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CONCEPTUAL BIG DATA CASE STUDY TO IDENTIFYING RISKS OF NEW NUCLEAR TECHNOLOGIES

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New technologies associated with nuclear power plants are being introduced regularly. However, many of the risks and uncertainties associated with these new nuclear technologies have yet to be identified. In this study, the risks related to newly-developed nuclear technologies were determined through an extensive review of the extant literature. A qualitative visual content analysis was selected as the research method employed to identify words repeatedly occurring in 147 journal articles. Through this conceptual "big data" approach, frequently mentioned words were identified using a co-occurrence map. The analysis results were then grouped into four categories: fuel resources, operational system designs, nuclear reactor cooling systems, and steam generators. Words used repeatedly to reference these four key categories were determined to also represent potential causes of risk factors. Many texts could be analyzed in a short period of time through the use of visual content analysis software. Frequently emphasized correlating words were then identified. This big data approach can also be applied to additional nuclear power practices to identify other uncertainties. Last, the limitations of a visual content analysis employed as a risk identification approach were revealed through this study.

Keywords: Risk identification, Visual text mining, Content analysis.

1 INTRODUCTION

Nuclear power is a major worldwide energy resource that accounted for 2,571 billion kWh, or about 11% of the global electricity production, in 2015. This immense amount of electricity was generated by approximately 450 nuclear reactors that are currently being operated in 30 countries (WNA 2018a). Governments looking for sustainable energy resources are aggressively investing in nuclear power in their respective countries. In 2018, approximately 50 nuclear power reactors were under construction in 13 countries (WNA 2018a). Moreover, nuclear power plant construction is just one representative international construction projects because seven countries – France, Japan, USA, Russia, Canada, South Korea, and Argentina – are capable of exporting nuclear reactors to other countries (NPP Exporters 2018). Although nuclear power is attractive as an energy resource for the next generation, the risks and uncertainties associated with it are inherent in nuclear power plant construction projects. These risks usually originate from non-recurring uncertainties that cannot be processed statistically such as social trends, technological developments, and economic changes (Hertz and Thomas 1984). The owners and contractors of international construction project must assess the political, geographic, economic, environmental, regulatory, and cultural risk factors before they engage in implementing alternatives if they hope to achieve business success (Walewski *et al*. 2006). Poor construction project performance and unsuccessful delivery are more common in international construction projects than in domestic efforts (Walewski *et al*. 2006). Thus, risk identification is crucial, especially in terms of nuclear power plant construction, if issues are to be avoided and proactive responses planned. Also, to comprehensively identify the risks of construction projects, both internal and external dangers must be considered at the same time (see Figure 1) (Khodeir and Mohamed 2015).

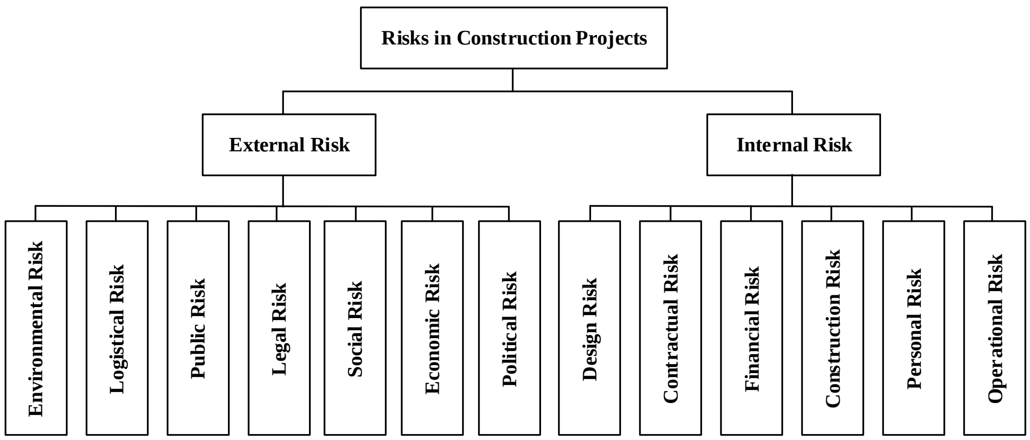

Figure 1 . General risk framework for construction projects (Khodeir and Mohamed 2015).

2 PROBLEM STATEMENTS

Various traditional and advanced technologies are employed in nuclear power plant construction projects. Even among the same types of construction, huge differences can exist in terms of schedule, cost, quality, and resources demanded, depending on the applied technology. In addition, countries that export nuclear reactors to other countries continue to develop new technologies in order to remain competitive in the market. However, new technology means additional risk because related uncertainties have yet to be investigated from a long-term perspective. To prevent and resiliently respond to risks, these issues should be classified systematically and their causes identified. Uncertainties associated with nuclear power can cause irreversible disasters. Thus, this study explored the causes of potential risks associated with new nuclear power plant technologies.

