ASSESSMENT OF THE COST OF UNDERGROUND FACILITIES OF A HIGH-LEVEL WASTE REPOSITORY IN KOREA

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This study presents the results of an economic analysis for a comparison of the single layer and double layer alternatives with respect to a HLW-repository. According to a cost analysis undertaken in the Korean case, the single layer option was the most economical alternative. The disposal unit cost was estimated to be 222 EUR/kgU.

In order to estimate such a disposal cost, an estimation process was sought after the cost objects, cost drivers and economic indicators were taken into consideration. The disposal cost of spent fuel differs greatly from general product costs in the cost structure. Product costs consist of direct material costs and direct labor and manufacturing overhead costs, whereas the disposal cost is comprised of construction costs, operating costs and closure costs. In addition, the closure cost is required after a certain period of time elapses following the building of a repository.

KEYWORDS : Cost Estimation, Spent Fuel, Repository, Construction Cost, Cost Driver

1. INTRODUCTION

Disposal costs largely relate to above-ground facilities and the underground facilities of a repository. According to a cost analysis undertaken in Finland, the cost required for building above-ground facilities is approximately twice the construction cost of underground facilities [1]. An underground facility cost is required to dispose of the spent fuel generated from a power plant in a place deep underground in order to safely isolate the spent fuel from the ecosystem for a long period of time. The repository cost with respect to the disposal of spent fuel largely consists of construction costs, operating costs and closure costs [2].

First, in order to construct a repository, it is crucial to comprehend the size of the repository necessary to dispose of the spent fuel generated from nuclear power plants in Korea. Thus, an assessment of the repository construction cost should be preceded by the concept design of the underground facilities for a repository. In addition, for the estimation of the disposal costs, such categories as a disposal plan, the disposal processes and various cost estimation methods should be taken into account. As no spent fuel repository has been built in Korea to date, it is difficult to accurately predict the cash flows with respect to the repository construction cost. For this reason, data from a reference repository is used in this study.

Fig. 1 shows the concept of a Korean surface waste facility.

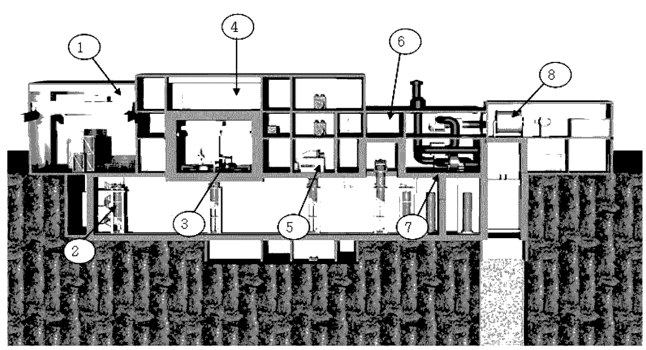

Fig. 1. Sketch of the Korean Surface Waste Facilities

The disposal area contains the central tunnel, panel tunnels, deposition tunnels and deposition holes. The dimensions of the total disposal area are approximately 2 x 2 km (1.8 x 2.2 km). The dimensions of the disposal area are presented in Table 1.

Table 1. Dimensions of the Disposal Area

FACILITY	DIMENSION
Central tunnel	Length 2,650 m
Panel tunnel	Length 14,900 m
Deposition tunnel	Length 95,758 m Number of tunnels 377
Deposition hole	Number 2,835 (CANDU) Number 11,375 (PWR)

Fig. 2 shows the concept of the under-ground facilities.

Disposal holes are closed immediately after canister deposition. Holes are closed with bentonite blocks, as shown in Fig. 3. Blocks are compacted under high pressure to the shape of pineapple rings and disks. Pineapple-ring shaped blocks are used for the sides of canisters and disk-shaped blocks are used for the bases and tops of canisters.

2. COST ESTIMATION METHODS

Valuations at specific points of the construction of a repository consist of:

1) a method whereby the time value of money is not considered (overnight cost method); 2) a method whereby the time value of money is considered and the cost required

