INEEL/CON-2000-00146
PREPRINT

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July 31, 2000 – August 4, 2000

International Ergonomics Association and Human Factors & Ergonomics Society Annual Meeting

B E C H T E L B W X T I D A H O , L L C

SIMPLIFIED PLANT ANALYSIS RISK (SPAR) HUMAN RELIABILITY ANALYSIS (HRA) METHODOLOGY: COMPARISONS WITH OTHER HRA METHODS

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The 1994 Accident Sequence Precursor (ASP) human reliability analysis (HRA) methodology was developed for the U.S. Nuclear Regulatory Commission (USNRC) in 1994 by the Idaho National Engineering and Environmental Laboratory (INEEL). It was decided to revise that methodology for use by the Simplified Plant Analysis Risk (SPAR) program. The 1994 ASP HRA methodology was compared, by a team of analysts, on a point-by-point basis to a variety of other HRA methods and sources. This paper briefly discusses how the comparisons were made and how the 1994 ASP HRA methodology was revised to incorporate desirable aspects of other methods. The revised methodology was renamed the SPAR HRA methodology.

INTRODUCTION

The 1994 Accident Sequence Precursor (ASP) human reliability analysis (HRA) methodology was developed for the U.S. Nuclear Regulatory Commission (USNRC) in 1994 by the Idaho National Engineering and Environmental Laboratory (INEEL) (Blackman and Byers, 1995a). This 1994 methodology made use of a two-page worksheet to rate a series of performance shaping factors (PSFs) and dependency factors to arrive at a screening level human error probability (HEP) for a given task. Noteworthy features of the 1994 methodology were a derivation of PSFs from a psychological model of human behavior (Blackman and Byers, 1995b), and an explicit dependency model. However, when compared to the open literature and Individual Plant Evaluation HRA data, the dynamic range for HEPs in the 1994 methodology was limited. Also, based on initial use, the taxonomy for distinguishing the processing (cognition) portion of a task from the response (action) portion of the task was somewhat difficult for non-human factors/HRA professionals to apply. The INEEL was tasked by the USNRC to revise the 1994 ASP HRA methodology for use in the Simplified Plant Analysis Risk (SPAR) program. A full description of the revision process, along with new SPAR HRA Worksheets and Definitions, was developed.

This paper will focus on why and how the 1994 ASP HRA methodology was compared to other HRA methods during the revision process. The results of the comparison, including the detailed descriptions and quantitative information, could not be included here because of paper length restrictions.

PURPOSE OF COMPARISONS

The initial task in revising the 1994 ASP HRA methodology was to compare it to other existing HRA methods and to other sources of HRA information. The primary purpose of these comparisons was, of course, to systematically evaluate possibilities for enhancement of the 1994 ASP HRA methodology. The comparison took place on several levels. The first was to compare the actual methods themselves, that is, how is information on human tasks and human performers manipulated to assess human reliability? The second comparison level was to compare the topics and extent of information on tasks and performers that the methods use (e.g., error types and PSFs used). Finally, a comparison of the quantification aspects of the methods was performed to look at the methods and numbers used to obtain a human error probability. All three levels of comparison provided information for enhancements made to the 1994 ASP HRA methodology, which resulted in the SPAR HRA methodology. No benchmarking across the methods for a specific Probabilistic Risk Assessment sequence was performed. This exercise is being considered for the next project phase.

HRA COMPARISON METHODS

On the basis of either relatively widespread usage, or recognized contribution as a newer contemporary technique, five HRA methods were chosen for comparison. The methods were:

- Technique for Human Error Rate Prediction (THERP) (Swain and Guttmann, 1983)
- Accident Sequence Evaluation Program (ASEP) (Swain, 1987)
- Cognitive Reliability and Error Analysis Method (CREAM) (Hollnagel, 1998)
- Human Error Assessment and Reduction Technique (HEART) (Williams, 1988)
- A Technique for Human Event Analysis (ATHEANA) (USNRC, 1998)

Note that of the five methods listed above, only ASEP qualifies as a screening method. The others either contain aspects of screening methods or can be truncated and used in that fashion. In addition to these five methods, other sources of information were also examined for insights about the treatment of human error. These sources were:

- Individual Plant Evaluations (IPEs) (USNRC, 1988; USNRC, 1997)
- Nuclear Computerized Library for Assessing Reactor Reliability (NUCLARR) (Reece et al., 1994)
- Human Performance Event Database (HPED) (S.G. Hill, personal communication, November 1998)
- JHEDI (Kirwan, 1997)
- Quantification of Errors of Intention (INTENT) (Gertman et al., 1990)
- Framework Assessing Notorious Contributing Influences for Error (FRANCIE) (Ostrom et al., 1997)
- Human Cognitive Reliability/ Operator Reliability Experiment (HCR/ORE) (Hannaman, Spurgin and Lukic, 1985, Moieni et al.,1994)
- 1994 ASP HRA Methodology user history.

