LOOKING ACROSS INDUSTRIES TO IMPROVE HUMAN RELIABILITY DATA FOR QUANTITATIVE RISK ANALYSES

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While meticulous work is often done to determine failure probabilities of SIS for QRAs, the work done to determine failure probabilities of humans performing specific tasks is often glossed over. Yet, human reliability data is just as important to the quality and accuracy of the QRA as non-human failure probabilities. The problem lies in the lack of availability of statistically reliable human failure probabilities for various tasks within the process industries. This paper will present and analyze the strengths and weaknesses of a variety of sources of such data. The sources of human reliability data that will be explored come from the nuclear industry, the aviation industry, the medical field, and of course the process industries. More specifically, the most emphasis will be placed on discussion of the NRC's HERA program and the possible applicability and worth of the program to the process industries. This presentation is based on work done for CCPS' Human Reliability Project.

BACKGROUND

In 1987, a CCPS report identified an industry wide need for a database of Human Reliability (HR) rates that can be used in QRAs. Since then, there have been significant strides in the field of Human Reliability. In 1994, CCPS published *Guidelines for Preventing Human Error in Process Safety*. While this book greatly increased the industry's knowledge of Human Factors, the work was still primarily qualitative in nature.

However, 22 years after CCPS issued its initial report, there is still no comprehensive database that can be used to aid quantitative analyses of human reliability rates. To produce human error rates that can be entered into QRAs, the chemical industry in general, relies extensively upon estimates from human factors experts. This reliance on subject matter experts is both costly and potentially ineffective. In many cases, the estimates of these experts are completely unfounded in statistically significant empirical studies. The result is the pervasive use of low quality, high cost estimates of human reliability rates throughout the chemical process industries. Clearly, an industry wide effort is needed to improve the quality and availability of human reliability data.

INTRODUCTION

The lack of availability of statistically reliable human failure probabilities for various tasks within the process industries continues to be a problem. In response to this, CCPS began its Human Reliability Research Project in 2008. The goal of this project is to look across industries to determine what knowledge and resources are currently available to:

- Provide a basis for human error rates for various studies/analyses related to process safety such as HAZOP and LOPA.
- Provide a basis for detailed quantitative human reliability analysis
- Help identify effective ways to improve worker performance by determining the most significant performance shaping factors (PSFs)

While this project is limited in scope to that of a research project, it is ultimately the goal of the committee to suggest that the chemical process industries work toward the creation of a human reliability database robust enough to produce statistically significant, empirically derived reliability rates for human actions in a variety of environments found in chemical processing plants. The output of such a database will not only help in the production of more accurate QRAs but will ultimately yield a richer knowledge of the risks associated with various types of human-equipment interaction and the most effective and efficient ways to mitigate those risks. This in turn will help the chemical process industry join the ranks of nuclear and aviation as a high reliability industry and lead to improvements in both safety and profitability.

RESEARCH DONE TO DATE

HOLISTIC VS. ATOMISTIC APPROACH

The committee began discussion by debating as to whether the human reliability database it was searching for should be atomistic or holistic in structure. An atomistic approach would entail breaking down both the type of task required of the human as well as the environment surrounding the human during the completion of the task into constituent subcomponents. In human reliability analysis, these subcomponents are called performance shaping factors (PSFs). The subcomponents are then individually assigned a weighting factor associated with how they have empirically been linked to affecting error rates. Then, all of the individual weighting factors for each subcomponent present are in some way combined, using one of any number of human reliability methods or equations, to produce a single error rate associated with the human action.

