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A Suggestion of Contingency Guidelines According to ISDC Based on Overseas Contingency Data

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When decommissioning nuclear power plant (NPP), the first task performed is cost estimation. This is an important task in terms of securing adequate decommissioning funds and managing the schedule. Therefore, many countries and institutions are conducting continuous research and also developing and using many programs for cost estimation. However, the cost estimated for decommissioning an NPP typically differs from the actual cost incurred in its decommissioning. This is caused by insufficient experience in decommissioning NPPs or lack of decommissioning cost data. This uncertainty in cost estimation can be in general compensated for by applying a contingency. However, reflecting an appropriate standard for the contingency is also difficult. Therefore, in this study, data analysis was conducted based on the contingency guideline suggested by each institution and the actual cost of decommissioning the NPP. Subsequently, TLG Service, Inc.'s process, which recently suggested specific decommissioning costs, was matched with ISDC (International Structure for Decommissioning Costing)'s work breakdown structure (WBS). Based on the matching result, the guideline for applying the contingency for ISDC's WBS Level 1 were presented. This study will be helpful in cost estimation by applying appropriate contingency guidelines in countries or institutions that have no experience in decommissioning NPPs.

Keywords: Cost estimation, Contingency, Decommissioning, ISDC, WBS

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1. Introduction

Many nuclear power plants (NPP) around the world are about to be decommissioned. As a result of verifying the IAEA PRIS data, 203 NPPs have permanently shutdown as of May 2022 [1]. 132 NPPs out of a total of 441 NPPs have been in operation for over 40 years [2]. This corresponds to 29.93% of the total. In other words, more NPPs will be shutdown.

The first task to be performed in decommissioning after shutdown is the cost estimation of NPP decommissioning. Cost estimation is a very important task in terms of securing funds and managing schedules for the decommissioning of NPPs. Accordingly, the cost of decommissioning NPPs is being estimated in domestic and foreign countries, and related research is continuously being conducted. However, the results of the NPP predecommissioning cost estimation and the actual cost of decommissioning work incurred in decommissioning NPP are different. Uncertainty in cost estimation is caused by various factors; uncertainty of basic data, lack of data, changes in cost estimation parameters during decommissioning, and variables occurring in the decommissioning procedure. Parameters that affect the estimation of NPP decommissioning costs include decommissioning regulatory requirements, licensing costs, and technical standards [3, 4, 5]. Therefore, a contingency is applied to solve the uncertainty in the cost estimation of NPPs and to secure adequate funds for decommissioning.

Contingencies are expenses incurred to deal with unexpected events that may affect the project as they occur throughout the project [6, 7]. However, contingencies depend on the estimation of the cost assessor and are the least understood internationally [8]. In addition, it is difficult to suggest an appropriate contingency in a country that has no experience in decommissioning NPPs. Therefore, in this study, the recommendations presented by the institution and the actual data on the decommissioning cost of NPP were analyzed. Based on the analysis results, it was intended to present guidelines for a contingency to the decommissioning process when estimating the cost of decommissioning NPP.

2. Contingency Definition

The contingency is defined as follows by Association for the Advancement of Cost Engineering International (AACEI). Contingency is an amount added to the estimate to allow for items of uncertain effectiveness and likely to incur additional costs [9]. The International Structure for Decommissioning Costing (ISDC) defines specific provisions for cost factors that cannot be predicted within defined project scope [10]. Generally, it is estimated by applying statistical analysis or judgment based on past project experience [9]. The contingency can be applied to the total cost estimation result or to the cost estimation result for each task [11].

The contingency can be applied to four major costing items, which are composed of man-hour calculation, experience-based cost estimations, project organization-related, and other costs. For each, it is estimated as a percentage value, and the cost is re-estimated by taking into account the cost contribution for each ratio [12]. In this case, the following items are not included in the contingency [8].

- Major scope changes such as changes in end product specification, capacities, building sizes, and location of the asset or project
- Extraordinary events such as major strikes and natural disasters
- Management reserves
- Escalation and currency effects

In case the recommendation of the contingency for each process is applied to the actual cost estimation, the reviewer can assess how the cost estimation is applied to the contingency through Table 1 below [8].

Table 1. Contingency application assessment checklist

Contingency	YES	NO	N/A
Does the estimate include Contingency?			
Is the definition of Contingency included in the report?			
Is the contingency stated as an overall single-valued percentage?			
Is the single value basis justified by reference?			
Is contingency calculated on a line-item basis (individual contingency % for each element of cost)?			
Are the percentages for contingency elements explained?			
Are the contingency percentage bases identified (by reference source or committee judgment)?			
Was Contingency developed using the Risk Analysis?			
Does the report identify how Contingency was developed from the Risk Analysis?			

