DECOMMISSIONING COST EVALUATION FOR KOREAN NUCLEAR POWER PLANTS

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ABSTRACT

A systematic study was performed to develop decommissioning cost evaluation technology and to establish optimum decommissioning plan for Korean nuclear power plants. Eight decommissioning options for Kori unit 1 including DECON, SAFSTOR and ENTOMB were considered for detailed cost analysis. Immediate and delayed dismantling scenarios were compared each other in regards to economic, technical and social aspects. Fourteen decommissioning unit activities were considered in estimating unit cost factors including labor cost, consumables cost and equipment cost. The decommissioning cost for Kori unit 1 was lowest for DECON option and highest for ENTOMB-3 option in which the site recovery was made after entombment of 300 years. The main cost of the SAFSTOR option resulted from the dismantling and extended safe storage. For a long decommissioning period, the discount rate is crucial in estimating the decommissioning cost. The difference among decommissioning options was negligible in cost if a discount rate of 2% was assumed. The long-term safe storage option also became advantageous relative to the immediate dismantling option as the discount rate increased.

1. INTRODUCTION

If the economic lifetime of domestic nuclear power plants is estimated to be 25 years, then the decommissioning of nuclear power plants in Korea is expected to start in the early 21st century beginning with Kori-1, the first commercial nuclear power plant in Korea. Hence, in the near future, the decommissioning of the nuclear power plants will be one of the important tasks as well as the reutilization of the nuclear power plant site. The rational management of this task will influence significantly the future of nuclear power development and the promotion of nuclear energy in any plans for the generation of power in Korea. Decommissioning of a nuclear power plant will emerge as an important subject for long-term electric power generation plan with respect to new nuclear power plant construction and reuse of the plant site, which is directly related to the treatment of wastes. So, review of the current state of decommissioning techniques, enhancement of technological capabilities, and evaluation of optimum decommissioning costs for domestic power plants are required.

For advanced nuclear nations, in spite of their extensive experience in decommissioning cost estimation for nuclear power plants, the estimations of the decommissioning cost reported from those nations are quite varied even for similar nuclear power plants. This could be understood from the difference in decommissioning regulation standards, difference in cost estimation methods in addition to the large uncertainties in the decommissioning databases, difference in economical and technical assumptions, and difference of the equipment specifications. Considering this situation, a selection of an optimum decommissioning method suitable for our circumstances and an evaluation of a site-specific decommissioning cost for domestic nuclear power plants with the consideration of domestic and international regulations are required.

In this study several decommissioning scenarios were investigated for Kori-1 and the required cost for each method was analyzed by computer programs that had been used to evaluate nuclear power plant decommissioning cost in the United States. The discounted cost of each decommissioning method was also analyzed for the purpose of comparing cost effectiveness of the decommissioning methods. In the following section, the decommissioning cost estimation method for Kori-1 is presented with computer programs used. The evaluation result is discussed in the third section.

2. DECOMMISSIONING COST ESTIMATION METHOD

2.1. Computer Program for Decommissioning Cost Evaluation

The computer program for decommissioning cost evaluation used in this study consists of DOS software, NANDS-K (developed by NUS) and general purpose commercial software applications, Quattro Pro and Microsoft Project. NANDS-K is a combination of a DOE program, which was developed to estimate decommissioning cost and schedule for a PWR, and a NUS developed data-base for removal and disposal of non-contaminated structures and buildings. The conceptual scheme of the decommissioning cost evaluation method used in this program can be summarized as follows:

1. Nuclear power plant is divided into a contaminated system and a non-contaminated system.
2. The cost for decontamination, dismantle, removal and disposal of detailed items of contaminated system is estimated by NANDS-K.
3. The cost for removal and disposal of buildings and structures in a non-contaminated system and decontaminated buildings and structures is estimated by Quattro Pro.
4. Revised decommissioning schedule is developed by integrating each time period of process by sequence of operations using Microsoft Project.
5. Developed decommissioning schedule is put into the NANDS-K program to obtain improved nuclear power plant decommissioning costs estimation.

The computed information and the classification of related files produced from NANDS-K program are shown in Figure 1.