3 RESEARCH METHOD

The risks were identified by quantitative and qualitative risk analysis methods; the general process of risk identification is shown in Figure 2. Quantitative research methods were applied when numerical data existed. These methods included multivariate statistical models, event trees, system dynamics models, sensitivity analyses, project simulations, stochastic simulation models, and additive models. In contrast, the methods of qualitative risk assessment were applied to situations involving risks that could not be quantified, were beyond the scope of the analytical models, or involved uncertainties that could not be processed statistically. These uncertainties were caused by unique situations that were not repeatable or by technology development, economics, or social changes. The qualitative risk analysis methods included project definition rating indexes, pareto diagrams, and failure modes and effects analyses (National Research Council 2005).

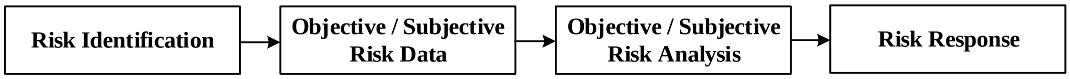

Figure 2. Risk identification process.

In this study, the research method selected to identify risk factors and their causes, as derived from the texts, was qualitative conventional content analysis (Hsieh and Shannon 2005). Identification of risk factors from repeated mention in an extensive literature review is not easy if one attempts to manually read each study. Therefore, in this study an extensive literature review was conducted via a visual text analysis method. Many journal articles and technical papers associated with nuclear power plant construction can be obtained online. However, newly developed nuclear power technologies cannot be researched in old publications. To search for trends in cutting-edge nuclear technology, the entirety of the Journal of Nuclear Energy and Technology (JNET) online was gathered for submission to the visual content analysis software because JNET provides articles associated with nuclear energy, training, science, and technology (NET 2018). The total number of articles collected was 169. Among these 169, 22 were excluded after reviewing the abstracts; their topics were outside the scope of this research. Thus, 147 articles from JNET were analyzed by KH Coder, the visual content analysis software was illustrated in Figure 3.

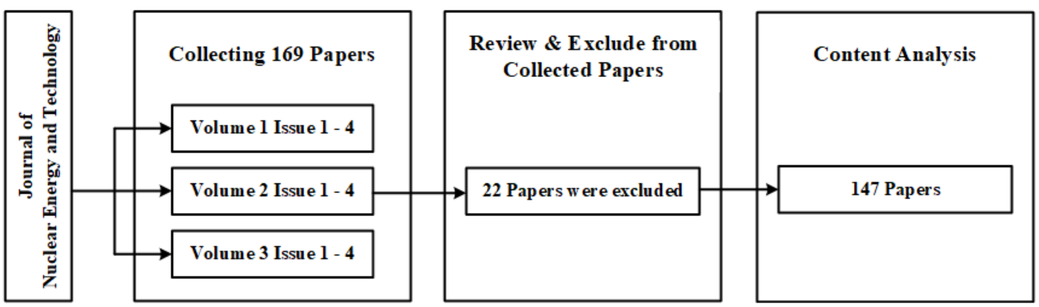

Figure 3. Data collection process.

This study was based on a conceptual big data approach. Through big data, new correlations were found among words mentioned repeatedly in an extensive literature review (Boyd and Crawford 2011). The advantage of visual content analysis software is that many occurrences of repeated words in a sizeable collection of literature can be counted in a short period of time (Weber 1990). KH Coder, the software selected for this study, is advantageous for counting word frequency and generating co-occurrence maps (Higuchi 2018). Co-occurrence maps are a powerful visualization tool for examining emphasized and frequently-connected words at a glance (Ryan and Bernard 2003). The repeated / emphasized words in this research were determined to be important nuclear energy risk factors that require attention. Words related to the emphasized words were identified as elements of risk.

4 RESULTS AND DISCUSSION

The results of the visual content analysis are shown in Table 1. The repeated words of greatest importance among the 30 most frequent words associated with new nuclear energy technologies, as obtained from 147 journal papers, were: reactor, temperature, neutron, coolant, heat, steam, design, uranium, and plutonium. To identify risks based on these repeated words, words related to the most frequently mentioned words needed to be identified. Thus, co-occurrence maps provided by a function of the visual content analysis software were generated.

Table 1. Consistency analysis results.

