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Which Distribution Best Describes Human Performance Time?

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1. Introduction

In many socio-complex systems, human performance times are often calculated and evaluated to predict human reliabilities or to evaluate performance levels of human-machine interactions. However, human performances are expected to have stochastic distributions because there is variability in the process of their interactive tasks. Not all probability distribution models are perfect, but if we use a useful probability distribution, it is possible to efficiently understand or predict the variability of human execution time and calculate the failure probability of time insufficiency. Therefore, this paper summarizes the results of examining empirical data on human performance time in the nuclear and non-nuclear fields.

2. Non-nuclear Field Data

Kim [1] presented a method for calculating standard repair times in military situations and estimated the distribution of standard repair times for combat equipment. The method was applied to four types of combat equipment, including tanks, self-propelled artillery, and armored vehicles based on the data from the Defense Logistics Integrated Information System (DELIIS). Statistical tests were performed with the AIC (Akaike Information Criterion) and K-S (Kolmogorov-Smirnov) statistics based on the maximum likelihood estimation method. Lognormal distributions were found to be most suitable to describe the distributions of repair times in all combat systems, but the paper also mentions that practical use is acceptable since there is no significant difference between the gamma distribution and the Weibull distribution.

Choi and Ma [2] derived the distribution of missile repair time based on 20 years of field data. This study found that the repair time distributions depend on outsourcing status and component types. In the case of internal repair, the navigator, guidance control system, and altimeter appear to follow lognormal distributions, and the battery repair time was revealed to follow an exponential distribution. In the case of outsourcing repairs, the navigator follows a triangular distribution, the battery follows an exponential distribution, the guidance controller follows a beta distribution, and the altimeter follows a Weibull distribution.

Kim et al. [3] analyzed the time data for fire suppressions in domestic residential apartments, which were collected by Lim [4]. 26 samples indicating the periods between the apartment arrival and the complete suppression were analyzed, and the Weibull distribution was found to be fit for the time data followed by the normal, gamma, lognormal, and exponential distributions.

Kline [5], Billinton & Allan [6], Jacobson & Arora [7], and Zapta et al. [8] also showed that lognormal distributions can be widely used to model repair time distribution. In particular, Zapta et al. analyzed the repair time data from various electric systems to compare the fitness of exponential, lognormal, beta, and Weibull distributions. They concluded that lognormal is the best for repair time estimation, followed by the Weibull, gamma, exponential, and normal distributions, in that order.

3. Nuclear Field Data

Electric Power Research Institute (EPRI) [9] has shown that the ratio values of time required and time available follow a lognormal distribution through the operator reliability experiments (ORE) (e.g., Fig. 1.). For this analysis, the performance time data during operator training sessions in the simulators and the time available data of human reliability analysis (HRA) were utilized. Jefferson et al. [10] re-analyzed the performance data of ORE by scale adjustment and confirmed that lognormal distributions explained the performance time best in most cases.

Garg et al. [11] extracted 17 performance time data from the simulator of an advanced reactor in India and compared their distributions. They compared chi-square, gamma, exponential, Weibull, and lognormal distributions through the Kolmogorov-Smirnov goodness of fit test and concluded that the lognormal distribution was the most suitable.

Kim et al. [12,13] analyzed the performance time of the main control room operators in emergency situations in the simulator of the APR1400 plant. For the 30-time data obtained from the seven crew teams, they compared the goodness of fit of the distributions with the AIC and the BIC (Bayesian Information Criterion). They concluded that the lognormal distribution was the most appropriate. Fig. 2 shows the diagnostic plot of the lognormal distribution.

Kim et al. [3] also attempted to analyze the response time for diverse and flexible coping strategies. Only 12 data from the stress tests were analyzed, but it was shown that the best-fit distribution was lognormal.

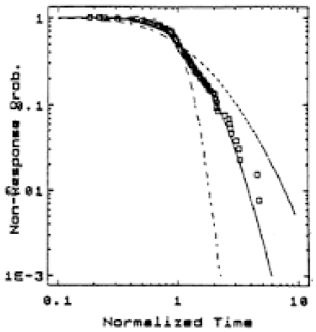

Fig. 1. The normalized time data of ORE and the lognormal function graph.

