personnel and other help. (Over 90 percent of the approximately 1000 deaths per year involving railroads are to trespassers, nontrespassers, and persons using highway grade crossings.)
- Tying down sufficient hand brakes on cars left on a gradient or on trains disabled or with a temporarily depleted trainline poses a problem of physical exertion for a one-person train crew. Will the singleton actually climb the ladder of all the cars in the train, tie down hand brakes, and apply any required retainers? Or will an effort saving short cut be taken?

5. Train Length and Walking Extensive Distances.

For one-person operation, current U.S. freight train lengths of a half-mile are too long and of a one-mile far too long for management of the risks inherent in railroading. Many trains are in excess of one mile in length.

- As a report of the American Association of Railroad Superintendents on one-person operation reasoned: "Consist length is another issue that we brought up. As the gentleman from New Zealand said, their trains are quite a bit shorter than ours in general. We needed to look at maybe getting our trains shorter" (Stoffer 1996:63).
- In making set outs, pick ups, mandatory inspections (as with UDEs and the tripping of wayside detectors), and replacing broken knuckles and burst air hoses, with a long train, extensive walking would be required by the single crewmember.

6. Notes on the Culture of Safety Encompassing "Accidents" in Railroad Operations.

Buried primordially deep in the culture history of our ideas about human safety and "accidents" is a bias against attempting to find root causes of such events. It is much less arduous, time consuming, mentally taxing, and costly to a business firm to facilely blame an "accident" on the single employee. The very word *accident*, the shorthand label for these ideas in our culture, is fraught with semantic ambiguity and excuse making, despite its nearly universal use in the literature on work safety, including in transportation. (The Latin root of the word is *accidere*, that is, "to fall upon," as a tree branch falling by chance upon one's head when one walks in a grove.)

As the etymology of the word informs, the first denotation of *accident* in common American discourse means "a happening not expected, foreseen, or intended," in short, a "fortuitous" event. Accidents, however, cannot be summarily dismissed as *fortuitous*, or having a complete absence of cause. Accidents are not *adventitious*, that is, something added extrinsically to an event and connotating no essential connection to it. Were accidents fortuitous, we would be at the mercy of a mindless, supernaturalistic fatalism, devoid of our empirical reflection or correction. In short, we would be back in the Upper Paleolithic painting shamanistic pictures on cave walls. Instead, we must realize that an intricately interwoven web of events underlies a final accident event/consequence. The best way to deal with such a web is by operating crews, of at least two persons, maintaining their customary judgments and skills from experience reinforced on the job.

Work accidents, beyond being nonfortuitous, may usefully be viewed as errors systematically produced during the work process. Moreover, work accidents are business problems evading the control of managers and the direction of any involved government regulators. Spectacular examples include Three Mile Island, Chernobyl, Bhopal, and the CN's Hinton, Alberta head-on collision of passenger and freight trains. It was not an alleged "accident" when, in 1992, the USS Saratoga fired two Sea Sparrow missiles at a Turkish destroyer during joint exercises (Gellman 1992). Management and government should opt to control problems by having operating crews of sufficient size maintain their customary judgments and skills from experience reinforced on the job.

For safe and efficient operations, the potentially catastrophic railroading requires the ability of its train crewmembers continuously to relearn, understand, manipulate, and correctly apply, in ever-varying combinations, directives from a complex code of rules to constantly changing events. These crewmembers must carry out their day-to-day, safety-critical tasks with a full understanding and a comprehension-reinforcing use of appropriate sets of interrelated rules. Such understanding and use is vitally important for maintaining safety on the rails. The minimum crewmember team of engineer plus conductor on every train insures a continuation of the highest degree of operational safety in American railroading. Maintaining the experience-based judgment and skills of this team assures an added level of safety in railroad operations.

Regarding public health and safety, a safety-critical need exists to maintain human abilities for judgments and skills in railroad operations and not to permit a total reliance on computer hardware and software. Computer algorithms must not become the sole solution to the quest for rail safety. At the time of a potentially catastrophic rail event, it is too late for the learning or reinforcement of safety-related knowledge.

Operating crewmembers must be kept informed by in-cab or on-RDC monitors and indicators of the changing critical operating statuses of the systems on their train and in the wayside operating environment. A supplier saying that computer programs will take care of such monitoring creates an opening in a closed system of operational safety. An engineer or RDC operator must remain informed of all the interrelated critical events for movement authority, running an engine, and train handling.