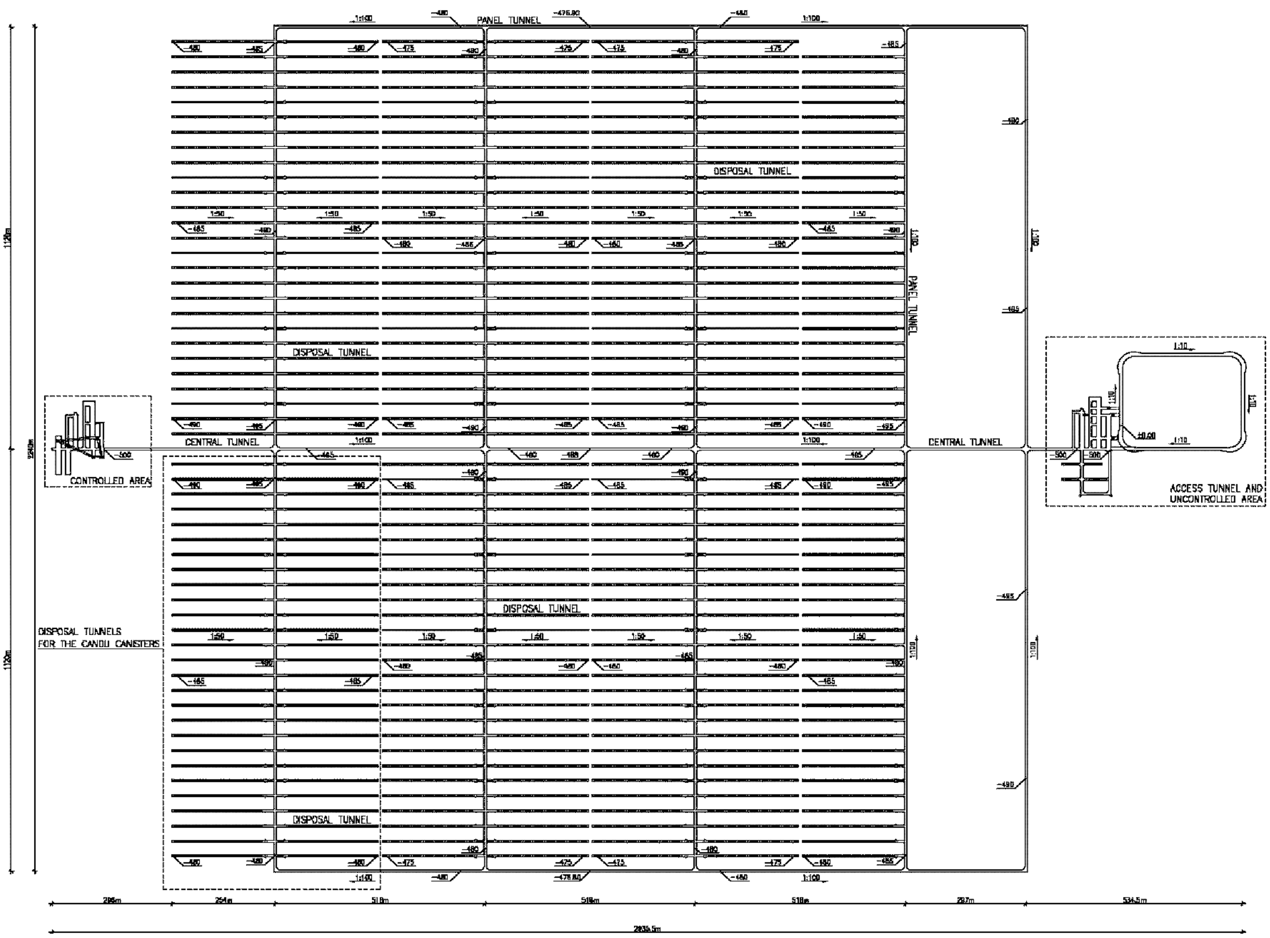

Fig. 2. Disposal Area of the Repository

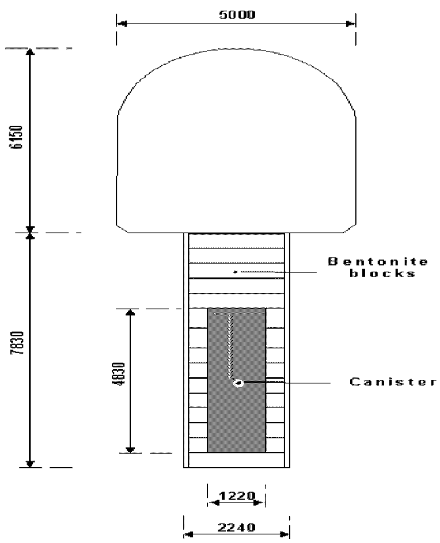

Fig. 3. Disposal Hole and Disposal Tunnel

for each stage of construction is converted into the cost that would be required for the completion of the building.

On the assumption that the construction period of a repository is n years and the related annual cost is C_1, C_2, C_3, $\cdots$, C_n, the construction cost (under the accounting system) using the overnight cost method is estimated based on Formula (1).

$$\text{Construction cost} = \sum_{i=1}^{n} C_i \qquad (1)$$

where the construction cost converted into its present value after its time value has been taken into account, referring to the capital expenditures used for each stage of construction converted to their present value. Its estimation is made based on Formula (2).

$$PV = \sum_{i=1}^{n} \frac{C_i}{(1+d)^i} \qquad (2)$$

(C_i: Phase cost, d: Discounted rate, i: elapsed year, n: completed year)

Given the condition that price increase rates are taken into account and the cost is incurred at the rate of C_1, C_2, C_3, $\cdots$, C_n, the repository construction cost can be expressed based on Formula (3).

$$FV = \sum_{i=1}^{n} C_i (1+r)^{(n-i)} (1+f)^{(n-i)} \qquad (3)$$

(r: interest rate, f: inflation, i: elapsed year, n: completed year)

2.1 Classification of the Analytic Methods for the Economics of a High-level Waste Repository

Methods may vary according to their own purpose. In the case of a cost analysis of a HLW-repository, the following categorization of the methods or tools can be considered;

- Volume based cost calculation
- Activity based cost calculation
- Project financing assessment; analysis of the economics for an investment appraisal, such as the internal rate of return (IRR), pay-back period, or profitability index [5].

Table 2 shows a comparison of the methodologies for the cost analysis.