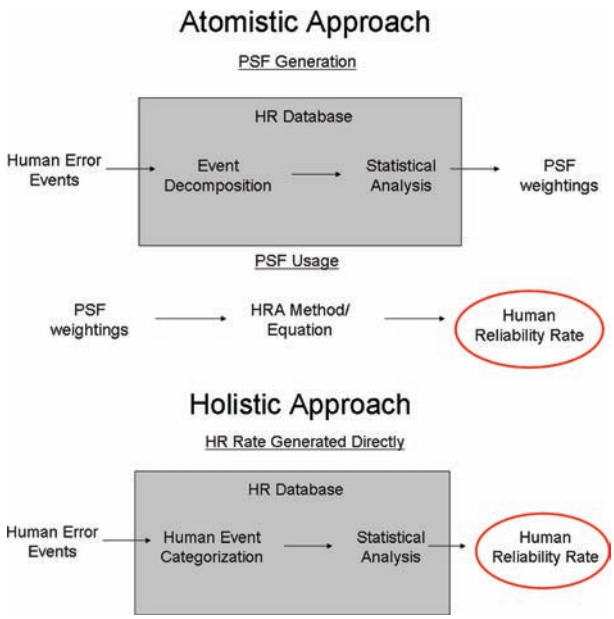

Figure 1. Overview of the holistic and atomistic approaches to the implementation of a human reliability database

The holistic approach asserts that the relationships between performance shaping factors are far too complex to allow for the isolation of PSFs and the subsequent weighting or ranking of their relative significances in determining error rates. A human reliability database created under the holistic approach would categorize every human error event as one of many, many possible human actions. The database would then keep track of error rates for each of these possible human actions.

As is true in most cases, both approaches have both positive and negative aspects. The atomistic database would require much less raw input data to begin generating statistically significant human reliability rates. This approach would also make it possible to generate reliability rates for new types of human actions, as long as these new actions were merely new combinations of previously analyzed performance shaping factors. The downside of the atomistic approach is that it relies on the truth of two basic assumptions: 1) PSFs can be isolated and analyzed independently and 2) quantitative HRA methods/equations can accurately account for the complex relationships between PSFs in any given human action. The factuality of these two assumptions has been the subject of heated debate amongst human factors experts.

Unlike those of an atomistic database, the human error rates produced by a holistic database would suffer from questions of statistical significance rather than legitimacy. Because there are so many different types of human actions in so many different environments within the chemical process industries, it would be a near impossible feat to generate statistically significant error rates by analyzing every human action as an irreducible entity. The diversity of the chemical process industry makes it clear that a human reliability database based on the holistic method would require far too great of a resource commitment in data input to be viable. As a compromise, the CCPS Human Reliability committee concluded that while a holistically structured database would be ideal, the human reliability database that would be of most use to the chemical process industry would be one based on the atomistic approach and would rely on the creation and analysis of performance shaping factors.

SEARCHING FOR HUMAN RELIABILITY INFORMATION FROM OTHER INDUSTRIES

After deciding which type of information (holistic vs. atomistic) that it was looking for, the CCPS Human Reliability Committee did a "high-level" search of what insight and information other industries had about PSFs and their impact on human error rates. The committee looked to the aviation industry, NASA, the medical field, the nuclear industry, the trucking industry, and others. The value that the search had in breadth, it unfortunately lacked in depth. But while the search was not comprehensive in that it did not look at all individual studies performed in each field, it did look for large bodies of work and systems, either in place or being developed, that could be used to help aid the creation of a human reliability database or the generation of human reliability rates in some other way.

Unfortunately, the committee found that much of the knowledge that existed in other industries was either too qualitative in nature or inapplicable to the chemical process industries. Much of the work that had been done focused on individual performance shaping factors and did not lend itself to the comparison and analysis of the relative significance of performance shaping factors. The committee also failed to find any in depth studies on the relationships and interactions between PSFs.

While much of the search proved fruitless, the committee did find one large body of work that seemed to have great potential for collaboration and applicability within the chemical process industries.

THE NUCLEAR INDUSTRY: THE HERA SYSTEM

The most promising source of human reliability data found thus far was found during a look at the Human Reliability work done by the nuclear industry. The specific body of work that appears most promising is the US Nuclear Regulatory Commission's (NRC) Human Event Repository and Analysis System (HERA). As far as producing information on Human Reliability, the HERA program has goals that overlap those of CCPS and the chemical process industries at large. As outlined in the diagram below, the HERA program works recursively to use empirical human reliability data to refine QRA models and improve the accuracy of the error rates predicted

The NRC already has a taxonomy for the decomposition of Human Error Events into subevents and PSFs