HOW COMPARISONS WERE MADE

The first step of the comparison was the assembly of a team of analysts (the authors of this report) with HRA knowledge. Next, each analyst was asked to review one or more of the methods and sources, and to prepare a precis for presentation and discussion at a team meeting. For this initial review and discussion, reviewers were asked to familiarize (or re-familiarize) themselves with the method and to concentrate on the overall method, that is, how is information on human tasks and human performers manipulated to assess human reliability?

Presentation and discussion of the initial reviews resulted in the basic outlines of the enhancement of the 1994 ASP HRA methodology. It became evident that the method of assigning base error rates for specific error types and then modifying those base rates through the operation of PSFs and dependency effects could be retained. However, some continued consideration was given to other methods, in particular the CREAM method of separate bins corresponding to control modes. This continued consideration, however, did not result in any changes being made to the basic 1994 method of modifying base error rates.

Once the initial review and discussion were completed, the team members were asked to construct more detailed summaries of their methods and sources, including specific lists of: 1) error types; 2) any base rates associated with the error types; 3) PSFs; 4) PSF weights, and; 5) dependency factors. Of course, not all methods and sources contained all of this information, and certainly not all used the same terminology of error types and PSFs.

Next, the information gathered from the various methods and sources was compared to the 1994 ASP HRA methodology. The PSFs from the 1994 ASP HRA methodology, with their associated definitions, were listed. The information from each of the other methods was reviewed, one method at a time. The PSFs were matched based on the 1994 ASP PSF definitions, the other method definitions (if available), and the analysts' judgment and knowledge of human performance. Most PSFs could be matched. Different words might be used, but the underlying concepts were so similar as to make the appropriate match clear. For example, the 1994 ASP methodology had a PSF category of "poor ergonomics" while HEART had a PSF related to "unreliable instrumentation." However, it was clear from the 1994 ASP definition that these PSFs could be matched.

Two points should be made about the PSF comparisons. One is that the PSFs in the different methods were often at different levels of detail. The previous example of "poor ergonomics" and "unreliable instrumentation" shows PSFs at two levels of detail. "Unreliable instrumentation" is a specific example of "poor ergonomics." Poor ergonomics also encompasses many other aspects such as poor workstation design, poorly designed displays and controls, and poor labeling. Therefore, "unreliable instrumentation" can be thought of as a subset of "poor ergonomics." However, the matching and comparison are still useful even if PSFs are at different levels of detail. First, the additional detail provides input for a better and more expanded definition of the SPAR PSF, so as to include as many concepts explored by other methods as possible. And, in looking to see how the related PSF weights compare, PSF weight multipliers of subsets of the SPAR PSF of interest are still useful.

The second point to be made is that the 1994 ASP HRA methodology divided each human task into a processing component and a response component (changed to diagnosis and action components in the SPAR methodology). Therefore, in making comparisons between 1994 ASP HRA PSFs and another method's PSFs, the analysts had to maintain awareness of the differences between processing and response, and if the PSF specifically addressed one or both aspects of the human task. For example, in HEART, the PSF that describes "a danger that finite physical capabilities will be exceeded" is clearly related only to operator responses or actions, and not to operator processing.

In a manner similar to the PSF matching, the base error types from the other methods were matched to the 1994 ASP HRA error types. This matching was considerably easier than the PSF matching. It was easier because it was relatively easy to judge whether or not other error types corresponded to either or both of the processing and response error types of the 1994 ASP HRA methodology.

METHODOLOGY REVISION

At this point, revision of the 1994 ASP HRA PSFs began. The changes made at this stage were in error types, definitions of error types, in PSFs, and in the definitions of the PSFs. Changes were made on the basis of a general trend in the methods, such as "The raters don't understand the processing/ response dichotomy and most of the other methods recognize separate diagnosis and action error types" or "Most of the other methods have organizational factors as a PSF." Changes were also made to ensure the SPAR HRA methodology would be as broad in coverage as possible, for example, the definition of "context" in the SPAR HRA definitions was broadened.

Once the changes in error types and PSFs were made, new matching lists were created for error types and PSFs. Next, comparison matrices were created (one for the new diagnosis error type, one for the new action error type) that showed the comparison of PSFs and their weight multipliers in table form. A table was also created showing the two 1994 ASP PSF base error types with the matching error types and base rates from the other methods. Creating this table was somewhat problematic since many of the error types in the other methods incorporated one or more PSFs. For example, the HEART error type, "Shift or restore system to a new or original state on a single attempt without supervision or procedures" incorporates aspects of the procedures PSF and the work processes PSF. Thus it was somewhat difficult to find base rates which were truly comparable.

After the comparison matrices had been completed, analyzed, and digested, changes were made to the ASP HRA PSF weights. Changes were driven by several considerations. Consonance with the other methods was the first of these. Second was the user desire to achieve realistic values, and third was to maintain as many of the 1994 ASP HRA values as possible, since they had been at least partially validated. A final consideration was to examine differences between the two error types in PSF weights.

Finally, consideration was given to changing the 1994 ASP HRA error type base error rates. However, no compelling reason was found for changing them and no changes were made to these rates.