Table 2. Comparison of the Methodologies for the Cost and Capital Budgeting Analysis

Category	Cost analysis		Capital budgeting analysis
	Volume based cost calculation	Activity based cost calculation	Project financing assessment
Object	Project/HLW repository	Project/HLW repository	Project/HLW repository
Purpose	Comparison of the techniques	Cost management by means of a cost driver.	To decide whether or not to invest in the project.
Index	Amount of spent fuel to be disposed of against time.	Amount of activity for disposing of the spent fuel	IRR, NPV, Pay-back period, profitability etc. for investment appraisal
Drawback	Adjustment needed when allocating an indirect cost.	Not easy to categorize the cost pool by the activity and to convert it to a unit cost per kgU generated	All of the specifications of the project to be assessed should be fixed prior to the calculation.

Table 3. Cost of the Product, Generation and Disposal

	Product cost	Generation Cost	Disposal cost(underground facility)		
			construction (investment)	operating cost	closure cost
Variable cost	Direct material cost	fuel cost	excavation cost, equipment cost, transportation cost of canister, etc.	bentonite, backfilling material cost, etc.	disassembling structure, backfilling of shaft, plugging of concrete at access of shaft, etc.
Fixed cost	direct labor cost, tax	capital recovery cost, maintenance cost, tax/insurance	labor cost, maintenance cost, insurance, etc.		

In the case of a cost estimation for a HLW repository, the volume based cost calculation was chosen for convenience of calculations.

Table 3 presents a comparison between the categories of the product cost and the cost of generating electricity in terms of variable and fixed costs [4].

The repository construction cost in terms of facilities (cost objects) is subdivided into the above-ground facilities and the underground facilities [3].

The authors did not estimate the sociological cost because of uncertainty.

When estimating the construction costs, it is necessary to rank them from high to low, and break down the cost objects selected to estimate the cost using the top-down estimation method. At this time, the cost object whose cost is considered to be the most crucial should be estimated first. Accordingly, the cost object whose cost is relatively higher should be estimated more accurately than the rest of the cost objects. As Korea has no experience in building a repository with respect to the disposal of spent fuel, a foreign case study was used as a reference case with respect to a number of cost units, except for the cost of the buffer. For example, the cost of Bentonite is 150 EUR/ton, and the labor cost for the compacting of the buffer is 200 EUR/ton.

Based on the above cost estimation process, the final disposal cost may be expressed as follows, in the form of the unit cost of uranium, which is a raw material of spent fuel.

Unit cost of U = Total disposal cost/Weight of the disposed U

Fig. 4 presents the estimation processes pertaining to the total disposal cost.

As uncertainties concerning the cost might arise as a consequence of the unfamiliarity with or lack of experience in related areas, a contingency cost should be taken into account in order to cope with such a problem. In addition, an owners cost is included in the construction cost. This cost includes such expenses as a development, designing, project and permission-related cost. In Finland, such expenses were estimated to be approximately 15% of the total construction cost [5].

The construction cost is estimated for each stage of construction from the planning and construction of the URL (underground research laboratory) through to the closure of the repository. In addition, undeterminable, unspecified expenses and contingency costs are reflected in the total cost relating to the final stage. Also, by considering an inadequate rock condition, a percentage (for example, 5.5%) of the cost for the disposal tunnels is assumed to be additional.

For the case study with respect to cost estimation in this paper, the material costs and labor costs based on the construction processes in Finland were applied, except that Korean commodity prices were applied for the cost of the buffer. In assessing such a cost in the future, a number of cost objects may be replaceable with cost objects obtained in Korea.

2.2 Investment Cost

Construction costs may be subdivided into direct costs such as the excavation and support costs of the tunnels and the disposal hole, the largest portion of all costs, and indirect costs such as the maintenance cost of the construction equipment, the incidental cost and the financing cost. The direct costs and indirect costs are referred to as the base costs. Subsidiary expenses include an owners cost, a spare parts cost and an incidental cost. In this paper, all of these costs, exclusive of the operating cost, were included in the investment cost.

