Cultural Profiles of Non-MCR Operators Working in Domestic NPPs

Jinkyun Park[a*], and Wondea Jung[a]
[a] Korea Atomic Energy Research Institute, Daejeon, Rep. of Korea

Abstract: Traditionally, the safety of NPPs has been evaluated by the PSA (Probabilistic Safety Assessment) or PRA (Probabilistic Risk Assessment) technique that quantifies the integrated safety of a whole system. In this regard, HRA (Human Reliability Analysis) plays an important role because it should quantify the possibility of HFEs (Human Failure Events) affecting the safety of NPPs. Therefore, the provision of sufficient data that are helpful for understanding the nature of HFEs under a given accident sequence is indispensable for estimating more realistic HRA results. To address this issue, one of the technical obstacles is the cultural effect on the performance of human operators. That is, it is suspicious for an HRA practitioner to use HRA data collected from another country or organization without sufficient understanding the nature of cultural differences. In this study, as one of the practical approaches to unravel this question, the cultural profiles of non-MCR operators are investigated in detail with respect to their operational experience.

Keywords: PSA, HRA, Operational Culture, Non-MCR Operators, Operational Experience.

1. INTRODUCTION

It is well known fact the performance of human operators (or human error) is decisive for the safety of nuclear power plants (NPPs). Accordingly, it is very natural that significant efforts continue to be applied to reduce the potential for human error. In this light, one of the most disseminated approaches is to conduct human reliability analysis (HRA).

Traditionally, the safety of NPPs has been evaluated by the PSA (Probabilistic Safety Assessment) or PRA (Probabilistic Risk Assessment) technique that quantifies the integrated safety of a whole system based on the analysis of event trees (ETs) and fault trees (FTs) representing all the plausible accident sequences. In this regard, since the accident sequences can be initiated by two kinds of events such as human failure events (HFEs) and hardware failure events, HRA takes part in quantifying the possibility of those HFEs. Therefore, the provision of sufficient data that are helpful for understanding the nature of HFEs under a given accident sequence is indispensable for estimating more realistic HRA results [1, 2]. To address this issue, recent efforts largely emphasize the collection of HRA data from simulated emergencies [3-6].

Unfortunately, the collection of HRA data seems not to be easy because of several technical reasons. One of them could be the cultural effect on the performance of human operators. Gertman et al. articulated that "Culture influences the probability of a person following a specific course of action and thus may affect the probability of actions [7]." Similarly, based on the results of existing studies, Kim et al. pointed out that "In addition, if an operator has their own strategy to use a procedure, or a specific operating culture exists in the operator's organization, the strategy will affect the method used for following the procedure [8]." Accordingly, it is suspicious for an HRA practitioner to use HRA data collected from another country or organization without sufficient understanding the nature of cultural differences. Conversely say, the HRA practitioner will use HRA data with confidence, if there is a clue upholding that the profiles of different cultures are very similar or even homogeneous.

In this light, Skraaning et al. showed a striking result indicating that six different organizations comprised of 81 MCR (Main Control Room) operators from three different countries (i.e., Sweden,

* kshpjk@kaeri.re.kr

Korea and United States) have similar culture profiles [9]. In addition, although there are some discrepancies, Park and Jung pointed out that the cultural profiles of MCR operators working in the domestic NPPs of Rep. of Korea seem to be similar to those of non-MCR operators [10]. These results strongly imply the possibility of a cross-cultural generalizability among operating personnel who have the responsibility of NPP operations. In this end, it is indispensable to clarify the reason of discrepancies observed from the comparison between MCR operators and non-MCR operators.

In this study, as one of the practical approaches to unravel this question, the cultural profiles of non-MCR operators are investigated in detail with respect to their operational experience. As a result, it is expected that the discrepancies can be soundly explained by the difference of operational experience among non-MCR operators.

