ASEAN-ROK Exploratory Study on Nuclear Research Reactor Operating Culture among ASEAN NPSR Member States

Wasin Vechgama[a, b, c], Jinkyun Park[a, b, *], Joon-Eon Yang [a, b], Kanokporn Boonsirichai[c], Weerawat Pornroongruengchok[c], Kanokrat Tiyapun[c], Anantachai Pechrak[c], Saensuk Wetchagarun[c], Kampanart Silva[d], Pidpong Janta[d], Piyawan Krisanangkura[e], Julia Abdul Karim[f], Phongsakorn Prak Tom[f], Mazleha Maskin[f], Ridzuan Abdul Mutalib[f], Ahmad Hassan Sallehudin Mohd Sarif[g], Topan Setiadipura[h], Ratih Luhuring Tyas[h], Restu Maerani[h], Mohammad Subekti[i], Kien Cuong Nguyen[j], Doan Hai Dang Vo[j], Carlo Arcilla[k], Dan Mangulabnan[k], Eugene Gregorio[k]

[a]Korea Atomic Energy Research Institute, 111, Daedeok-daero 989 beon-gil, Yuseong-gu, Daejeon, 34057, Republic of Korea.
[b]Korea National University of Science and Technology (UST), 217, Gajeong-ro, Yuseong-gu, Daejeon, 34113, Republic of Korea.
[c]Thailand Institute of Nuclear Technology (Public Organization), 16 Vibhavadi Rangsit Road, Chatuchak, Bangkok, 10900, Thailand.
[d]National Energy Technology Center, National Science and Technology Development Agency, 114 Thailand Science Park, Phahonyothin Road, Khlong Nueng, Khlong Luang, Pathum Thani, 12120, Thailand.
[e]Office of Atoms for Peace, 16 Vibhavadi Rangsit Road, Chatuchak, Bangkok, 10900, Thailand.
[f]Malaysian Nuclear Agency, Bangi Complex, 43000 Kajang, Selangor, Malaysia.
[g]Universiti Tun Hussein Onn Malaysia, Persiaran Tun Dr. Ismail, 86400 Parit Raja, Johor, Malaysia.
[h]Research Center for Nuclear Reactor Technology, Research Organization for Nuclear Energy, National Research and Innovation Agency (BRIN), Kawasan Sains dan Teknologi BJ Habibie Gedung 80, Tangerang Selatan, Banten, Indonesia, 15314.
[i]Directorate for Nuclear Facilities Management, National Research and Innovation Agency (BRIN), Gedung BJ Habibie Jl. M. H. Thamrin Nomor.8, Jakarta Pusat, Indonesia, 10340.
[j]Dalat Nuclear Research Institute, Vietnam Atomic Energy Institute, 01 Nguyen Tu Luc, Dalat 66000, Lamdong, Vietnam.
[k]Philippine Nuclear Research Institute, Commonwealth Avenue, Diliman Quezon City 1101, Philippines.

[*]Corresponding Email: kshpjk@kaeri.re.kr

Abstract: According to the human culture concept, homogeneous and heterogeneous cultures are important indicators to classify who is in-group and out-group of the people in the society, respectively. The human culture concept was applied to many industries such as construction, infrastructure, oil and gas production, nuclear plants, aviation, and health to study the differences in culture from various working environments for specific objectives, especially in the national culture dimension. In the human reliability analysis (HRA) of nuclear industries, the sharing of human performance data between different countries or organizations is a common transferring approach of similar operating cultures among nuclear plants. Culture values of operators between different nuclear plants are the essential indicator to check and confirm homogeneous operating cultures for supporting the transfer of human performance data in other nuclear plants. In this study, five countries operating seven nuclear research reactors (NRRs) in the ASEAN Network on Nuclear Power Safety Research (ASEAN NPSR) planned to develop an ASEAN HRA platform and collect human performance data together. Thus, HRA practitioners aimed to survey and analyze the national culture values of NRR operators to investigate homogeneous culture through five dimensions of Hofstede's models namely (1) power distance index (PDI), (2) individualism index (IDV), (3) masculinity index, (MAS), and (4) uncertainty avoidance index (UAI), and (5) long-term orientation index (LTO) based on the questionnaire and expertise from the successful nuclear power plant (NPP) case study of the Republic of Korea (RoK) in the past. As a result, the five national culture values of NRR operators dominantly showed high correlations among seven NPPs to support the potential of HRA data sharing. Moreover, the discrepancy of each culture value such as MAS and UAI helped explain the working characteristic differences of each NRR well.