Table 2. Contingency ratio in the AIF/NESP-036 report

Decommissioning process	Contingency (%)
Engineering	15
Utility (Energy) and DOC Costs	15
Decontamination	50
Remove Contaminated Instruments	25
Remove Contaminated Concrete	25
Steam generator, pressurizer, and circulation pump removal	25
Reactor Removal (Cutting)	75
Reactor (waste) packaging	25
Reactor (waste) transport	25
Reactor (waste) disposal	50
Radioactive waste packaging	10
Radioactive waste transport	15
Radioactive waste treatment	25
Non-contaminated instruments removal	15
Supply/Consumables	25

3. Criteria and Examples of Contingency Application

Recommendations for contingencies are presented in the AIF/NESP-036 report, NRC, and OECD/NEA. The AIF/NESP-036 is a report prepared by TLG Service, Inc. based on the experience of decommissioning activities of a NPP in 1986 [13]. It includes a list of decommissioning tasks and unit cost factors (UCF). This was prepared to systematize the decommissioning cost of commercial NPPs and to present a common cost estimation guideline among agencies. In this report, as shown in Table 2, each contingency according to 15 decommissioning processes is presented [14]. The US NRC designated 25% of the total cost as a contingency [15]. In the OECD/NEA reports, it is suggested to apply the maximum contingency of 30% in the cost estimation because there is a maximum of 30% uncertainty in the estimation of the current NPP decommissioning cost estimation [11, 16].

Examples of contingencies applied in the decommissioning NPPs in each country are listed in Table 3 [16, 17]. In Finland, Slovakia, Switzerland, the UK, Belgium, France, Sweden, Canada, and the UK, cost estimation has been performed by adding an average value or a contingency within the range of the total cost.

In the case of Sweden, it was confirmed that the contingency was applied at a rate of 6% to the total cost. However, when decommissioning the BWR type Oskarshamn NPP, it was confirmed that the contingency was applied according to the decommissioning process of ISDC. ISDC is a nuclear decommissioning classification system jointly developed by OECD/NEA, IAEA and EU. This was developed to estimate the cost by matching the cost factors based on the Work Breakdown Structure (WBS) constructed as a hierarchical structure of the decommissioning project. The purpose is to improve the consistency of decommissioning cost estimates across countries [10]. ISDC is a recommendation when

Table 3. Contingency ratio by country

Country	Average	Range	Reference
Finland	9%	9.08−9.1%	[16]
Slovak Republic	8%	0.2−16.5%	[17]
Switzerland	30%	-	[16]
United Kingdom	17%	1−24%	[17]
Belgium	15%	-	[17]
France	15%	-	[17]
Sweden	6%	-	[17]
Canada	-	10−30%	[17]
United States	25%	-	[17]

estimating the cost of decommissioning NPPs and is applied to cost estimation programs in many countries.

Table 4 shows the contingencies by the process for the decommissioning of the Oskarshamn NPP, a type of BWR prepared by Svensk Kärnbränslehantering AB in Sweden in accordance with the OECD/NEA format [12]. ISDC's WBS Level 1 presents the contingency according to 11 items. Among the items of Level 1, miscellaneous expenditures reflect the highest rate of contingency, and pre-decommissioning activities have the lowest rate of contingency. Contingencies are not provided for additional activities for safe enclosure, research and development, fuel and nuclear material.

Table 4. Contingency for each process at the time of decommissioning of the Oskarshamn NPP

Decommissioning process	Contingency (%)
01 Pre-decommissioning activities	10
02 Facility shutdown activities	15
03 Additional activities for safe enclosure	-
04 Dismantling activities within the controlled area	13
05 Waste processing, storage and disposal	13
06 Site infrastructure and operation	15
07 Conventional dismantling, demolition and site restoration	15
08 Project management, Engineering and support	17
09 Research and development	-
10 Fuel and nuclear material	-
11 Miscellaneous expenditures	29

TLG Service, Inc. has been preparing decommissioning cost estimates since 1982 and specializes in decommissioning engineering and planning. In this study, the WBS of ISDC and the NPP decommissioning cost estimation results of TLG were referred to match the appropriate contingency for each process. TLG presents cost results for two scenarios; DECON and SAFSTOR. Table 5 below is information on NPPs that TLG presents