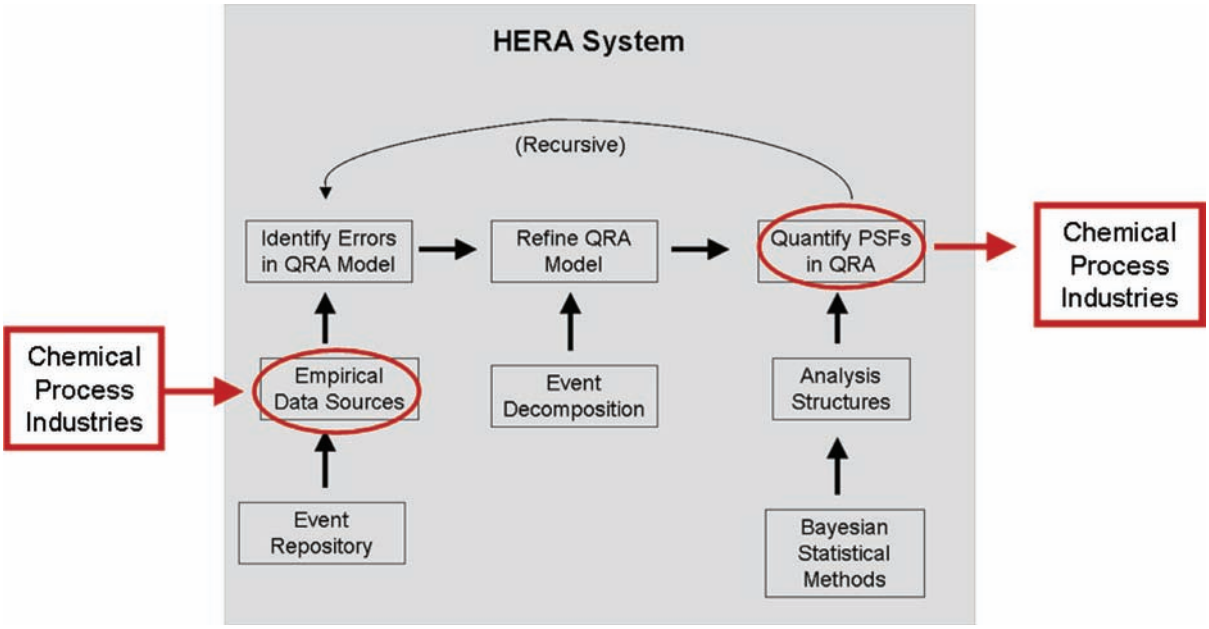

Figure 2. Overview of the US NRC's HERA system and how a possible collaboration with the chemical process industries would work

setup and running. The NRC also has a data collection and analysis system written and beginning to collect data and produce initial reports on PSFs. The main problem plaguing the HERA program is the lack of large quantities of raw data to input in to their system. Thus far, the NRC has looked to various sources of data that for various reasons have proved less than ideal. The NRC has used data from nuclear power plant control room simulator experiments. However, this in vitro experimentally derived data, while useful in helping isolate the impact of individual PSFs, has the potential to skew the output of the database because of the inherent differences in environment and human behavior between real nuclear power plants and simulators. The NRC has also been working to retroactively input data from previously submitted regulatory forms used during incident investigations at nuclear power plants. Because the regulatory forms were not created with this use in mind and are not specifically geared toward understanding the effect of various PSFs, retroactively culling the human factors information from these reports is a time and resource intensive project.

POTENTIAL FOR COLLABORATION

As it stands now, the HERA system is actively looking for sources of raw data input that are comparable to its sources within the nuclear power industry. Conversely, CCPS and the chemical process industries in general are looking for a taxonomy and analysis system in which to process their raw data on human error events. The opportunity for collaboration is obvious with mutual effort undoubtedly resulting in clear synergisms. With a collaboration posing such great opportunity, the question then becomes: how could such a collaboration between the nuclear and chemical process industries be implemented? While the "big picture" view of the program shows great promise, the success of such a collaborative effort surely hinges on the details of implementation.