Keywords: Hofstede's model, Operating culture, Human reliability analysis, Nuclear Research Reactor, ASEAN NPSR.

1. INTRODUCTION

In general nuclear energy industries, concerns about safety and the risks of nuclear operations are raised among the public due to the handling of radioactive and hazardous materials [1]. These nuclear industries need to be recommended to review and improve the safety issues by their national regulatory body [2, 3]. Among safety issues, human reliability analysis (HRA) is a mandatory human risk quantification requirement not for only nuclear power plants (NPPs) but also for nuclear research reactors (NRRs). HRA is realized as a human risk assessment tool to help manage potential negative incidents because of human failures.

On the NPP side, the HRA data or human failure rates among the NPPs were able to be shared with each other based on the assumption of a homogenous culture [4, 5]. Homogenous cultures are used as evidence to support sharing the HRA data or human failure rates among the NPPs due to a lack of available HRA data in the NPPs having different HRA methods. For example, in 2021, Korea Atomic Energy Research Institute (KAERI) investigated the international culture values profile for understanding human performance data collected from three countries namely Korea, the US, and Sweden [6].

Likewise, in 2023, ASEAN Network on Nuclear Power Safety Research (ASEAN NPSR) started developing the HRA platform and methodology for collecting and sharing HRA data among five ASEAN NPSR Members States (MSs) that are currently operating NRRs, namely Thailand, Malaysia, Indonesia, Vietnam, and the Philippines [7]. Basically, HRA is a national requirement related to periodic safety review (PSR), or integrated safety assessment of research reactors (INSARR) [3, 8]. Thus the concept of homogenous culture profile study in NPPs was extended to seven NRRs of these five ASEAN NPSR countries for sharing HRA data.

The objective of this study is to investigate and compare the operating culture profile among five ASEAN NPSR countries operating NRRs using five Hofstede's culture indices and understand the working characteristics of NRR institutes among ASEAN NPSR countries from different national cultures indices namely power distance index (PDI), individualism index (IDV), masculinity (MAS), uncertainty avoidance index (UAI), and long-term orientation index (LTO) with statistical analyses of Pearson's correlation and principal components analysis (PCA).

This article includes four sections. The first section (this section) is the introduction of this work. The second section showed methodologies and related theories for ASEAN NPSR operating cultures. The third section was the results and discussion of the findings. The last section is the conclusion.

2. METHODOLOGY

2.1. Culture Profile Survey

Figure 1 shows the questionnaire for capturing the cultural characteristics [9]. To investigate the operating culture profile of five ASEAN NRRs, a questionnaire for extracting the culture characteristics of NRRs' operators in five Hofstede's culture indices was set based on the NPP operators' survey prototype [9]. The correlation of the questionnaire to five Hofstede's culture indices is determined by the empirical data in value survey module 1994 (VMS94) [10]. The meaning of five Hofstede's culture indices was shown in the following;

- Power distance index (PDI): Culture value representing inequality of workers in society,
- Individualism index (IDV): Culture value indicating individualism in the working environment,
- Masculinity index (MAS): Culture value reflecting assertive behaviors using social gender roles,
- Uncertainty avoidance index (UAI): Culture value explaining feelings to avoid uncertain situations,
- Long-term orientation (LTO): Culture value describing the worker's habit of persistence and thrift.