Table 5. TLG Service, Inc. decommissioning case

NPP Type	NPP Name	Decommissioning Scenario	
		DECON	SAFSTOR
PWR	Comanche Peak NPP Unit 1	●	
	Comanche Peak NPP Unit 2	●	
	Arkansas Nuclear One Unit 1	●	
	Arkansas Nuclear One Unit 2	●	
	Donald C. Cook Nuclear Plant Unit 1	●	
	Donald C. Cook Nuclear Plant Unit 2	●	
	Crystal River Unit 3 Nuclear Generation Plant		●
	Indian Point Energy Center Unit 3		●
	Zion Nuclear Power Station Unit 1		●
	Zion Nuclear Power Station Unit 2		●
BWR	Columbia Generating Station	●	●
	Oyster Creek		●
	Monticello	●	
	Pilgrim Nuclear Power Station		●
	Vermont Yankee Nuclear Power Station		●

cost results for nuclear decommissioning [18-28]. Contingency for 10 Pressurized Water Reactors (PWRs) and 5 Boiling Water Reactors (BWRs) were reviewed. Among them, 8 NPPs correspond to the DECON scenario, including Comanche Peak NPP Unit 1, and 8 NPPs, including the Crystal River Unit 3 Nuclear Generation Plant, correspond to the SAFSTOR scenario.

4. Result and Discussion

Table 6 below shows the results of the cost estimation of each NPP decommissioning process carried out by TLG for each scenario. The NPP decommissioning process consists of 13 items from PERIOD 0a - Pre-Shutdown Early Planning to PERIOD 5b - Site Restoration. Different processes

Table 6. Contingency by the process for each TLG decommissioning scenario

(Unit : %)

Scenario	DECON		Scenario	SAFSTOR	
NPP	Columbia, Monticello, Comanche Peak Unit 1, Comanche Peak Unit 2, Arkansas Unit 1, Arkansas Unit 2, DC Cook Unit 1, DC Cook Unit 2		NPP	Columbia, Oyster Creek, Crystal River Unit 3, Indian Point Unit 3, Pilgrim, Zion Unit 1, Zion Unit 2, Vermont Yankee	
Decommissioning process	Average	Range	Decommissioning process	Average	Range
PERIOD 0a - Pre-Shutdown Early Planning	13	13	PERIOD 0a - Pre-Shutdown Early Planning	9	4−13
PERIOD 1a - Shutdown through Transition	13	13	PERIOD 1a - Shutdown through Transition	13	13
PERIOD 1b - Decommissioning Preparations	15	14−16	PERIOD 1b - SAFSTOR Limited DECON Activities	18	17−19
PERIOD 2a - Large Component Removal	19	18−21	PERIOD 1c - Preparations for SAFSTOR Dormancy	14	14
PERIOD 2b - Site Decontamination	15	14−18	PERIOD 2a - SAFSTOR Dormancy with Wet Spent Fuel Storage	12	8−13
PERIOD 2c - Spent Fuel Delay prior to SFP Decon	13	12−13	PERIOD 2b - SAFSTOR Dormancy with Dry Spent Fuel Storage	13	12−13
PERIOD 2d - Decontamination	16	15−18	PERIOD 2c - SAFSTOR Dormancy without Spent Fuel Storage	11	3−13
PERIOD 2f - License Termination	17	15−18	PERIOD 3a - Reactivate Site Following SAFSTOR Dormancy	13	13−15
PERIOD 3b - Site Restoration	13	13	PERIOD 3b - Decommissioning Preparations	15	13−16
PERIOD 3c - Fuel Storage Operations/ Shipping	12	12−13	PERIOD 4a - Large Component Removal	19	13−23
PERIOD 3d - GTCC shipping	13	12−14	PERIOD 4b - Site Decontamination	16	15−17
PERIOD 3e - ISFSI Decontamination	17	13−20	PERIOD 4f - License Termination	16	2−18
PERIOD 3f - ISFSI Site Restoration	13	13	PERIOD 5b - Site Restoration	13	12−16
Total Contingency	15	15−16	Total Contingency	15	15−16

are applied depending on the decommissioning scenario, but the general framework is similar.

In this study, the ratio of contingencies according to the process for each application scenario of each NPP was confirmed, and the average value and range of the applied contingencies were derived. As a result, even with the same process, if the scenarios were different, the reflected contingency ratios were different. In addition, the ratio of total contingencies according to the total cost of decommissioning NPPs was confirmed. That most NPPs apply a contingency of 15% to 16% even in different decommissioning scenarios, and on average, 15% of the total decommissioning cost is applied.