2. PREVIOUS STUDIES

It is very natural to anticipate that the behavior of human operators will be largely affected by the cultural characteristics of an organization to which they belong (e.g., organizational culture). However, in addition to the organizational culture, it is strongly expected that there could be other cultural characteristics affecting the performance of human operators. For example, Hofstede articulated that is the culture is the collective programming of the mind which distinguishes the members of one group or category of people from another [11]. In addition, he articulated that the culture has several layers distinguishable from many levels, such as a national, regional, ethnic, religious, linguistic, gender, social class and organizational level. Of them, he proposed 5 and 6 cultural dimensions to represent the national and organizational culture, respectively. Table 1 summarizes 11 cultural dimensions with their meaning. The value of each dimension can be quantified by the scores of several questionnaires developed by Hofstede [11]. More detailed information can be found from Ref. [9, 10].

In this regard, based on the review of existing literatures, Heimdal claimed that not only an organizational culture but also a national culture can affect the behavior of human operators [12]. In other words, it is assumed that not only the organizational culture but also the national culture should be considered in parallel in order to properly understand the behavior of human operators working in a certain organization. From this assumption, Skraaning et al. compared the cultural profiles of 81 MCR operators based on the Hofstede's cultural dimensions [9]. All of the participants are working in Westinghouse 3-loop PWRs (Pressurized Water Reactors) in three different countries (i.e., Sweden, Rep. of Korea and United States of America). As a result, although there are some discrepancies, it was observed that both the national and the organizational culture profiles of MCR operators seem to be very similar. These results are very interesting because it is generally anticipated that the cultural profiles of human operators are probably different along with their nationalities (i.e., the national culture) as well as organizations (i.e., the organizational culture).

One plausible explanation for these results would be that MCR operators in three different countries share similar values and norms probably acquired from the operational experience of NPPs [9]. That is, it is possible to assume that the cultural profiles of MCR operators could be comparable to those of non-MCR operators. This is because, although working places are different, they are likely to share similar knowledge and expertise acquired from: (1) the operation of Westinghouse 3-loop PWRs, and (2) similar education and training contents. In order to scrutinize this expectation, the cultural profiles of MCR operators working in the domestic NPPs of the Rep. of Korea are additionally compared with those of non-MCR operators (e.g., field operators and auxiliary operators) who are working in the identical units. In other words, if the cultural profiles of non-MCR operators are also similar to those of MCR operators, it could be good evidence supporting the existence of a homogeneous operational culture across operating personnel working in NPPs. Table 2 summarizes the age and operational experience of participants belonging to domestic NPPs, and Figure 1 shows the results of these comparisons.

Table 1. 11 Cultural Dimensions with Their Meaning; reproduced from Ref. [10]