7. References Cited.

- Adams, Charles Francis
1879 *Notes on Railway Accidents*. New York. G. P. Putnam's Sons.
- Armstrong, John
1982 "Why Are Some Railroads Safer Than Others?" *Railway Age* 11 Jan.:32-39.

1998 *The Railroad--What It Is and What It Does: The Introduction to Railroading*, 4th ed. Omaha, NE: Simmons-Boardman.
- Beniger, James
1986 *The Control Revolution: Technological and Economic Origins of the Information Society*. Cambridge, MA: Harvard University Press.
- Dalby, Harry A.
1904 *Train Rules and Train Dispatching*. New York: Derry-Collard.
- DOA (Department of the Army)
1968 *Railway Train Operations*. TM 55-206, through Change No. 4, 1972.
- Dwyer, Tom
1991 *Life and Death at Work: Industrial Accidents as a Case of Socially Produced Error*. New York: Plenum.

- Forman, Harry W.
1904 *Rights of Trains on Single Track*. New York: Railroad Gazette.
- FRA
2000 PTC [Positive Train Control] STANDARDS TASK FORCE NRPM DRAFT #7 - June 7, - Clean Copy.
- Gamst, Frederick C.
1975a "Human Factors Analysis of the Diesel-Electric Locomotive Cab," *Human Factors* (special issue on "Human Factors in Civil Systems." D. H. Harris, ed.) 17:149-156.

1975b "The Diesel-Electric Locomotive as a Work Environment: A Study in Applied Anthropology." *Studies in Cultural Anthropology*, Rice University Studies 61(2):37-78.

1980 *The Hoghead: An Industrial Ethnology of the Locomotive Engineer*. New York: Holt, Rinehart and Winston.

1983 "The Development of Operating Rules." *Proceedings of the Railway Fuel and Operating Officers Association*, 1982 46:155-171.

1986 "The Development of Railroad Discipline." *Proceedings of the Railway Fuel and Operating Officers Association*, 1985 49:85-98.

1989 "The Railroad Apprentice and the 'Rules': Historic Roots and Contemporary Practices." In *Apprenticeship: From Theory to Method and Back Again*, Michael W. Coy, ed. Pp. 65-86, 258-9, 274-7.

1990 *Highballing with Flimsies: Working under Train Orders*. Crete, NE: J. B. Publishing Co.

1993 "'On Time' and the Railroader: Temporal Dimensions of Work." In *Ethnologie der Arbeitswelt: Beispiele aus europäischen und außereuropäischen Feldern*. Sabine Helmers, ed. Pp. 105-131. Bonn: Holos Verlag.

1996a Railroad Operations in New Zealand Compared to Those in the United States. Research Memorandum No. FCG-U-96-1.

1996b Human and Operational Factors in the Use of One-Person Train Crews. Report No. FCG-UTU-96-2.

2001 "Concerns Regarding Remote-Control Locomotive (RCL) Operations," Paper FCG-TRB-01-2.
- Garner, Steve
1991 *Human Factors*. New York: Oxford University Press.
- GCOR
2000 *General Code of Operating Rules*, 4th edition, effective April 4, 2000], Adopted by the railroads listed therein].
- Gellman, Barton
1992 "Saratoga Missile Firing Seen as Accident," *Washington Post* Dec. 2, 1992:1.
- Hale, A., and H. H. Jacobs
1975 Proposed Qualification Requirements for Selected Railroad Jobs. Report No. FRA/OR&D-75/44. Washington, DC: DOT, FRA, Office of Research and Development.
- Jacobs, Warren
1939 "Early Rules and the Standard Code," *Railway and Locomotive Historical Society Bulletin* No. 50:29-55.
- Josserand, Peter
1957 *The Rights of Trains*, 5th ed. New York: Simmons-Boardman.
- Kroemer, K. H. E.
1997 *Engineering Physiology: Bases of Human Factors*, Ergonomics, 3d ed. New York: Van Nostrand Reinhold.
- McDonnell Douglas Corporation
1972 Railroad Enginemen Task and Skill Study. Report No. FRA-OPP-73-2. Washington, DC: DOT, FRA.
- Carl D. Martland,
1999 "Productivity and Prices in the U.S. Rail Industry: Experience from 1965 to 1995 and Prospects for the Future," *Journal of the Transportation Research Forum* 38, no. 1:12-25.