Count	Word	Frequency	Count	Word	Frequency
1	fuel	2,041	16	rate	662
2	reactor	1,857	17	parameter	618
3	system	1,300	18	process	593
4	power	1,150	19	core	557
5	value	1,061	20	heat	554
6	temperature	977	21	steam	543
7	calculation	870	22	material	520
8	result	825	23	method	520
9	neutron	814	24	energy	496
10	model	751	25	level	490
11	datum	750	26	water	486
12	flow	743	27	design	478
13	coolant	712	28	uranium	478
14	time	709	29	plutonium	450
15	operation	701	30	unit	438

The generated co-occurrence map is shown in Figure 4. Through this map, risk factors associated with new nuclear power plant technologies were categorized. The first risk factor was related to fuel resources such as uranium and plutonium that are used to generate energy in nuclear reactors. The risk factor related to uranium is human health dangers when uranium is mined and processed because doing so emits radiation (National Research Council 2011). Also, plutonium is a radioactive substance and dangerous when inhaled (Voelz 2000). The second risk factor was related to the design of a reactor's operational system. Uncertainties associated with the design of newly developed nuclear technologies could include design defects stemming from a lack of specification, differences in site conditions, or communication problems between designers and installers (Perry and Hayes 1985). The third risk was connected to the temperature of a nuclear reactor. Most of the new technologies introduced in the literature dealt with coolants used to control the temperature in a reactor and keep it under 350^{o}C (WNA 2018b); this reduces the likelihood that an explosion will occur. The fourth most frequently mentioned word was related to steam generators. Many new technologies associated with stream generators have been introduced. Electricity is generated when a steam turbine is made to spin by steam produced from heated water (Trigilio 2006). This type of generator is not directly related to a risk. However, many studies have been conducted on steam pressure generators, meaning that technical change factors such as new laws and designs related to new steam generator technology could produce risk during a long-term project lifecycle.

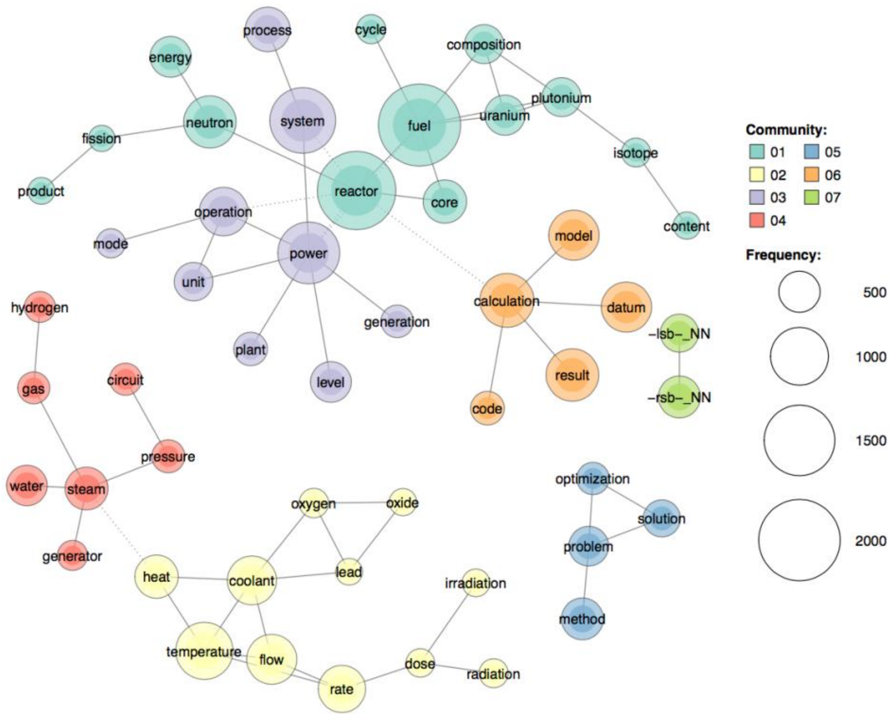

Figure 4. Co-occurrence map.

5 CONCLUSION

In this study, the risks related to newly developed nuclear technologies were identified using visual context analytics (i.e. the KH Coder). The texts of 147 papers published in the Journal of Nuclear Energy and Technology were analyzed through a big data approach. Four potential risk categories associated with nuclear technologies were identified: fuel resources, operational system designs, nuclear reactor cooling systems, and steam generators. Through a co-occurrence map, words correlating with the four categories were determined. These words could be causes of risks or newly determined key words. However, a deep-level analysis to determine the exact causes of these uncertainties is difficult. Thus, these texts should be manually analyzed by readers after specific uncertainties are identified by the visual context analysis software. This limitation should be addressed as a topic of future work.

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