After that, the decommissioning process performed by TLG was matched with ISDC WBS. This was done at the lowest level in the WBS, and this approach can maintain transparency in the establishment of results [16]. In this study, decommissioning scenarios were classified into DECON and SAFSTOR. Then, the WBS sub-items of TLG and ISDC were reviewed and matched for similar tasks. As a result, it was confirmed that the matching was shown in Table 7 below. Matching items are different for each scenario. In the DECON scenario, the items of additional activities for safe enclosure, site infrastructure and operation, project management, engineering and support, research and development of ISDC were not matched. In the SAFSTOR scenario, the items of Facility shutdown activities, site infrastructure and operation, project management, engineering and support, research and development, fuel and nuclear material of ISDC were not matched.

Since the composition and structure of the cost items of TLG and ISDC are different, it is difficult to match them. TLG's WBS consists of 13 items. The sub-items differ by decommissioning scenario and NPP type. TLG's cost categories consist of DECON cost, removal cost, packaging cost, transport cost, off-site processing cost, LLRW disposal cost, other cost, contingency, and total cost [16].

ISDC WBS Level 1 consists of 11 items, and each item is composed of sub-items. ISDC presents standard decommissioning activities as a hierarchical structure for all types of nuclear facilities and decommissioning activities. The cost category consists of labor cost, investment cost, expenses, and contingency. The hierarchical structure consists of cost categories, typical activity (level 3), activity groups (level 2), and principal activities (level 1) [10].

Because of these structural differences, one-to-one matching is difficult. If there is no one-to-one matching, the WBS sub-items of TLG and ISDC are compared. Thereafter, ISDC WBS level 3 including the most WBS sub-items of TLG is confirmed. WBS level 1 corresponding to ISDC level 3 is derived as a result value.

Based on the matching results, the contingency guideline according to ISDC WBS for each type of NPP was presented. Table 8 presents the average value of contingencies according to the process for each type of NPP through the report and case data that presented contingencies. The applied data are the AIF/NESP-036 report value, the Oskarshamn NPP cost estimation result, and the result value in Table 6. The contingency provided in the AIF/NESP-036 report was also presented by matching it with the ISDC WBS. The contingency ratio presented in the AIF/NESP-036 report is based on the PWR, so it is included in the PWR in Table 8 below.

There is a difference between the AIF/NESP-036 report and the cost estimation results performed by TLG, which is believed due to the large difference in evaluation time. With the development of technologies such as decommissioning technology and the increase of various decommissioning experiences, it will be possible to apply a more accurate contingency. Therefore, it is considered to reflect TLG's contingencies more realistic.

As a result of examining the cost estimation results performed by TLG, in the case of PWR, the contingency of each process was reflected in the range of 13% to 18.83% in the DECON scenario, and 12.17% to 19.25% in the SAFSTOR scenario. For BWR, the contingency for each process is reflected in the range of 13% to 19.67% in the DECON scenario and 11.83% to 18.25% in the SAFSTOR scenario.

Table 7. TLG decommissioning process and ISDC WBS matching result

ISDC decommissioning process	TLG decommissioning process	
	DECON	SAFSTOR
01 Pre-decommissioning activities	PERIOD 0a - Pre-Shutdown Early Planning	PERIOD 0a - Pre-Shutdown Early Planning
	PERIOD 1b - Decommissioning Preparations	PERIOD 1b - SAFSTOR Limited DECON Activities
	-	PERIOD 3b - Decommissioning Preparations
02 Facility shutdown activities	PERIOD 1a - Shutdown through Transition	PERIOD 1a - Shutdown through Transition
03 Additional activities for safe enclosure	-	PERIOD 1c - Preparations for SAFSTOR Dormancy
		PERIOD 3a - Reactivate Site Following SAFSTOR Dormancy
04 Dismantling activities within the controlled area	PERIOD 2a - Large Component Removal	PERIOD 4a - Large Component Removal
05 Waste processing, storage and disposal	PERIOD 2c - Spent fuel delay prior to SFP decon	PERIOD 2a - SAFSTOR Dormancy with Wet Spent Fuel Storage
	PERIOD 2d - Decontamination	PERIOD 2b - SAFSTOR Dormancy with Dry Spent Fuel Storage
	-	PERIOD 2c - SAFSTOR Dormancy without Spent Fuel Storage
06 Site infrastructure and operation	-	-
07 Conventional dismantling, demolition and site restoration	PERIOD 2b - Site Decontamination	PERIOD 4b - Site Decontamination
	PERIOD 3b - Site Restoration	PERIOD 5b - Site Restoration
08 Project management, Engineering and support	-	-
09 Research and development	-	-
10 Fuel and nuclear material	PERIOD 3c - Fuel Storage Operations/Shipping	-
	PERIOD 3d - GTCC shipping	-
	PERIOD 3e - ISFSI Decontamination	-
	PERIOD 3f - ISFSI Site Restoration	-
11 Miscellaneous expenditures	PERIOD 2f - License Termination	PERIOD 4f - License Termination