National culture (NC) survey	Rating scale				
NC1. Have sufficient time for your personal or family life	① Most importance	② Very important	③ Moderate importance	④ Little importance	⑤ Very little or no importance
NC2. Have good physical working conditions (good ventilation and lighting, adequate work space, etc.)	① Most importance	② Very important	③ Moderate importance	④ Little importance	⑤ Very little or no importance
NC3. Have a good working relationship with your direct superior	① Most importance	② Very important	③ Moderate importance	④ Little importance	⑤ Very little or no importance
NC4. Have security of employment	① Most importance	② Very important	③ Moderate importance	④ Little importance	⑤ Very little or no importance
NC5. Work with people who cooperate well with one another	① Most importance	② Very important	③ Moderate importance	④ Little importance	⑤ Very little or no importance
NC6. Be consulted by your direct superior in his/her decisions	① Most importance	② Very important	③ Moderate importance	④ Little importance	⑤ Very little or no importance
NC7. Have an opportunity for advancement to higher level jobs	① Most importance	② Very important	③ Moderate importance	④ Little importance	⑤ Very little or no importance
NC8. Have an element of variety and adventure in the job	① Most importance	② Very important	③ Moderate importance	④ Little importance	⑤ Very little or no importance
NC9. Have thrift in private life	① Most importance	② Very important	③ Moderate importance	④ Little importance	⑤ Very little or no importance
NC10. Have respect for tradition in private life	① Most importance	② Very important	③ Moderate importance	④ Little importance	⑤ Very little or no importance
NC11. How often do you feel nervous or tense at work?	① Never	② Seldom	③ Sometimes	④ Usually	⑤ Always
NC12. How frequently, in your experience, are subordinates afraid to express disagreement with their superiors?	① Very seldom	② Seldom	③ Sometimes	④ Frequently	⑤ Very frequently
NC13. Most people can be trusted	① Strongly agree	② Agree	③ Undecided	④ Disagree	⑤ Strongly disagree
NC14. One can be a good manager without having precise answers to most questions that subordinates may raise about their work	① Strongly agree	② Agree	③ Undecided	④ Disagree	⑤ Strongly disagree
NC15. An organization structure in which certain subordinates have two bosses should be avoided at all costs	① Strongly agree	② Agree	③ Undecided	④ Disagree	⑤ Strongly disagree
NC16. Competition between employees usually does more harm than good	① Strongly agree	② Agree	③ Undecided	④ Disagree	⑤ Strongly disagree
NC17. A company's or organization's rules should not be broken - not even when the employee thinks it is in the company's best interest	① Strongly agree	② Agree	③ Undecided	④ Disagree	⑤ Strongly disagree
NC18. When people have failed in life it is often their own fault	① Strongly agree	② Agree	③ Undecided	④ Disagree	⑤ Strongly disagree

Figure 1. Questionnaire for capturing the cultural characteristics [9].

2.2. Pearson's Correlation Coefficient

Pearson's correlation coefficient was used to compare the culture profiles of NRRs' operators in order to prove the overall homogeneous culture of ASEAN operating teams. The coefficient is used to check the linear relationship between the two variables through the ratio of covariance and the multiple of the standard deviation as shown in the following equation [11];

$$r_P = \frac{\sigma(x,y)^2}{\sigma(x)\sigma(y)}, \tag{1}$$

where r_P is the Pearson correlation coefficient, $\sigma(x,y)^2$ is the covariance of variables x and y, $\sigma(x)$ is the standard deviation of variables x, and $\sigma(y)$is the standard deviation of variables y.

2.3. Principal Components Analysis (PCA)

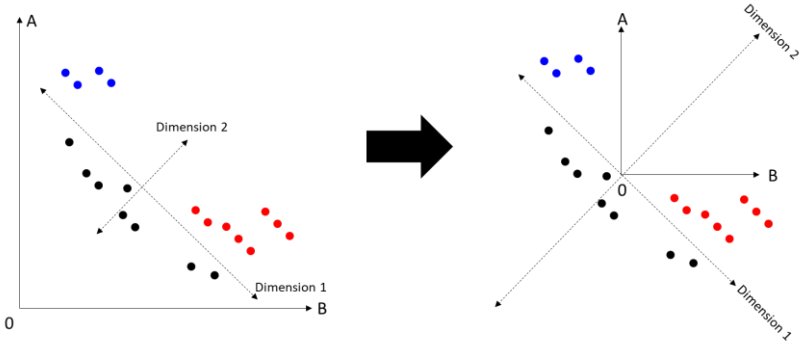

Figure 2. PCA example of the correlation of two variables in various experiments.