2.2. Calculation of Input Data for the Evaluation of Kori-1 Decommissioning Cost

In this section the calculation procedure of input data for the decommissioning cost evaluation for Kori-1 is discussed. The main scheme in the cost evaluation is based on the estimation procedure of American decommissioning cost. Since the database for the input data to evaluate the cost and the database related to the decommissioning of nuclear power plant are not established domestically, decommissioning cost is derived by the adjustment and transformation of basic input data based on the actual measurement data from Kori. The default data in the decommissioning cost evaluation program is based on the Trojan nuclear power plant (1,175 MWe, 3,500 MWt) in the United States. The basic assumptions for the evaluation of the decommissioning cost for Kori-1 are as follows:

1. The starting point of the calculation of the cost is set to January of 1995. For this, early 1995 cost data is applied to the domestic data and the default data in the program is converted to the price of 1995 using United State’s recent consumer price inflation rate (about 6% of inflation rate is assumed from 1993 to 1995).
2. Exchange rate is set to 770 won/dollar
3. The decommissioning methods to be analyzed are shown below:
   - DECON: immediate decommissioning after final shut down.

- SAFSTOR-1: partial decommissioning after 60 years of inactivity period from shut down
- SAFSTOR-2(10), (30), (51.38): SAFESTOR-1 with safe storage period of 10, 30, and 51.38 years
- ENTOMBMENT-1 and -2: Restoration of the site after up to 60 years of entombment following the shutdown
- ENTOMBMENT-3: Restoration of the site after up to 300 years of entombment following the shutdown