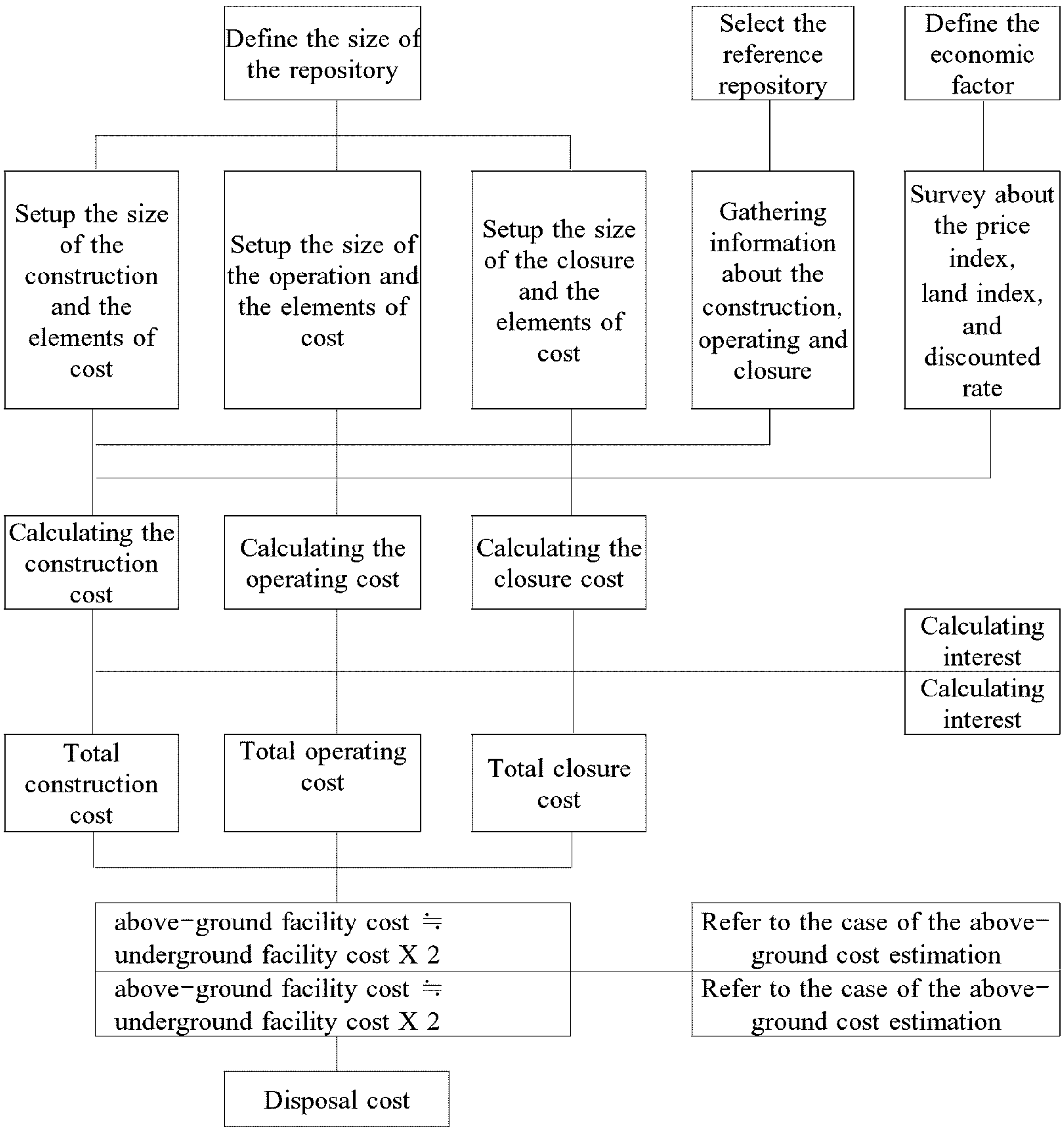

Fig. 4. Process of the Disposal Cost Estimation

Direct costs are directly required for the site and facilities of a repository, in addition to any special materials. Direct costs are thus classified as depreciable assets and non-depreciable assets. Indirect costs have a more general feature compared to direct costs, encompassing such expenditures as the designing, supervisory service cost and installation cost of the temporary structures, in addition to rent.

The repository construction cost is determined by the site condition of the repository, construction period, disposal capacity, price increase rates, discount rates and regulatory matters (laws and regulations, etc.) during the construction period. Table 4 lists the elements of the repository construction cost, expressed in expense items.

The construction work cost includes all of the expenses required for the concrete, aggregate, walls, floors, doors, disposal hole, finish materials and the crane and paint in the technical room. The excavation and support cost includes the excavation and support cost of the tunnel in addition to the grouting and support cost of the tunnel. In addition, the disposal hole cost includes the boring and

Table 4. Construction Cost Objects

<table>
<tr><td rowspan="11">Total construction cost (underground facility)</td><td rowspan="9">Overnight cost (Fore cost)</td><td rowspan="6">Base cost</td><td rowspan="3">Direct cost</td><td>Land cost</td></tr>
<tr><td>Shaft/Tunnel/Excavating cost of the disposal hole</td></tr>
<tr><td>Transporting cost of Canister</td></tr>
<tr><td rowspan="3">Indirect cost</td><td>Subsidiary facility</td></tr>
<tr><td>Equipment maintenance cost and service</td></tr>
<tr><td>Technical supporting cost</td></tr>
<tr><td colspan="2" rowspan="3">Incidental cost</td><td>Owner's cost</td></tr>
<tr><td>Spares</td></tr>
<tr><td>Extra cost</td></tr>
<tr><td colspan="3" rowspan="2">Financing cost</td><td>Escalation</td></tr>
<tr><td>Interest During Construction</td></tr>
</table>

grouting cost. Furthermore, the survey cost with respect to the disposal hole includes the excavation and support cost and the survey cost required for surveying a tunnel in the center prior to excavating the tunnels and holes. The construction cost incurred during each stage of the construction is estimated based on these cost objects.

Since Korea has no experience building a repository to date; moreover, there have been a number of difficulties in estimating the cost including the machinery and facilities costs, tunnel excavation capacity, and building, in addition to the repository structure required for a cost estimation. For this reason, a foreign case study is used in order to obtain the data and unit cost required in the estimation of the construction cost.

For the estimation of the labor cost, for example, it was assumed that 1/3 of the operating staff for the disposal facilities are working in underground facilities [1]. In addition, the cost statement presents the aggregate of the investment cost, operating expenses and the closure cost.