- Matthews, C. S.
1943 *Train Rules*, parts 1 and 2. Scranton, PA: International Textbook Co.
- Meister, David
1971 *Human Factors: Theory and Practice*. New York: Wiley.
- Murrell, K. F. H.
1979 *Ergonomics: Man in His Working Environment*. London; Chapman and Hall.
- NTSB (National Transportation Safety Board)
1973 Texas and Pacific Work Extra 523/Missouri Pacific Extra 1902 East, Head-on Collision, Taft, Louisiana, February 21, 1973. Report No. NTSB-RAR-73-6.

1976 Penn Central Transportation Company, Train Collisions, Leetonia, Ohio, June 6, 1975. Report No. NTSB-RAR-75-2.

1978 Rear-end Collision of Two Conrail Freight Trains, Stemmers Run, Baltimore, Maryland, June 12, 1977. Report No. NTSB-RAR-78-1.

1988 Rear-end Collision of Amtrak Passenger Train 94, The Colonial and Consolidated Rail Corporation Freight Train ENS-121, on the Northeast Corridor, Chase, Maryland, January 4, 1987. Report No. NTSB-RAR-88/01.

1990 Derailment of Southern Pacific Transportation Company Freight Train on May 12, 1989 and Subsequent Rupture of Calnev Petroleum Pipeline on May 25, 1989, San Bernardino, California. Report No. NTSB/RAR-90/02.

1995 Rear-end Collision of Atchison, Topeka and Santa Fe Railway Freight Train PBHLA1-10, and Union Pacific Railroad Freight Train CUWLA-10, near Cajon, California, December 14, 1994. Report No. NTSB-RAR-95/04.

1999 Collision of Norfolk Southern Corporation Train 255L3 with Consolidated Rail Corporation train TV 220, Butler, Indiana, March 25, 1998. Report No. NTSB-RAR-99/02.
- Osborne, David J.
1994 *Ergonomics at Work: Human Factors in Design and Development*, 3d ed. Chichester: Wiley.

1995 *Ergonomics and Human Factors*. Aldershot: Elgar.
- Perrow, Charles
1983 "The Organizational Context of Human Factors Engineering." *Administrative Science Quarterly* 28:521-541.

1999 *Normal Accidents: Living with High Risk Technologies*. Princeton: Princeton University Press.
- Phillips, Don
1996 "Have Railroad People Been Stretched Too Far?" *Trains* May:19-20.
- Reasons, C. L. Ross, and C. Paterson
1981 *Assault on the Worker: Occupational Safety and Health in Canada*. Toronto: Butterworths.
- Roberts, K. H., and D. M. Rousseau
1990 "Research in Nearly Error-Free, High Reliability Organizations: Having the Bubble." *IEEE Transactions* 36:132-139.
- Roberts, K. H., and K. Weick
1993 "Group Mind: Heedful Interaction on Aircraft Carrier Flight Decks." *Administrative Science Quarterly* 38.
- Robinson, J., D. Piccone, and G. Lamers
1976 Locomotive Cab Design Development, vol. 1: Analysis of Locomotive Cab Environment & Development of Cab Design Alternatives. Report No. FRA/OR&D-76/275.1. Washington, DC: DOT, FRA, Office of Research and Development.
- Salvendy, Gavriel
1997 *Handbook of Human Factors and Ergonomics*, 2d ed. New York: Wiley.
- Sanders, Mark
1974 Task Analysis for the Jobs of Train Conductor and Brakeman. Report No. RDTR 263. Crane, IN: Applied Sciences Department, Naval Ammunition Depot.
- Savage Ian