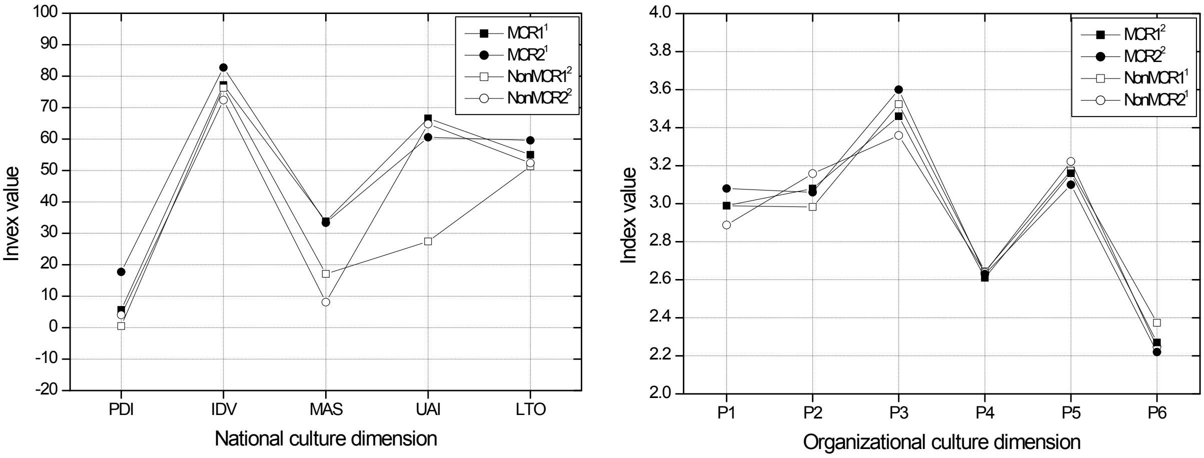
Culture	Dimension	Meaning
National culture	PDI (Power Distance Index)	The extent to which the less powerful members of institutions and organizations within a society expect and accept that power is distributed unequally
	IDV (Individualism Index)	Individualism stands for a society in which the ties between individuals are loose
	MAS (Masculinity Index)	Masculinity stands for a society in which emotional gender roles are clearly distinct; Femininity stands for a society in which emotional gender roles overlap
	UAI (Uncertainty Avoidance Index)	The extent to which the members of institutions and organizations within a society feel threatened by uncertain, unknown, ambiguous, or unstructured situations
	Long-term Orientation Index (LTO)	Long-term Orientation stands for a society that fosters virtues oriented towards future rewards, in particular perseverance and thrift
Organizational culture	P1 (process vs. result oriented)	In a result oriented culture, people perceive themselves to be comfortable in unfamiliar situations
	P2 (employee vs. job oriented)	An employee-oriented organization takes responsibility for people’s welfare, and important decisions are often made by groups or committees
	P3 (parochial vs. professional	With high professional scores, the employees’ private lives are perceived to be their own business, where they are hired on the basis of their professional skills only
	P4 (open vs. closed system)	In an open culture, almost everyone fits into the organization, and it takes only a few days to feel at home
	P5 (loose vs. tight control)	Tight control cultures are cost-conscious, keep meeting times, and jokes about the company are rare
	P6 (normative vs. pragmatic)	Employees of normative cultures view their tasks toward the outside world as implementations of inviolable rules, correctly following organizational procedures

Table 2. Summary of participants

Unit	Belong to	Designation	Number of participants	Age (year)		Experience (year)	
				Mean	SD*	Mean	SD*
1	MCR	MCR1	24	39.08	4.99	12.17	7.19
1	Non-MCR	Non-MCR1	31	38.20	6.17	9.24	5.93
2	MCR	MCR2	20	40.30	6.13	12.67	5.45
2	Non-MCR	Non-MCR2	21	34.10	4.24	4.93	3.13

*SD is short for standard deviation.

From Fig. 1, at a glance, it seems that organizational culture profiles obtained from non-MCR operators are almost identical with those from MCR operators. In addition, except two dimensions (i.e., MAS and UAI), the national culture profiles of non-MCR operators appear to be congruent with those of MCR operators. This implies that operating personnel probably share similar cultural profiles. In this light, it is necessary to explain why operating personnel showed some discrepancies on two dimensions. In other words, if there is a reason clarifying why operating personnel have different values in these two dimensions, then it is possible to anticipate the existence of a common operational culture that is reproducible, predictable, and in common under the context of NPP operations. For example, in the MAS dimension, it seems that MCR operators have different values compared to non-MCR operators. In contrast, in the case of the UAI dimension, except non-MCR operators working in the Unit 1 (i.e., Non-MCR1), even Non-MCR2 showed similar values to those of MCR operators (i.e., MCR1 and MCR2). Of them, one plausible explanation on the MAS dimension is the responsibility of operating personnel working in MCRs.



1. MCR1 and MCR2 denote operating personnel working in the MCR of the Units 1 and 2, respectively.
2. NonMCR1 and NonMCR2 designate operating personnel working as non-MCR operators in the Units 1 and 2, respectively.

Figure 1. Cultural profiles identified from two groups of operating personnel; reproduced from Ref. [10]

According to Table 1, it is expected that the Masculinity will decrease when emotional gender roles are largely overlap. This allows us to assume that the value of the MAS dimension on a certain group will increase if all the group members have distinctive and unique roles and responsibilities. Conversely, if the distinctions of both roles and responsibilities among group members are blurred, it is expected that the value of the MAS dimension will decrease. In this regard, the values of the MAS dimension rated by MCR operators should be greater than those of non-MCR operators because the former have clear roles and responsibilities with respect to the operation of NPPs [13, 14]. On the contrary, in comparison with MCR operators, the roles and responsibilities of non-MCR operators are apt to be overlapped with respect to the situation of a local field. Therefore, although other causes may exist, it is promising that the roles and responsibilities of operating personnel is one of the important factors affecting the MAS dimension across operating personnel [10].