Figure 2 shows the PCA example of the correlation of two variables in various experiments. Principal component analysis (PCA) is the explanation of the multidimensionality of many data sets in the two-dimensional scheme [12, 13]. In other words, PCA is the comparative statical tool that decreases the number of variables in the data set, while preserving the originality of information. In this study, the R-program [14] was used to generate the PCA scheme to compare the correlation of each Hofstede culture index with NRRs among ASEAN NPSR countries to explain the working characteristics.

3. RESULTS AND DISCUSSION

3.1. ASEAN NRRs' operator cultures versus general national culture

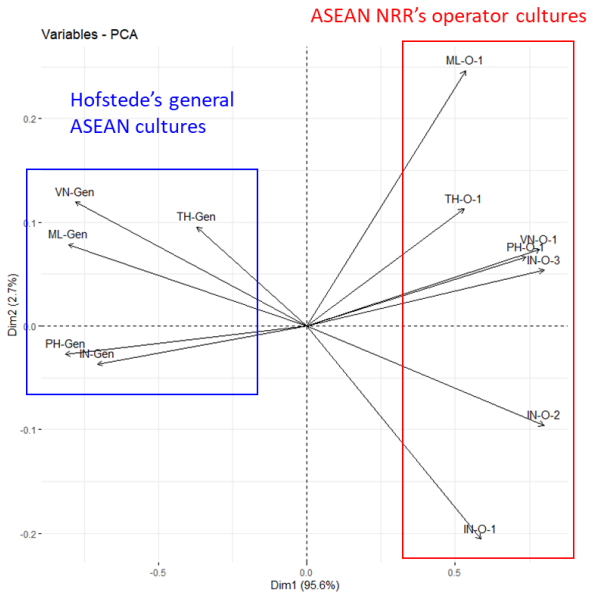

Figure 3. PCA culture comparison of ASEAN NRRs' operators and the general ASEAN workers [15].

Figure 3 shows the PCA results of the culture comparison of ASEAN NRRs' operators and the general ASEAN workers [15] of these five ASEAN countries. It was found that the PCA vectors of these two cases obviously posit in the opposite direction. All PCA vectors of ASEAN operator cultures were directed to the right-hand side in the blue box but all PCA vectors of general ASEAN cultures were shown on the left-hand side in the red box. The opposite directions reflected that there was an insignificant correlation between ASEAN NRRs' operators and the general ASEAN workers. In other words, the influences of inside-institute management and measurements such as safety issues can have more impact on workforce behavior than general national cultures. The same situation happened in the culture study of high-risk industries such as oil and gas companies, and aviation industries [16, 17].

3.2. Culture correlation of ASEAN NRRs' operators

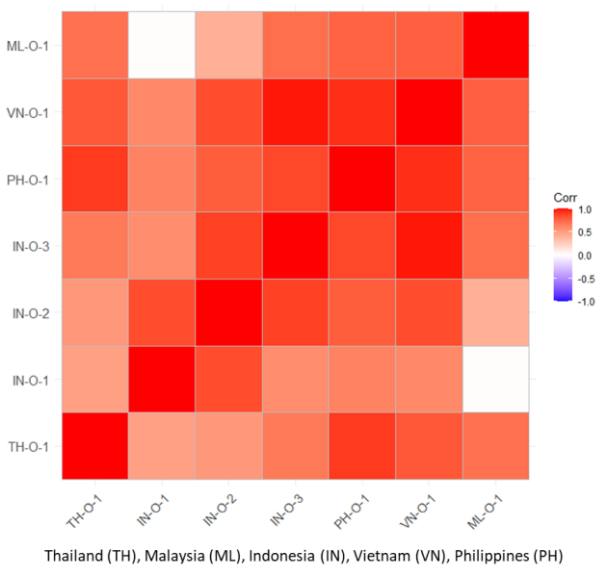

Figure 4. Pearson's correlation results between ASEAN NRRs' operators.