- 1998 *The Economics of Railroad Safety*, Boston: Kluwer.
- Shaw, Robert B.
1978 *A History of Railroad Accidents, Safety Precautions, and Operating Practices*. Binghamton, NY: Vail-Ballou Press.
- Singleton, W. T.
1972 *Introduction to Ergonomics*. Geneva: World Health Organization.
- Stoffer, John
1996 "Summary of Workshop No. 1 [on one-person operations]." *Proceedings of the American Association of Railroad Superintendents*, 1995 99:60-64.
- USGAO (U.S. General Accounting Office)
1997 "Federal Railroad Administration's New Approach to Railroad Safety." Report No. GAO/RCED-97-142.
- USRRB (U.S. Railroad Retirement Board)
1962 *Safety in the Railroad Industry*. Chicago: RRB, Division of Safety.
- Viscusi, W. Kip
1992 *Fatal Tradeoffs: Public and Private Responsibilities for Risk*. New York: Oxford University Press.
- Welty, Gus
1996 "'Re-Engineering' May Need Rethinking," *Railway Age* August:12.
- Westrum, Ron
1997 "Social Factors in Safety-Critical Systems." In *Human Factors in Safety-Critical Systems*. F. Redmill and J. Rajan, eds. Pp. 233-256. London: Butterworth-Heinemann.
- Woodson, Wesley E., Barry Tillman, and Peggy Tillman
1992 *Human Factors Design Handbook*, 2d ed. New York: McGraw-Hill.

¹ The advocacy of this presentation is from the perspective of human- and social-factors study and experience with the railroad industry, across the past 45 years and around the world. By *human factors* (ergonomics) is meant study of human-device and human-human interactions in a work environment including related processes of performing work. The interdiscipline of human factors focuses on the design of machines and other devices, work processes, and work environments (Meister 1971; Singleton 1972; Gamst 1975a, 1975b; Murrell 1979; Garner 1991; Osborne 1994, 1995; Kroemer 1997; Salvendy 1997). Most of the literature on human factors concerns the interface of one person or a crew of persons and a machine (Woodson, et al. 1992:vi-vii, 729-731).

The broad concern of social factors goes beyond the customary human factors, by explicit reference to a social network of humans interfacing with technology. By *social factors* is meant a focusing on human groups in human-device and human-human systems of work. Here accidents are not defined narrowly by insisting that they are usually caused by one worker using a device (the classic managerial charge of "man failure"). Instead, the social interactions within and among groups, of any size, using technology are studied to determine how the social relations of work might affect accidents. Social factors thus include but are not limited to study of accidents produced by the social relations of work and the rationalizing of such accidents by these relations. Examples could be an officer pressuring a subordinate to infract the rules, for meeting a cut-off time, and hiding the consequences of accidents, for excelling during a safety-first competition among divisions. (For social factors see Reasons, et al. 1981; Perrow 1983, 1984; Roberts and Rousseau 1990; Dwyer 1991; Viscusi 1992; Roberts and Weick 1993; Westrum 1997).

Human-factors caused accidents are often defined to be those from a single-operator error such as getting by a stop signal or exceeding speed restrictions (e.g., USGAO 1997:33, n. 3). But, from the broader perspective of social factors, the cause could be from the social relations that underlay such error, for example, pressures from other persons to infract rules. Similarly, an error caused by an operator falling asleep while on duty could be owing to not being allowed to mark off for sufficient rest. Or the error could be because of a law providing for a minimum of 8 hours off duty but not allowing time for 8 hours sleep, say, in a situation where an operator must commute for an hour or more in each direction from worksite to home and bed.

² I can give locomotive engineers' and other railroaders' viewpoints, but I cannot represent organized labor or give the BLE or UTU positions. These are under the authority of the apical international officers of each labor organization.

³ Objects of the police powers of the state, including its administrative agency the Federal Railroad Administration, are the safeguarding of sanitary conditions and the protecting from injury and danger of the public at large. Thus the argument of this presentation is germane to the responsibilities of the FRA.

⁴ One could do further taxonomy here, even going back to the 1700s and the engineman and his stationary engine in the massive enginehouses of Cornwall, after Newcomen's invention of the atmospheric steam engine. The engineman used his engine to pump water from mines, hoist material and persons, and to pull railcars by a cable. The engineman was also called an engine-er or engineer in corrupted form.

⁵ "Railway shops, yards, and trains have always been places of potential personal injury and property damage" DOA, 1968, pp. 39-40.

⁶ As Carl Martland (1999:22) summarizes the railroads' quandary from another perspective:

"Despite the very impressive gains in productivity, especially over the 1983 to 1995 period, the net effect for the rail industry was simply to reduce the size of the industry by 50%, without any increase at all in profitability. The industry was unable to retain the savings that it worked so hard to gain through productivity improvements."