Unfortunately, this explanation does not seem to be enough for the UAI dimension because human operators belonging to the NonMCR2 group showed higher value comparing to those who belong to the NonMCR1 group. This strongly implies that there could be other causes resulting in the discrepancies of two dimensions. For this reason, the effect of the operational experience of human operators on each cultural dimension is investigated in detail.

3. THE EFFECT OF OPERATIONAL EXPERIENCE ON CULTURAL DIMENSIONS

First of all, a total of 52 non-MCR operators are assigned into four classes based on their operational experience that represents how many years they have worked in Westinghouse 3-loop PWRs. After that, the mean values of 11 cultural dimensions are calculated with respect to the each class of operational experience. Table 4 shows the number of non-MCR operators included in each class, and Table 5 summarizes the mean values of each cultural dimension. For example, the mean values of 5 cultural dimensions (i.e., PDI, IDV, MAS, UAI, and LTO) pertaining to the national culture of non-MCR operators who have experienced the operation of Westinghouse 3-loop PWRs greater than 15 years are -25.00, 83.00, 90.00, 31.00, and 60.00, respectively. It should be noted that the values of the

5 cultural dimensions usually vary between 0 and 100, but there are times when it could be below 0 or above 100 [9].

Table 3. Number of non-MCR operators involved in the four levels of operational experience

Level	Experience	Unit 1 (ratio)	Unit 2 (ratio)
1	< 5 years	9 (29%)	12 (57%)
2	5-10 years	10 (32%)	6 (29%)
3	10-15 years	4 (13%)	3 (14%)
4	> 15 years	8 (26%)	0 (0%)

Table 4. Mean values of 11 cultural dimensions with respect to experience levels

Level	PDI	IDV	MAS	UAI	LTO	P1	P2	P3	P4	P5	P6
1	9.76	65.00	17.14	37.86	51.43	3.17	3.14	3.51	2.54	3.16	2.10
2	-0.31	80.00	-11.88	63.75	50.00	2.94	2.90	3.77	2.60	3.04	2.25
3	0.71	86.43	-8.57	20.71	51.43	2.81	3.00	3.38	2.71	3.05	2.67
4	-25.00	83.00	90.00	31.00	60.00	2.73	3.20	2.93	3.00	3.40	2.33

From Table 4, two kinds of interesting tendencies can be identified. Figure 2 will be helpful for clarifying them.

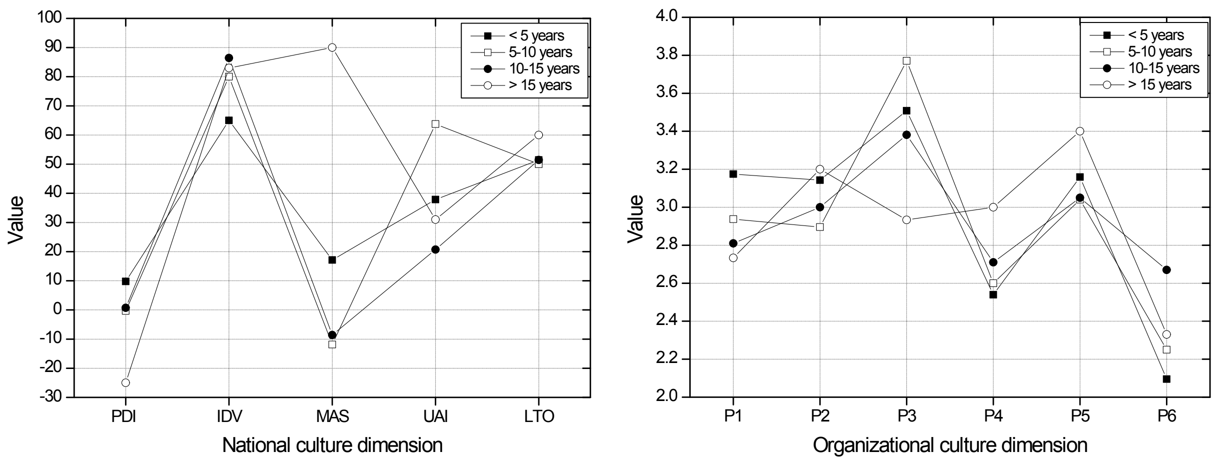


Figure 2. Cultural profiles with respect to the operational experience of non-MCR operators