Figure 4 shows Pearson's correlation results between ASEAN NRRs' operators. Pearson's correlation was used to compare the operating culture profile among seven NRRs. It was found that Pearson's correlation scheme mostly showed a strong positive correlation through the red shade color zone of the cultures of ASEAN operating teams. Overall, there is no doubt that the positive correlation of these seven ASEAN NRRs can be considered strong evidence to support the idea of collecting, using, and sharing human performance data in the HRA scope among five ASEAN countries. However, it is difficult to claim that the operating cultures in all NRRs are similar to each other 100 percent due to the different working environments of NRRs such as the weak color zone. Thus the significant culture differences in Hofstedes' indices such as MAS and UAI were explained more in the difference of ASEAN NRR operating culture in the following.

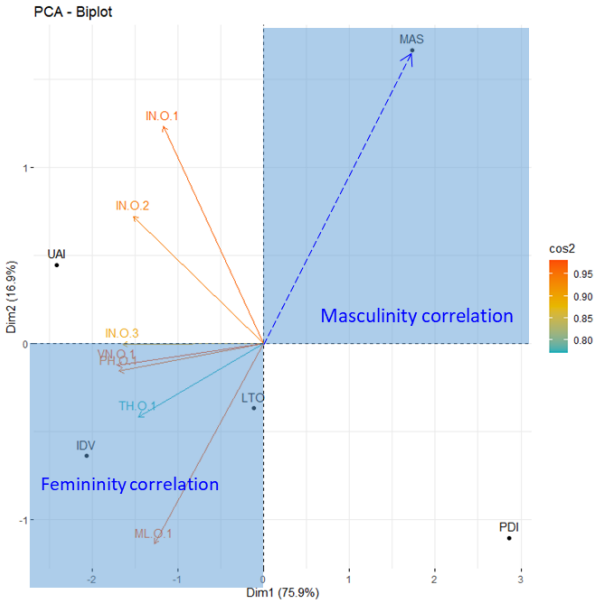

Figure 5. PCA MAS of the ASEAN NRRs' operator cultures.

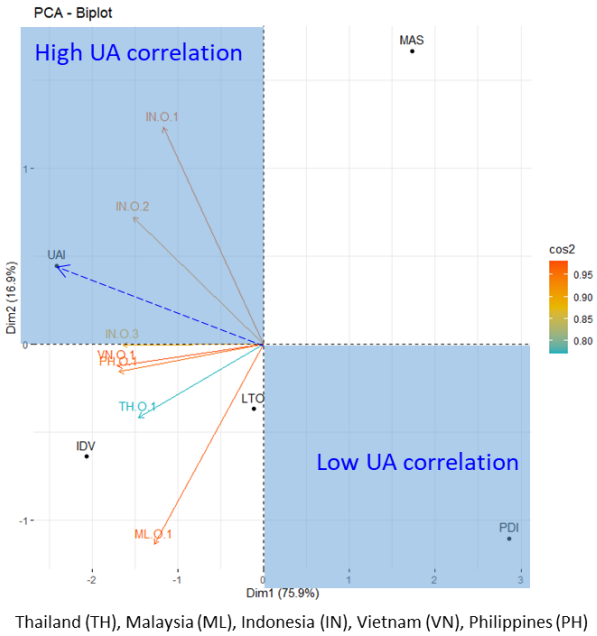

Figure 6. PCA UAI of the ASEAN NRRs' operator cultures.