The investment cost relates to two subgroups - the construction cost and the machinery and equipment cost. In addition, 20% of the operating expenses were set as a contingency cost, which may fluctuate depending on the rock condition during each stage of construction. With respect to the estimation of the excavation capacity for the tunnels, the area of a cross section was estimated in a conservative manner by multiplying the width by the height. The investment cost includes the machinery cost required for the mixing and emplacement of the backfilling materials.

The total repository cost is classified into several construction stages for the estimation, taking into account the amount of work to be done.

The investigation cost required for a cost-effective construction of the disposal tunnel and hole is required to investigate a hole made in a deep place for such a disposal tunnel and hole. Based on the artificial allocation process and by referring to the aforementioned case study undertaken in Finland, a fixed percentage of the cost required for the disposal tunnel and hole has been accounted for in the investigation cost. This is the method in which the indirect cost required for the construction of the repository was estimated.

The equipment and system costs necessary to construct the repository were estimated independently; Table 5 presents the list of the equipment covered by these equipment and system costs.

It was found that the largest parts of the construction cost is the hole excavation cost followed by the tunnel excavation cost. Another major cost item is the shaft excavation cost and the construction work cost, followed by the investigation cost, owners cost and contingency cost.

Table 5. Equipment and System Elements

Item	
Rock hosting system	Personnel lift non-controlled
Personnel lift controlled	Canister lift
Canister transfer vehicle	Candu handling frame
PWR handling frame	Bentonite handling equipment
Back-filling mixing station	Other vehicles
Electric power system system	Control and monitoring
Ventilating and heating system	Water system
Fire fighting system	Other systems
Contingency for unspecified costs	

In general, the construction cost is converted into its value as of the date of the completion of the repository.

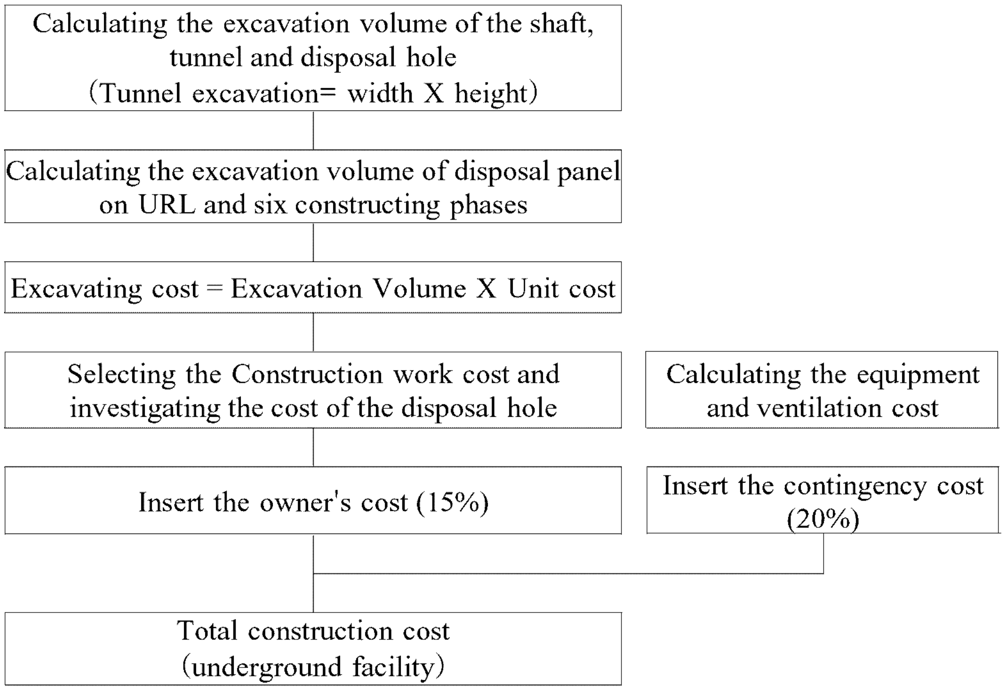

Fig. 5. Process of the Construction Cost Estimation

Table 6. Operating Cost Elements

Operating cost (Underground facility)	Fixed cost	Personnel costs Maintenance and reparation Insurance Owner's cost
	Variable cost	Tunnel and shaft backfilling, Bentonite blocks, Concrete plugs at tunnel front, etc.

That is, it is the cost incurred each year converted to the total sum as of the date of completion. After this time its future value incurred each year is taken into consideration.

Fig. 5 presents the estimation process with respect to the construction cost.

2.3 Operating Cost

A major part of the disposal cost is the operation cost. The operation and maintenance cost encompasses all of the expenses required to operate the repository. These expenses include all direct and indirect costs pertaining to such expenses as labor, consumables, equipment, outside support services, and insurance against accidents.

The wages required for the backfilling work are included in the labor cost, while the machinery and system costs are included in the investment cost. In general, the operating cost is subdivided into fixed and variable factors. The total variable cost is correlated with the changes in the cost drivers.

The total fixed cost is independent of the change in the cost drivers. A cost driver is a factor affecting the cost. Therefore, a change in the cost drivers causes a change in the total cost for a related cost object. The fixed operating cost is determined by the size and type of the repository.