Regardless of the NPP type, the DECON scenario applies the lowest contingency for facility shutdown activities and the highest for dismantling activities within the controlled area. In the SAFSTOR scenario, the lowest contingency ratio is applied for waste processing, storage and disposal processes, and the highest contingency ratio is applied for dismantling activities within the controlled area.

As a result of analyzing the average value of TLG's contingency by NPP type, both PWR and BWR had the highest contingency ratios in the order of '04 dismantling activities within the controlled area' and '11 miscellaneous expenditures'.

As a result of analyzing the average value of total contingency by NPP type, the contingency ratio of item '03

Table 8. Guidelines for applying contingencies by process and type of NPP

	PWR				BWR			
	AIF/NESP -036	TLG DECON	TLG SAFSTOR	Average TLG / (Total)	SKB	TLG DECON	TLG SAFSTOR	Average TLG / (Total)
01 Pre-decommissioning activities	15.00	14.25	15.25	14.75 / (14.83)	10.00	14.17	12.00	13.09 / (12.06)
02 Facility shutdown activities	-	13.00	-	13.00 / (13.00)	15.00	13.00	13.00	13.00 / (13.67)
03 Additional activities for safe enclosure	50.00	-	13.00	13.00 / (31.50)	-	-	13.50	13.50 / (13.50)
04 Dismantling activities within the controlled area	37.50	18.83	19.25	19.04 / (25.19)	13.00	19.67	18.25	18.96 / (16.97)
05 Waste processing, storage and disposal	25.00	15.10	12.17	13.64 / (17.42)	13.00	15.33	11.83	13.58 / (13.39)
06 Site infrastructure and operation	-	-	-	-	15.00	-	-	- / (15.00)
07 Conventional dismantling, demolition and site restoration	15.00	13.75	14.88	14.32 / (14.54)	15.00	14.50	14.63	14.57 / (14.71)
08 Project management, Engineering and support	-	-	-	-	17.00	-	-	- / (17.00)
09 Research and development	-	-	-	-	-	-	-	-
10 Fuel and nuclear material	-	13.31	-	13.31 / (13.31)	-	14.17	-	14.17 / (14.17)
11 Miscellaneous expenditures	-	16.50	13.75	15.13 / (15.13)	29.00	16.67	17.25	16.96 / (20.97)

additional activities for safe enclosure' was high in PWR, and the contingency ratio of item '11 miscellaneous expenditures' was high in BWR. As such, it is judged that an appropriate contingency can be applied by referring to the data based on the actual decommissioning cost estimation experience.

5. Conclusion

Currently, many NPPs in domestic and foreign countries are about to be decommissioned. The results of the NPP decommissioning cost estimation performed before the decommissioning have uncertainty, and the contingency is reflected to complement the unavoidable discrepancy. In reflecting the contingency, it is based on actual decommissioning experience, but in a country without decommissioning experience such as Korea, it is difficult to present a guideline for applying the contingency due to the lack of actual decommissioning experience data and cost estimation result data. In addition, the contingency is affected by the way the person who estimates it applies. Therefore, it is necessary to present a guideline for this, and a distinct explanation of how to apply the contingency is required.

Therefore, in this study, the average value and range of the contingency for each process were derived from the contingency recommendation suggested by various organizations and the cost estimation result data of TLG, which conducted actual NPP decommissioning cost estimation. After that, ISDC's WBS and TLG's decommissioning processes were matched, and the contingency guideline for ISDC's WBS Level 1 process were presented. Since this study utilized the actual cost estimation data for NPP decommissioning, it is judged that it will be possible to present a guideline for applying the contingency for each process in a country that has no experience of decommissioning. However, it is necessary to derive quantified results as the uncertainty of cost estimation is high. For this purpose, it is judged that a more reliable guideline can be presented if quantified values through sensitivity analysis or statistical analysis are presented in future studies.

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