Figure 5 and Figure 6 show the PCA results of the ASEAN NRRs' operator cultures in the MAS and UAI dimensions, respectively. Based on the direction of the MAS vectors in Hofstede's theory [18], Indonesian operators showed higher masculinity which reflects the decisive management of their organization. Employers and employees tend to accept assertive behavior in the workplace. Having a conflict is a common process to reach a goal in a working society. On the other hand, Malaysia, Thailand, the Philippines, and Vietnam operators showed more consensus society with lower MAS or femininity. Modest behavior is the main characteristic of both employers and employees. Hence, when having conflicts during a discussion, the leader has to compromise to find a solution together. As for UAI, Indonesian operators strongly showed an awareness of uncertainty or ambiguity in the workplace with higher UAI. Formal law or regulation in the operation or management to prevent uncertainties is preferable. Thus these teams need the precision of steps and results when following the procedures or instructions. However, Malaysia, Thailand, the Philippines, and Vietnam showed less uncertainty avoidance with lower UAI. Generally, these operators rely on their experience to manage difficult tasks or prevent uncertainties and implement only important rules or regulations.

Based on the PCA operating culture results, the ASEAN NRRs' operators can be classified into two groups in terms of the nation. The first group (Group 1) included Malaysia, Thailand, the Philippines, and Vietnam while the second group (Group 2) of the big organization of Indonesian NRRs. The two groups can be differentiated by using the characteristics of organizations and nuclear facilities. Group 1 indicates ASEAN NRR's operators operating a single low-power NRR such as a TRIGA reactor. Group 2 indicates that the big organization of Indonesia with decentralization control, that governed the three NRRs including 1 high power RSG at 30 MW and 2 low-power TRIGA reactors. To improve natural cultures in the safe operation and to support effectively sharing human error data in ASEAN NPSR, the two groups can learn from each other through their culture differences. For example, Group 1 can learn how to compromise the conflicts during a discussion with Group 2. Also, Group 2 learned how to set and use formal laws or regulations effectively with Group 1.

4. CONCLUSION

To investigate the operating culture profile of ASEAN NRRs in Thailand, Malaysia, Indonesia, Vietnam, and the Philippines, Hofstede's culture indices were used to explain their culture using the culture profile survey. The comparison of ASEAN NRR operators and the general ASEAN workers reflected the unique influences of inside-institute management and measurements of the ASEAN NRR industry especially in safety issues. Pearson's correlation proved the homogeneous cultures among ASEAN operating teams which is important evidence to support sharing human performance data in the HRA scope among NRRs in ASEAN MSs. However, there were some interesting ASEAN NRRs' operator cultures in MAS and UAI dimensions affecting the culture difference. The culture differences helped lead to learning from each other in ASEAN NPSR to improve natural cultures in the safe operation and to support effectively sharing human error data in the future.

Acknowledgments

This work was supported by a grant from the Nuclear Safety Research Program from the Korea Foundation of Nuclear Safety (KOFONS), funded by the Nuclear Safety and Security Commission of the Republic of Korea (No. RS-2021-KN052610). Also, the authors thank the Korea Atomic Energy Research Institute (KAERI), the Korea National University of Science and Technology (UST), the Thailand Institute of Nuclear Technology (TINT), and the ASEAN Network on Nuclear Power Safety Research (ASEANNPSR) for the opportunity and resources for conducting this project. Finally, we would like to thank all participants in the 1st Joint TINT – NUCLEAR MALAYSIA ASEAN NPSR Technical Meeting on Probabilistic Safety Assessment and Human Reliability Analysis on Nuclear Research Reactor in ASEAN Region, July 18-20, 2023, Bangkok, Thailand, for supporting the first project collaboration in the HRA benchmark assessment as well as the culture profile survey respondents from seven NNRs namely the Thai Research Reactor 1/Modification 1 (TRR-1/M1), the PUSPATI TRIGA Reactor (RTP), the G.A. Siwabessy Multi Purpose Nuclear Reactor (RSG-GAS), the Kartini Nuclear Research Reactor (Kartini NRR), the Bandung TRIGA MARK II the Nuclear Research Reactor (Bandung NRR), the Dalat Nuclear Research Reactor (DNRR), and the Philippine Research Reactor-1 – Subcritical Assembly for Training, Education and Research (PRR-1-SATER).