However, variable operating costs change depending on the size of the disposal capacity. That is, as an increase in the disposal capacity results in an increase in the size of the underground facilities of the repository, the cost of the backfilling materials (bentonite) as well as the plugging costs increase. Table 6 presents elements of the operating cost and Fig. 6 shows the estimation process with respect to the operating cost.

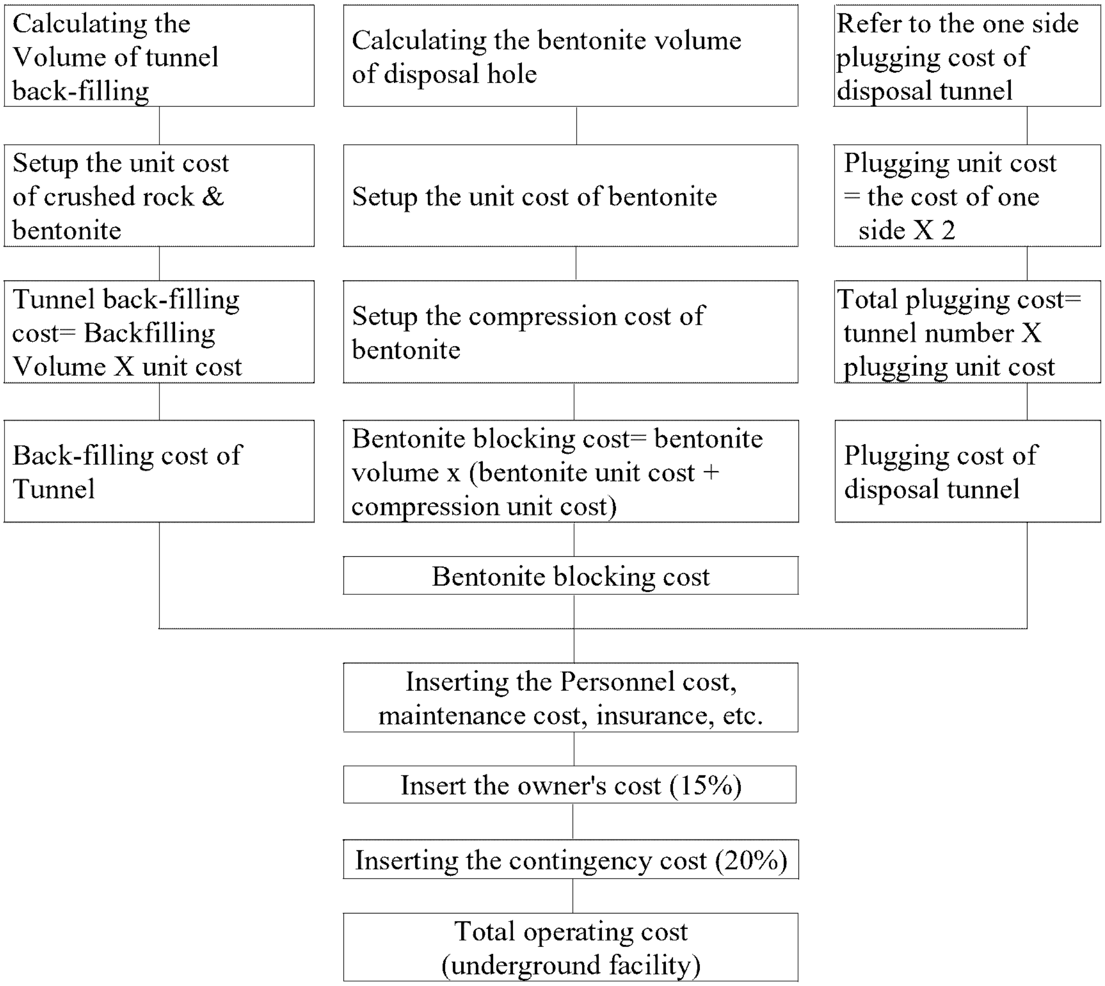

Fig. 6. Process of the Construction Cost Estimation

Under several accounting systems, all the material costs required in connection with the operation of a repository are accounted for independently under the accounting title of an expendable operating cost.

2.4 Closure Cost

The cost incurred during the closure stage is required to undertake such finishing works as the backfilling of the disposal tunnel and a closure of the shaft (a pathway connecting the above-ground facilities and the underground facilities).

The disposal tunnel is filled with crushed rock flooring. The shaft is also filled with these materials. The total cost for a plugging within the repository is estimated using the unit cost necessary to undertake a plugging with concrete at the entry of the shaft. Table 7 presents the cost items pertaining to each work unit during the closure stage, whereas Fig. 7 shows the estimation process with respect to the closure cost.