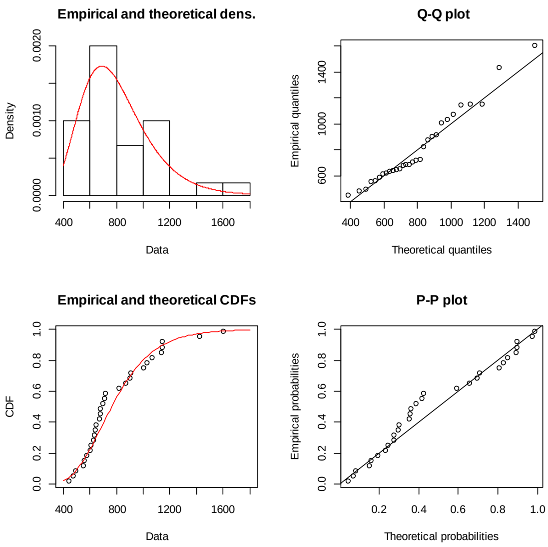

Fig. 2. The four graphs (i.e., histogram, quantile plot, cumulative density plot, and probability-to-probability plot) showing the fitness of lognormal distribution to the performance time of APR1400 operators.

3. Conclusions

This paper summarizes studies that have analyzed empirical data on human performance time in various fields. The results showed that, with a few exceptions, human performance times can be well modeled by a lognormal distribution in most cases. This implies that a lognormal function is a good candidate for predicting driver reliability. Of course, the best way to estimate human performance is to collect and analyze the operator's time data from real-world or simulator records. However, the abovementioned studies provide a technical basis for estimating human performance and reliability with insufficient data.

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REFERENCES

[1] M. H. Kim, A Study on the Method of Computing Standard Wartime Maintenance Man-Hour Incorporating Wartime Maintenance Condition, Journal of the Korea Academia-Industrial cooperation Society Vol. 22, No. 6 pp. 477-483, 2021.
[2] Y. Choi, J. Ma, Impact of Maintenance Time of Anti-Ship Missile Harpoon on Operational Availability with Field Data, Journal of the KIMST, vol.23, no.4, pp. 426-434, 2020.
[3] Y. Kim, J. Kim, J. Park, S. M. Shin, & J. W. Park, Estimating the Performance Time of FLEX Implementation Based on Staffing Level Considering Multi-Unit Accidents, In Proceedings of the 33rd European Safety and Reliability Conference, September 3-8, United Kingdom, 2023.
[4] J. W. Lim, An Experimental Study on Prediction of Firefighting Activity Time for Residential Fire, Doctoral dissertation, Graduate School of Seoul National University of Science and Technology, 2018.
[5] M. B. Kline, Suitability of the lognormal distribution for corrective maintenance repair times. Reliability engineering, 9(2), 65-80. 1984.
[6] R. Billinton & R. N. Allan, Reliability evaluation of engineering systems (Vol. 792). New York: Plenum press, 1992.
[7] D. W. Jacobson, & S. R. Arora,). A nonexponential approach to availability modeling. In Annual Reliability and Maintainability Symposium 1995 Proceedings (pp. 253-260), IEEE, 1995, January.
[8] C. J. Zapata, S. C. Silva, & O. L. Burbano, Repair models of power distribution components. In 2008 IEEE/PES Transmission and Distribution Conference and Exposition: Latin America (pp. 1-6). IEEE, 2008, August.
[9] Electric Power Research Institute, An Approach to the Analysis of Operator Actions in Probabilistic Risk Assessment, Electric Power Research Institute TR-100259, California, 1992.
[10] B. A. Jefferson, G. Coles, J. Baweja, Y. H. J. Chang, R. Prasad, Estimating the Contributions to Human Error Probability from the Convolution of the Distribution of Time Available and Time Required, NPIC&HMIT 2023, Knoxville, TN, 2023, July.
[11] V. Garg, G. Vinod, V. Kant, C. Smith, Evaluation of Human Error Probability from Simulator Experiments based on Operator Response Times, NPIC&HMIT 2023, Knoxville, TN, 2023, July.
[12] Y. Kim, J. Kim, J. Park, S. Y. Choi, S. Kim, W. Jung, H. E. Kim, S. K. Shin, An HRA Method for Digital Main Control Rooms—Part I: Estimating the Failure Probability of Timely Performance. KAERI, KAERI/TR-7607/2019, 2019.
[13] Y. Kim, J. Choi, J. Park, W. Jung, S. J. Lee, Estimating Diagnosis Time of Emergency Situations in Digitalized Control Rooms, Proceedings of the AHFE 2018 International Conference on Human Error, Reliability, Resilience, and Performance, July 21-25, Florida, USA, 2018