References

[1] International Atomic Energy Agency (IAEA), 1992. Ranking of safety issues for WWER-440 model 230 nuclear power plants, IAEA-TECDOC-640, Vienna. https://www-pub.iaea.org/MTCD/Publications/PDF/te_640_web.pdf.

[2] International Atomic Energy Agency (IAEA), 2012. Periodic safety review for nuclear power plants, STI/PUB/1588, Vienna. https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1588_web.pdf.

[3] International Atomic Energy Agency (IAEA), 2020. Periodic safety review for research reactors, STI/PUB/1889, Vienna. https://www-pub.iaea.org/MTCD/Publications/PDF/P1889_web.pdf.

[4] Park, J., Jung, W., 2015. Comparing cultural profiles of MCR operators with those of non-MCR operators working in domestic nuclear power plants, Reliability Engineering & System Safety 133, 146-156, https://doi.org/10.1016/j.ress.2014.09.011.

[5] Park, J., 2016. Investigating a homogeneous culture for operating personnel working in domestic nuclear power plants, Reliability Engineering & System Safety 156, 256-265, https://doi.org/10.1016/j.ress.2016.08.011.

[6] Shin, S., Cho, J., Park, J., 2021, Do we have a domain-specific group culture?, Reliability Engineering & System Safety 213, 107692, https://doi.org/10.1016/j.ress.2021.107692.

[7] Vechgama, W., Silva, K., Yang, J., Park, J., 2023. Initiating risk assessment research collaboration between South Korea and ASEAN NPSR member states, The Asian Symposium on Risk Assessment and Management (ASRAM2023), Hong Kong, China, 4-6 December 2023.

[8] International Atomic Energy Agency (IAEA), 2013. Guidelines for the review of research reactor safety: Revised edition, IAEA/SVS/25, Vienna. https://www-pub.iaea.org/MTCD/Publications/PDF/SVS-25_web.pdf.

[9] Skraaning, G., Park, J., Heimdal, J.O., 2012. Corss-cultural generalizability in the nuclear domain: a comparison of culture profiles for control room operators in Swedish, Korean, and US plants. HWR-1027, OECD Halden Reactor Project, Halden, Norway.

[10] Hofstede, G., 1994. VSM 94, Values Survey Module 1994 Manual, Geert Hofstede BV.

[11] Chee, J. D., 2015. Pearson's product-moment correlation: Sample analysis. University of Hawaii at Manoa School of Nursing, Honolulu, Hawaii. https://doi.org/10.13140/RG.2.1.1856.2726.

[12] Jaadi, Z., 2023. A step-by-step explanation of Principal Component Analysis (PCA): Learn how to use a PCA when working with large data sets, Built In. Available at (as of March 2023) https://builtin.com/data-science/step-step-explanation-principal-component-analysis.

[13] Holand, S. M., 2019. Principal Component Analysis (PCA), Department of Geology, University of Georgia, Athens, Georgia. http://stratigrafia.org/8370/handouts/pcaTutorial.pdf.

[14] R Core Team, 2016. R: A language and environment for statistical computing, Vienna, Austria. Available at: https://www.R-project.org/.

[15] Hofstede, G., 2020. Hofstede insights, National culture. Available at (as of August 2020) https://hi.hofstede-insights.com/national-culture.

[16] Mearns, K., Yule, S., 2009. The role of national culture in determining safety performance: Challenges for the global oil and gas industry, Safety Science 47(6), 777-785, https://doi.org/10.1016/j.ssci.2008.01.009.

[17] Chan, T., Li, W., 2022. Investigating professional values among pilots, cabin crew, ground staff, and managers to develop aviation safety management systems, International Journal of Industrial Ergonomics 92, 103370, https://doi.org/10.1016/j.ergon.2022.103370.

[18] Hofstede, G., Hofstede, G. J., Minkov, M., 2010. Cultures and organizations: Software of the mind, Third edition, McGraw Hill, New York. https://books.google.co.kr/books?id=o4OqTgV3V00C&source=gbs_book_similarbooks.