Table 7. Closure Cost Elements

Item	
Dismantling of the structures	Back-filling of the tunnels
Back-filling of the shafts	Concrete plugs at the top of the shafts
Bentonite plugs in the access tunnels and shafts	Owners costs 15%

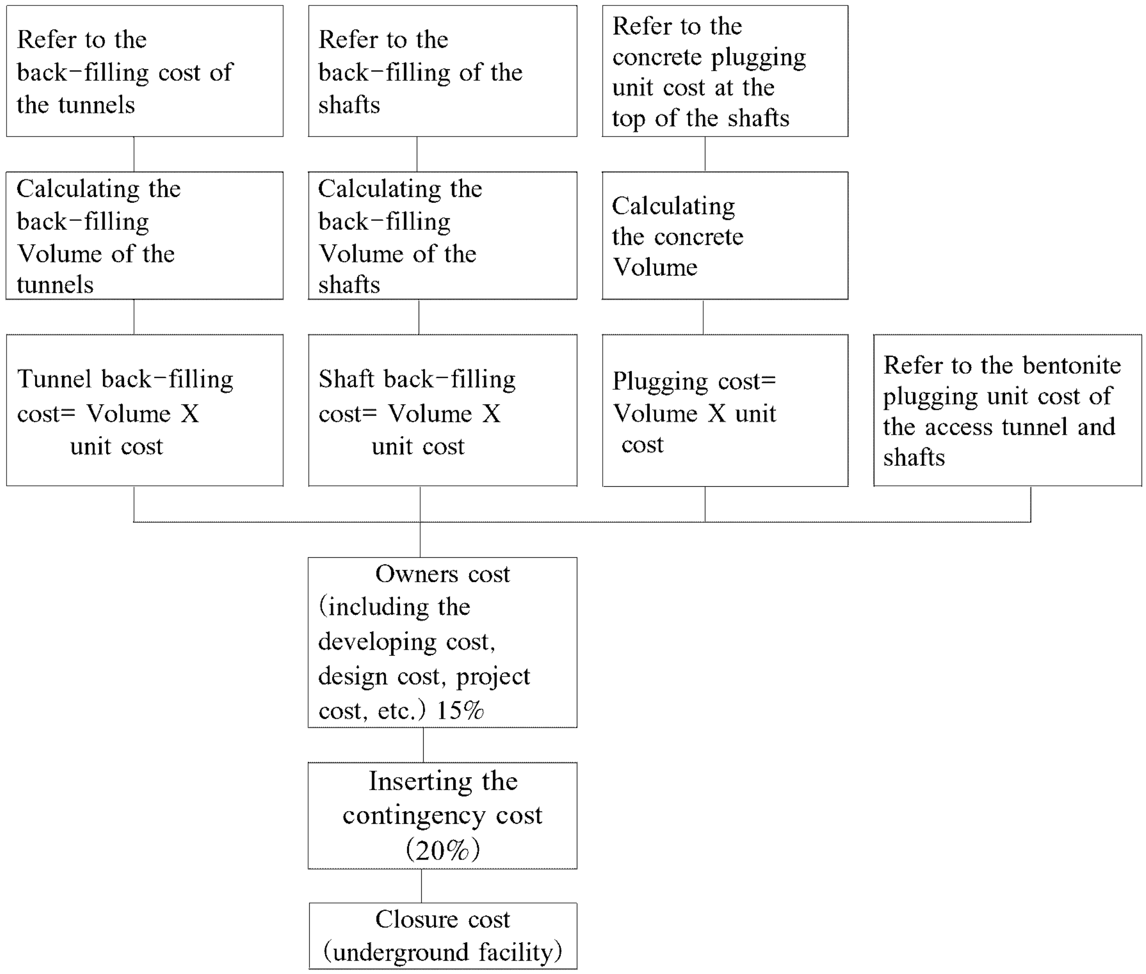

Fig. 7. Process of the Closure Cost Estimation

2.5 Miscellaneous Cost

It is also possible to disregard the disposal cost pertaining to the crushed rock flooring in the estimation of the disposal cost, as when crushed rock flooring is used for the backfilling, the remainder of the disposal cost with respect to the crushed rock flooring is not expected to be high. Other miscellaneous costs include a safeguard cost.

3. CASE STUDY REGARDING COST ESTIMATION

POSIVA (Finland) in co-operation with KAERI (Korea Atomic Energy Research Institute), undertook a research in order to estimate the costs necessary in the construction of a repository with a disposal capacity of up to 36,000 ton of spent fuel, which was presented by KAERI as an example. The repository and the disposal tunnel were estimated to be 3.3 million m^3 in size and 105 km long, respectively. The disposal tunnel was divided into restricted areas and unrestricted areas, as even during construction disposal canisters are brought into the repository to dispose of spent fuel. The difference between these areas in the excavation capacity was minimal during the final stage of the construction; the restricted areas and the unrestricted areas were estimated to be 731,000 m^3 and 799,000 m^3 in volume, respectively (1.53 million m^3 in total) [5].

3.1 Cost Estimation Terms

3.1.1 Structure of the Underground Facilities of the Repository

The repository is classified into above-ground facilities and underground facilities. The above-ground facilities are used to undergo the processes prior to transferring the disposal canister to the underground facilities in order to place it into the disposal hole. These include the gathering of spent fuel from the nuclear power plant, and wrapping and inspecting it within the disposal canister. Underground facilities, including all of the facilities in the shaft, access tunnel, panel tunnel, and the disposal tunnel and disposal hole are used to transfer and place the disposal canister in the disposal hole [6].

For the cost estimation for the HLW repository, the author used the technical and economic variables shown in Table 8.

It is crucial to have a proper number of underground tunnels in order to transfer and place the disposal canister into the deep rock. Access tunnels are intended to facilitate the moving of disposal canisters to the repository, whereas disposal tunnels are designed to facilitate the placement of disposal canisters into the disposal hole.