The process for inputting data into the HERA system involves filling out two worksheets that have been produced by the NRC specifically for the nuclear power industry. Should the chemical process industry choose to work with the HERA system, it is clear that there would be a few major obstacles that would have to be in some way overcome. First, the worksheets would have to be tailored to, or at least generalized to incorporate, the chemical process industries. Chemical process plants are clearly much more diverse than nuclear power plants and the feasibility of generalizing the HERA system to incorporate such diverse input data was questioned. However, in analyzing the relative effects of PSFs, the diversity of tasks and environments surrounding human actions in chemical plants would actually aid the process of isolating the effects of individual PSFs and understanding the relationships between PSFs and their impact on human error rates. In this case, rather than being a detriment to a collaboration, the diversity of the chemical process industries would be a great strength to the HERA program or, for that matter, any human reliability database.

A second obstacle facing the collaboration would be the need for trained personnel to spend valuable time filling out the data collection forms during incident investigation and near miss reporting. While not dependent on human factors experts, the HERA forms do require some

	Factor1	Factor2	Factor3	Factor4
Communication	0.825	-0.042	-0.053	-0.229
Team Cohesion	0.818	-0.104	0.342	-0.301
Staffing	0.777	0.378	-0.461	-0.225
Direct Supervision	0.584	0.045	0.186	0.493
Team Coordination	0.579	0.376	0.441	-0.158
Training	0.562	0.096	-0.362	0.492
Work Processes	0.510	0.375	-0.508	-0.068
Conditioning Event	0.403	0.157	0.132	-0.036
Safety Culture	-0.117	0.806	0.227	0.215
Task Scheduling	-0.379	0.759	0.316	0.124
Corrective Action Prog.	-0.318	0.724	-0.400	-0.089
Info Use	0.198	0.281	0.240	-0.089
Time Load	0.378	-0.420	0.249	0.020
Knowledge / Experience	0.261	0.319	0.542	0.098
Procedure Quality	0.283	0.133	-0.300	0.110
Task Load	0.399	-0.329	-0.030	0.457

Figure 3. An example of the initial reports the HERA program has begun producing. Courtesy of the US NRC

training to correctly complete. The chemical process industries would in general be reluctant to allow any non-staffers in to their plants, especially when investigating incidents or reporting near misses. This means that the only way to have plants fill out the HERA forms would be to train workers from each company on how to properly complete the worksheets. This would also require a commitment of time of train personnel from individual companies and organizations. In order to obtain this commitment, the benefits of the output of the HERA database must be clearly outlined and explained to the chemical process industries.

BENEFITS OF COLLABORATION

While the NRC has had difficulty finding raw data to enter in to its HERA system, it has nonetheless already begun producing reports on the relative significance of various performance shaping factors on human error rates. Figure 3 illustrates one such report. While the system has not yet begun generating actual human error rates for use in QRAs, the quantitative comparison of the PSFs and their impact on human error is nonetheless very valuable information. In essence, this information gives insight into where and how to commit resources and implement changes that will most effectively and efficiently improve human reliability rates. As more data is added to this system, the output will grow both in terms of its applicability, significance, and accuracy.

CONCLUSIONS AND PATHS FORWARD

The HERA program currently has its taxonomy for human reliability data collection established and has completed the software used to implement data collection and organization. However, the NRC has had difficulty acquiring raw data from nuclear power plants to input into its system. With the chemical process industry's need for a HR taxonomy and collection system and with the HERA program's need for raw HR data, there seems to be a good fit for a synergistic collaborative effort.

The CCPS Human Reliability Project plans on proposing a new HR project in which CCPS would either:

- Develop its own database for the collection of HR data and the production of qualitative and quantitative analyses of performance shaping factors.
- Collaborate with the NRC on the HERA program by inputting empirical HR data from its member companies and providing its members with the reports on PSFs that are output by the system.

Both plans of action are associated with different sets of difficulties and benefits. Creating a stand alone database is resource intensive and could take years to fully implement. Working with the NRC would require using forms and taxonomic systems that were initially designed for use in the nuclear power industry. Whichever plan of action is ultimately chosen, it will be dedicated to addressing the decades old need for accurate information on human reliability rates.