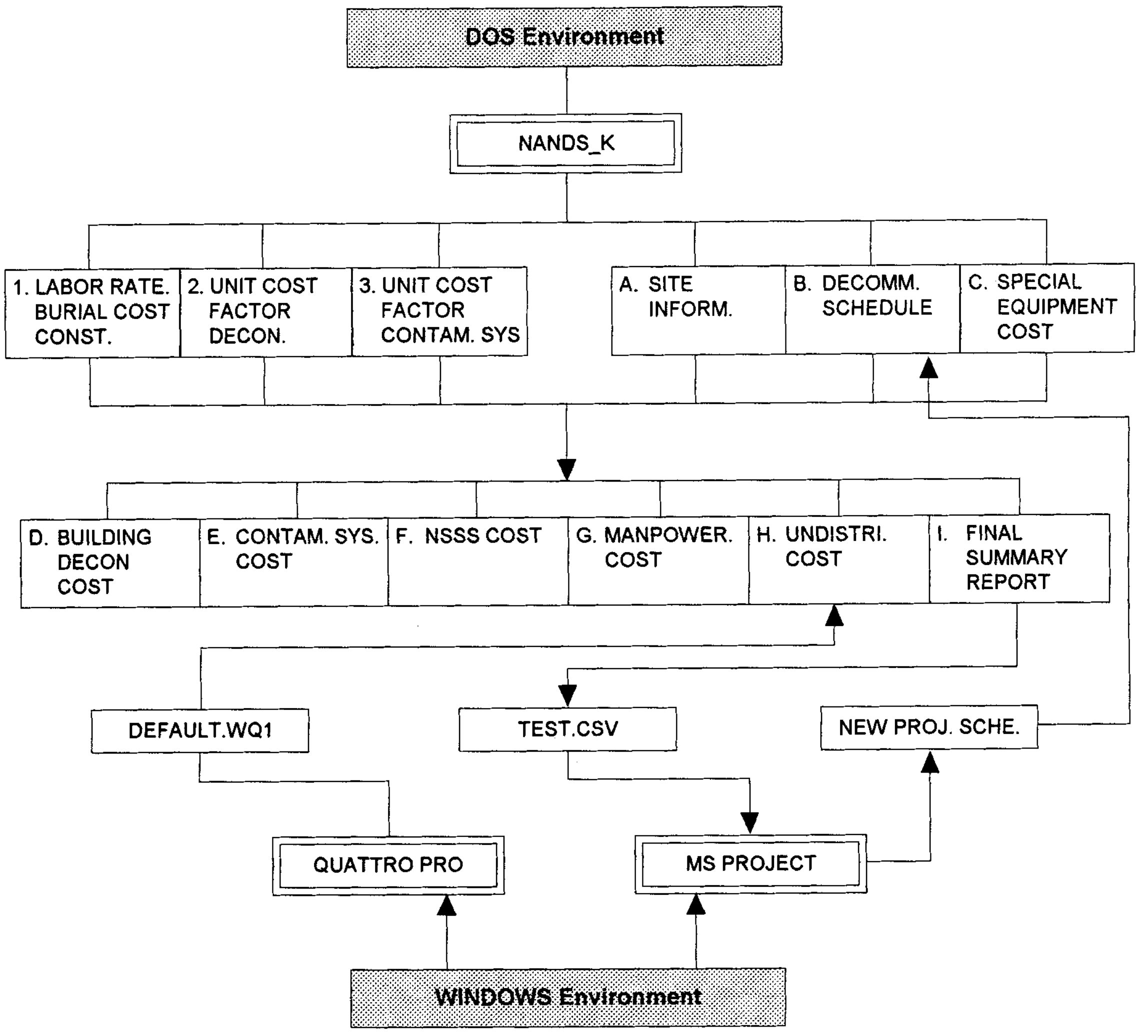

Figure 1. Schematic Structure of Computer Program Used for Decommissioning Cost Evaluation

1. The cost of radioactive waste disposal is derived from the assumption that radwaste is disposed of in the Swedish cavern repository. The cost for disposal of waste greater than Class C uses the default data.

2. The radioactivity level after the shutdown is calculated with the assumption that EFPY of the nuclear power plant is 30 years.
3. The technologies required for the decommissioning and the regulations for the decommissioning activity are based on the current state of these technologies in the United States, not assuming future development.
4. A single decommissioning general contractor is assumed to manage the decommissioning program under the auspices of a utility.
5. The removal of contaminated concrete surface is set to a depth of 1 inch, and the cutting length of the pipes is set to 15 feet.
6. The costs related to the storage/disposal of spent nuclear fuel are not included in the decommissioning cost.
7. The minimum period required to withdraw spent nuclear fuel from S/F pool is set to about 7 years after the shutdown.
8. The completion of decommissioning operation means the restoration of the site to reusable state and all the expenses for the complete removal of decontaminated and non-contaminated structures are included in all decommissioning strategies.

The fundamental basis for calculating input data stemmed from the DECON method. The value of input data in the menu items shown in Figure 1 are almost same except for those of B, G, and H.

3. THE EVALUATION ANS ANALYSIS OF THE DECOMMISSIONING COST OF KORI-1

3.1. Analysis of Unit Decommissioning Processes and Calculation of Unit Cost Factors

To calculate Kori-1 decommissioning cost, unit cost factors including personnel expenses, material costs, and equipment expenses were calculated for the following unit decommissioning processes:

1. removal and packaging of contaminated pipes
2. removal and packaging of pipes on contaminated tanks
3. removal and packaging of pumps and small equipment
4. removal and packaging of pressurizers
5. removal and packaging of primary cooling pumps
6. washing with pressurized water/ vacuum cleaning of the surface
7. cutting of non-contaminated concrete walls and floors
8. cutting of contaminated concrete walls and floors
9. removal of biological shields
10. removal and packaging of contaminated metal surfaces
11. removal and packaging of contaminated ducts
12. removal of floor metal screen
13. decontamination of railings

14. removal of contaminated floor drain holes

3.2 Evaluation of Costs for Decommissioning Strategies

Eight decommissioning strategies were considered in this study, including one DECON, four SAFSTOR, and three ENTOMBMENT strategies where all costs were evaluated based on January 1995 costs. The first results of this study are the costs listed by decommissioning strategies without the use of any discount concepts. A sensitivity analysis of decommissioning costs, when the pipe cutting length was 5 feet and low-level radioactive waste disposal costs are doubled or quadrupled, is also performed. The second results of this study include measurements of the expense changes by the strategies and by periods when discount rate, which is an important factor in evaluation cost effectiveness, is changed from 2% to 5% to 8%. The two results are described below.

3.2.1 Basic Decommissioning Cost

Tables 1, 2 and 3 summarize the basic decommissioning costs according to the decommissioning strategies. The contingency rate applied to all strategies is 25%. The values in the tables are obtained from a simple addition of future decommissioning costs evaluated at the present value, not considering discount rate.