The first tendency is that non-MCR operators who experienced the operation of Westinghouse 3-loop PWRs more than 15 years (i.e., *Level 4*) seem to have quite different cultural profiles comparing to others belonging to the rest three levels. For example, the value of MAS dimension observed from non-MCR operators involved in the *Level 4* is 90.00 while those of non-MCR operators belonging to the *Levels 1, 2*, and *3* are 17.14, -11.88 and -8.57, respectively. Similarly, the value of P3 dimension observed from the *Level 4* is 2.93 that is quite lower than the values gathered from the *Levels 1, 2* and *3*. This tendency could become more evident if we look at Fig. 3 in which cultural profiles corresponding to the Level 4 are not considered.

The second tendency is that, even though the cultural profiles of non-MCR operators who experienced plant operations more than 15 years are not considered, there are some discrepancies in several dimensions, such as the MAS and UAI. For example, from Fig. 3, the values of the MAS dimension observed from the *Levels 2* and *3* are quite close (i.e., -11.88 and -8.57) while that of the *Level 1* is relatively different (i.e., 17.14). In addition, it seems that the values of the UAI dimension gathered from the *Levels 1, 2,* and *3* are quite different each other (i.e., 37.68, 63.75, and 20.71, respectively).

At the same time, conversely say, the values of other dimensions are relatively close each other (e.g., the values of the LTO observed from the *Levels 1, 2* and *3* are almost identical). This tendency strongly alludes to the fact that, to some extent, the cultural profiles of a certain group could be *estimated* based on the weighted average of the cultural profiles of all group members with respect to their experience on plant operations.

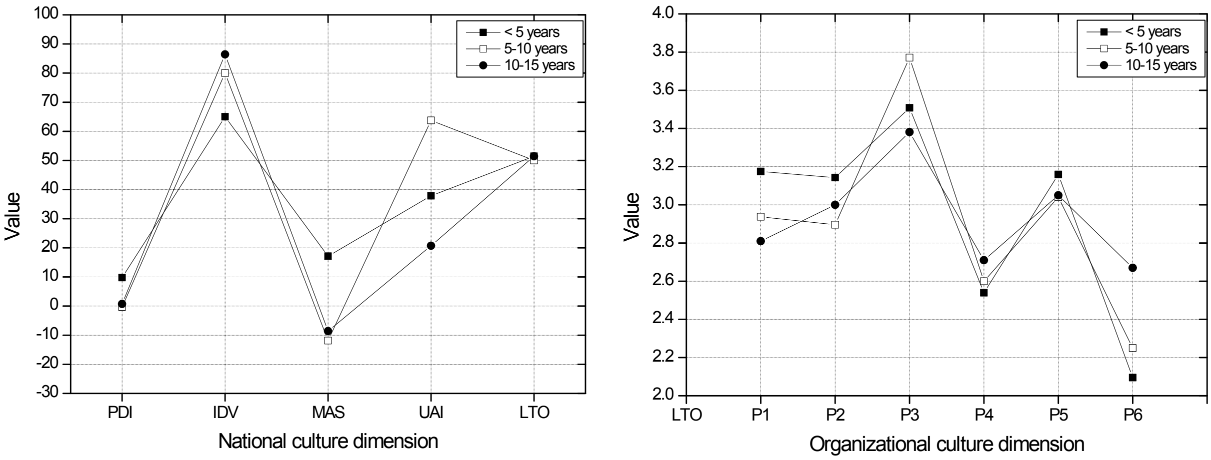


Figure 3. Cultural profiles for non-MCR operators belonging to the *Levels 1, 2* and *3*

For example, let us recall Table 3 in which the relative percentages of non-MCR operators are classified with respect to the four levels of operational experience. Based on these relative ratios, the value of the PDI dimension in the Unit 1 can be estimated by the weighted average of mean values with respect to the four levels of operational experience (refer to Fig. 4).