SUMMARY

Overall, as a result of the comparison of the 1994 ASP HRA methodology to other methods and sources, enhancements were made in error type names, error type definitions, PSFs, PSF weights, PSF definitions, dependency conditions and dependency definitions. No changes were made to the base error weights. Each task no longer has to be rated on both processing (diagnosis) and response (action) components, only if the task contains diagnosis does diagnosis get rated, and similarly for action. Changes were also made to the worksheet to enhance usability and to gather more information when non-nominal ratings are made. Examples drawn from the Human Performance Events Database (Schurman et al., 1998) have been added to increase rater understanding of the PSFs and PSF levels. The overall range of possible HEPs has been expanded.

As they now stand, SPAR HRA methodology error types, error type base weights, PSFs, and PSF weights are roughly comparable (given the different levels of granularity of the methods) to those of the other HRA methods.

The enhanced SPAR HRA methodology is useful as an easy-to-use, broadly applicable, HRA screening tool. The comparisons and enhancements described in this paper allow the SPAR HRA methodology to maintain the strengths of the original 1994 ASP HRA methodology, while taking advantage of the information available from user feedback and from other HRA methods and sources. The SPAR HRA methodology has been and is being used successfully in several applications, most recently in the Spent Fuel Pool Analysis for the USNRC.

ACKNOWLEDGEMENTS

Work supported by the U.S. Nuclear Regulatory Commission under DOE Idaho Operations Office Contract DE-AC07-99ID13727.

REFERENCES

Blackman, H.S. and Byers, J.C. (1995a). ASP Human Reliability Methodology Development. In *Proceedings of the International Conference on Probabilistic Safety Assessment Methodology and Applications* (pp. 67-72). Yusong, Taejon, Korea: Korea Atomic Energy Research Institute.

Blackman, H.S. and Byers, J.C. (1995b). Development of a Behaviorally Based Human Reliability Analysis Method. In *Proceedings of the Human Factors and Ergonomics Society 39th Annual Meeting* (pp. 1006-1010). Santa Monica, CA: Human Factors and Ergonomics Society.

Gertman, D., Blackman, H., Haney, L., Seidler, K., Sullivan, C., and Hahn, H. (1990). *INTENT: A Method for Estimating Human Error Probabilities for Errors of Intention*, Rev. 1 (EGG-SSRE-9178). Idaho Falls, ID: Idaho National Engineering Laboratory

Hannaman, G., Spurgin, A., and Lukic, Y. (1985). A Model for Assessing Human Cognitive Reliability in PRA Studies. In *1985 IEEE Third Conference on Human Factors and Power Plants*, Monterey, CA, June 23-27, 1985. NY: Institute of Electronic and Electrical Engineers, 1985.

Hollnagel, E. (1998). *Cognitive Reliability and Error Analysis Method CREAM.* New York: Elsevier.

Kirwan, B. (1997). "The Development of a Nuclear Chemical Plant Human Reliability Management Approach HRMS & JHEDI." *Reliability Engineering and System Safety*, *56*, 109-133.

Moieni, P., Spurgin, J. A., and Singh, A. (1994). "Advances in HRA Methodology Part I: Frameworks, Models, and Data", *Reliability Engineering and System Safety*, *44*, 27-55.

Ostrom, L., Nelson, W., Haney, L., Richards, R., Wilhelmsen, C., Owen, R. (1997). *Structured Human Error Analysis for Airplane Maintenance and Design* (INEEL/EXT-97-01093). Idaho Falls, ID: Idaho National Engineering Laboratory.

Reece, W. J., Gilbert, B. G., and Richards, R. E. (1994). *Nuclear Computerized Library for Assessing Reactor Reliability (NUCLARR) Data Manual, Part 2: Human Error Probability (HEP) Data* (NUREG/CR-4639, EGG-2458, V. 5 Rev. 4). Idaho Falls, ID: Idaho National Engineering Laboratory.

Swain, A. D. (1987). *Accident Sequence Evaluation Program Human Reliability Analysis Procedure* (NUREG/CR-4772) (SAND-86-1996). Washington, DC: USNRC.

Swain, A. D., and Guttmann, H. E. (1983). *Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications* (NUREG/CR-1278). Washington, D.C.: USNRC.

USNRC (1988). *Individual Plant Examination for Severe Accident Vulnerabilities-10 CFR §50.54(f)*, Generic Letter 88-20 (November 23, 1988).

USNRC (1997). *Individual Plant Examination Program: Perspectives on Reactor Safety and Plant Performance* (NUREG-1560, Vols. 1, 2, 3). Washington, D.C.: U.S. Nuclear Regulatory Commission.

USNRC (1998). *Technical Basis and Implementation Guidelines for A Technique for Human Event Analysis* (ATHEANA) (Draft Report for Comment) (NUREG-1624). Washington, DC: USNRC.

Williams, J. (1988). "A Data-based Method for Assessing and Reducing Human Error to Improve Operational Performance," In 1988 *IEEE Fourth Conference on Human Factors and Power Plants* (pp. 436-450). NY: Institute of Electronic and Electrical Engineers.