Table 1. Decommissioning Cost for DECON Option

Classification	**Basic Cost ($)**	**Sensitivity Analysis**		
		5 ft pipe cutting	LLW disposal cost (155.6 $/ft^3$)	LLW disposal cost (311.2 $/ft^3$)
Total (excluding contingency)	150,277,160	154,277,775	162,692,840	187,492,199
Total (including contingency)	187,886,450	192,847,219	203,366,050	234,365,248

Note: Basic cost assumes 15 ft pipe cutting, LLW disposal cost of 77.8 $/ft^3$

Table 2. Decommissioning Cost for SAFSTOR Option

Classification	**Cost($)**			
	SAFSTOR-1	SAFSTOR-2(10)	SAFSTOR-2(30)	SAFSTOR-2 (51.38)
Total (excluding contingency)	191,606,779	168,178,523	200,486,188	235,019,769
Total (including contingency)	239,508,474	210,223,154	250,607,735	293,774,712

Table 3. Decommissioning Cost for ENTOMBMENT Option

Classification	Cost ($)		
	ENTOMBMENT-1	ENTOMBMENT-2	ENTOMBMENT-3
Total (excluding contingency)	187,437,760	189,347,441	432,900,640
Total (including contingency)	234,297,200	236,684,301	541,125,800

3.2.2 Discounted Decommissioning Cost

The expenses paid at different chronological points should be converted into the values at a certain point in time because of the factors such as the depreciation of the currency by inflation. Considering that discount rate is a factor that has a decisive influence on the expenses, a method to supply the capital, and comparison of the strategies, discount rates of 2%, 5%, and 8% are applied to each decommissioning strategy. The discount rate is applied to early 2006, when the decommissioning plan for Kori-1 is expected to be launched with the assumption that the shutdown of Kori-1 occurs in mid-2008. Therefore, all discounted decommissioning costs are at the 1995 currency value. The discounted decommissioning cost for each decommissioning strategy is listed in Table 4.

As demonstrated by evaluating decommissioning costs by different strategies, when real discount rate is about 2%, there are almost no differences in decommissioning costs. The long-term safety storage strategy becomes more attractive as the discount rate increase. Thus, when selecting decommissioning strategy, cost effectiveness of decommissioning strategies should be compared and all the factors such as the amount of expenses by time period, the availability of technologies for decommissioning operations, and radioactive waste disposal site plan should be reviewed together for the decision. Especially, reservation of the radioactive waste disposal site and disposal cost have great effect on the promotion of the decommissioning plan itself. If the disposal cost is quadrupled from the basic cost by the worsening of any circumstances, the waste disposal costs will play an important role in determining the total decommissioning cost.

Table 4. Summary of Discounted Decommissioning (unit: US$)

Strategy	Discount rate		
	2%	5%	8%
DECON	163,179,555	134,217,465	112,424,378
SAFSTOR-1	143,090,417	92,621,253	73,887,345
SAFSTOR-2(10)	163,188,033	118,518,689	91,969,991
SAFSTOR-2(30)	160,560,321	101,667,120	77,448,464
SAFSTOR-2(51.38)	158,863,809	95,203,695	74,331,878
ENTOMBMENT-1	154,895,760	109,186,395	88,763,345
ENTOMBMENT-2	156,852,270	110,648,654	89,865,212
ENTOMBMENT-3	158,580,004	107,528,010	88,169,536

4. CONCLUSION

To investigate the optimum decommissioning strategy and related cost for domestic nuclear power plants, 8 decommissioning options including DECON, 4 SAFSTOR, and 3 ENTOMBMENT strategies were systematically studied with Kori-1 plant.

The decommissioning cost for Kori 1 was lowest for DECON option and highest for ENTOMB-3 option in which the site recovery was made after entombment of 300 years. In DECON option, the basic decommissioning cost (excluding a contingency of about 150 million dollars) and the cost for removal and disposal of clean equipment and facility was higher than that for dismantling. The cost for mothballing with delayed dismantling (SAFSTOR option) was not much different from the prompt removal/dismantling(DECON option). The main cost of SAFSTOR option resulted from the dismantling and extended safe storage. The costs for ENTOMB-1 and 2 option, where the entombment period was 60 years, were slightly lower than that for SAFSTOR-1 option.

For the long decommissioning period, the discount rate is crucial in estimating the decommissioning cost. If the discount rate of 2% was assumed, however, the difference in decommissioning cost among the decommissioning options was negligible. The long-term safe storage option also became advantageous relative to immediate dismantling option as the discount rate increased.

5. REFERENCES

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6. KEY WORDS

Decommissioning Cost, NANDS_K, Quattro Pro, Microsoft Projects, DECON, SAFSTOR, ENTOMBMENT, Unit Cost Factor.