Level	Ratio
1	29%
2	32%
3	13%
4	26%

Level	PDI
1	9.76
2	-0.31
3	0.71
4	-25.00

$$0.29 \times 9.76 + 0.32 \times (-0.31) + 0.13 \times 0.71 + 0.26 \times (-25.00) = -3.63$$

Figure 4. Estimating the value of the PDI dimension in the Unit 1

In this way, all the values of 11 dimensions can be estimated. Figure 5 compares the cultural profiles of the Unit 1 with the estimated values of 5 cultural dimensions pertaining to the national culture.

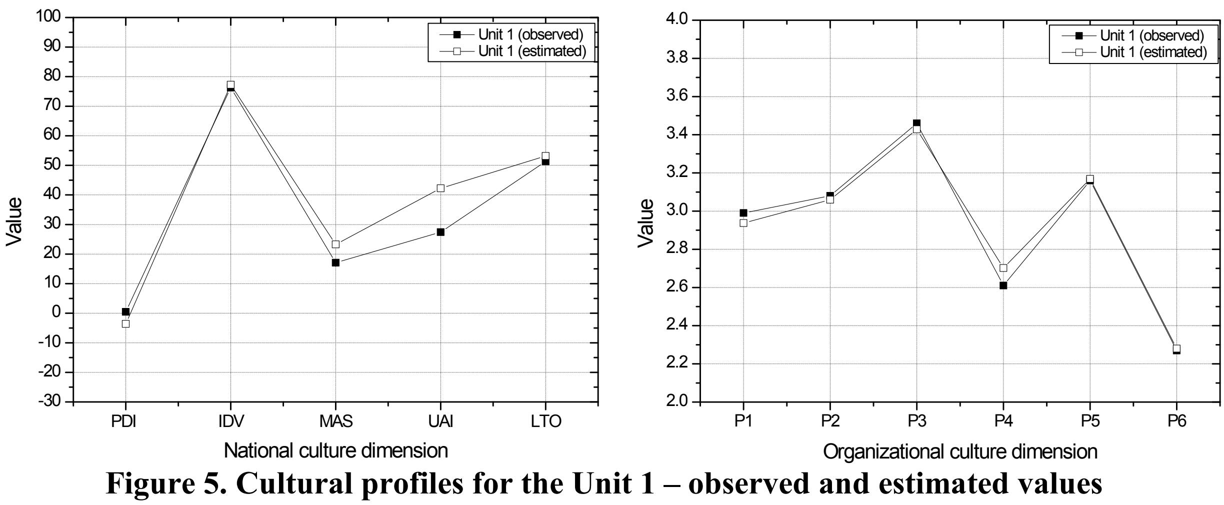


Figure 5. Cultural profiles for the Unit 1 – observed and estimated values

4. GENERAL CONCLUSION

It is evident that the amount of available data for conducting HRA is one of the decisive factors affecting the quality of HRA results. Unfortunately, the collection of HRA data is not easy because of several technical reasons including the cultural effect on the performance of human operators. In this light, several researchers empirically observed that, although there are some discrepancies, operating personnel seem to share similar cultural profiles even though they are working in NPPs located in different countries. In order to confirm this observation, it is indispensable to clarify the reason of discrepancies observed from the comparison between MCR operators and non-MCR operators.

In this study, as one of the practical approaches to unravel this question, the cultural profiles of non-MCR operators are investigated in detail with respect to their operational experience. To this end, the variations of cultural profiles are compared with respect to the four levels of operational experience. As a result, it is expected that, to some extent, the cultural profiles of a certain group could be *estimated* based on the weighted average of the cultural profiles of all group members with respect to their experience on plant operations. This means that the discrepancies could be soundly explained by the difference of operational experience among non-MCR operators. Therefore, although the result of this study is not sufficient for drawing a firm conclusion, it is possible to say that this study is able to contribute to start the very first step to scrutinize the possibility of a cross-cultural generalizability among operating personnel who have the responsibility of NPP operations.

Acknowledgements

This work was supported by Nuclear Research & Development Program of the National Research Foundation of Korea grant, funded by the Korean government, Ministry of Science, ICT & Future Planning (Grant Code: 2012M2A8A4025991).

References

[1] R. L. Boring. "*Fifty Years of THERP and Human Reliability Analysis*," Proc. 11th Probabilistic Safety Assessment and Management / European Safety and Reliability 2012 (PSAM11/ESREL 2012), Helsinki, Finland, June 25-29 (2012)

[2] J. Chang, and E. Lois. "*Overview of the NRC's HRA data program and current activities*," Proc. 11th Probabilistic Safety Assessment and Management / European Safety and Reliability 2012 (PSAM11/ESREL 2012), Helsinki, Finland, June 25-29 (2012)

[3] E. Lois, V. N. Dang, J. Forester, H. Broberg, S. Massaiu, M. Hildebrandt, P. Ø. Braarud, G. Parry, J. Julius, R. Boring, I. Männistö, and A. Bye. "*International HRA empirical study - Description of overall approach and pilot phase results from comparing HRA methods to simulator performance data*," NUREG/IA-2016, Vol. 1, Washington, DC: US Nuclear Regulatory Commission, 2009 (also issued as HWR- 844, OECD Halden Reactor Project Work Report, Halden, Norway, 2008)

[4] A. Bye, E. Lois, V. N. Dang, G. Parry, J. Forester, S. Massaiu, R. Boring, P. Ø. Braarud, H. Broberg, J. Julius, I. Männistö, I., and P. Nelson. "*International HRA empirical study - Results from comparing HRA method predictions to simulator data from SGTR scenarios*," NUREG/IA-2016, Vol. 2, Washington, DC: US Nuclear Regulatory Commission, 2011 (also issued as HWR-915 OECD Halden Reactor Project Work Report, Halden, Norway, 2010)

[5] J. Marble, L. Huafei, M. Presley, J. Forester, A. Bye, V. N. Dang, and E. Lois. "*Results and insights derived from the intra-method comparisons of the US HRA empirical study*," Proc. 11th Probabilistic Safety Assessment and Management / European Safety and Reliability 2012 (PSAM11/ESREL 2012), Helsinki, Finland, June 25-29 (2012)

[6] Y. J. Chang, D. Bley, L. Criscione, B. Kirwan, A. Mosleh, T. Madary, R. Nowell, R. Richards, E. M. Roth, S. Sieben, and A. Zoulis. "*The SACADA database for human reliability and human performance*," http://dx.doi.org/10.1016/j.ress.2013.07.014 (2013)
[7] D. Gertman, S. Novack, and J. Marble. "*Culture representation in human reliability analysis*," Proc. Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC).
[8] Y, Kim, J. Park, and W. Jung. "*Measuring variability of procedure progression in proceduralized scenarios*," Annals of Nuclear Energy, vol. 49, p. 41-47 (2012)
[9] G. Skraaning, J. Park, and J. O. Heimdal. "*Cross-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 (2012)
[10] J. Park, and W. Jung. "*Comparing cultural profiles of MCR operators with those of non-MCR operators working in domestic nuclear power plants*," Submitted to Reliability Engineering and System Safety.
[11] Hofstede, G. "*Culture's consequences*," 2nd ed., Saga Publication, 2001
[12] J. O. Heimdal. "*Operational culture literature review*," HWR-901, OECD Halden Reactor Project, Halden, Norway (2007)
[13] N. Moray. "*Cultural and national factors in nuclear safety,*" In: Safety Culture in Nuclear Power Operations, Wilpert, B., and Itoigawa, N. (eds.), p. 37-59, Taylor and Francis, 2001, London
[14] J. Park. "*The complexity of proceduralized tasks*," Springer-Verlag, 2009, Berlin