The repository is comprised of restricted areas and unrestricted areas. Such a division is intended to ensure safety against radiation during construction. An alternative proposal for a repository under study by KAERI, suggests the connection of eight shafts for the above-ground area, with four restricted areas and four unrestricted areas in the repository. The diameter of the disposal canister shaft and the rock hoisting shaft is 6 m.

The authors referred to a conceptual drawing of the underground structure of the repository in order to estimate the disposal cost [2]. Fig. 2 shows the layout of the tunnel. As shown in this figure, the underground repository has shafts dug on both sides, which are connected to the access tunnel. The access tunnel is connected to the disposal tunnel and the panel tunnel to facilitate the transport of the disposal canister. The concept of this design is such that the disposal hole is dug vertically, descending from the disposal tunnel floor, therefore the PWR spent fuel and CANDU spent fuel can be placed separately in two different sectors.

3.1.2 Disposal Capacity and Disposal Canister

It was assumed for the cost estimation that the disposal capacity was up to 36,000 ton of spent fuel. This is the total amount of spent fuel expected to be generated from the nuclear power plants to be built and operated by 2015, according to the long-term power plan made public by the former Ministry of Commerce and Trade (the Ministry of Commerce, Industry and Energy). 20,000 tons of PWR spent fuel and 16,000 tons of CANDU spent fuel are covered by such a disposal capacity [7].

In the paper, in order to dispose of this amount of fuel, given the assumption that the situation requires 11,375 PWR disposal canisters and 2,926 CANDU disposal

Table 8. Technical and Economic Variables

	Item	Value
Technical variables	Disposal area	1.8 km x 2.2 km
	Depth	500 m
	Canister shaft	Diameter 6 m
	Personnel shaft	Diameter 4.5 m
	Ventilation shaft	Diameter 4 m
	Deposition holes	Diameter 2240 mm
		Depth 7830 mm
	Distance between holes	PWR 6 meters (centre points)
		CANDU 4 meters (centre points)
	Deposition tunnels	Length 251 meters:
		Width 5.00 meters, Height 6.15 meters
	Panel tunnels	Width 6.00 meters
		Height 7.60 meters
	Central tunnels	Width 7.00 meters
		Height 8.40 meters
	Access tunnel	Width 8.00 meters
		Height 7.95 meters
Economic Variables	Escalation	2.3%*
	Discount rate & Interest rate	4.36%*

* The economic values were fixed by Article 50 of the enforcement regulations under the Korean Electricity Enterprises Act.

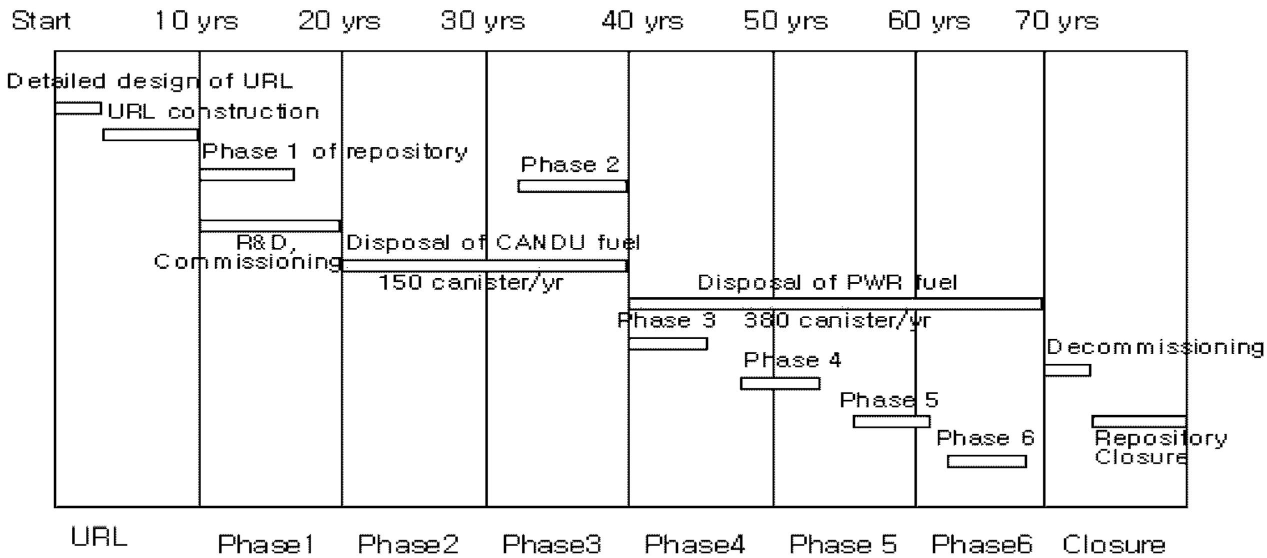

Fig. 8. Implementation Time Schedule

canisters, the cost necessary to dispose of the fuel into the deep rock in a manner ensuring safety against radiation as well as cost effectiveness was estimated. It was assumed that four assemblies are put into a PWR disposal canister, while it was assumed that there are to be 33 assemblies in a basket within a CANDU disposal canister, in order to fill the disposal canisters to nine layers accommodating 297 CANDU assemblies. The size of a disposal canister was assumed to be 40 ton in weight, 1.22 m in diameter and 4.83 m in length.

3.1.3 Repository Construction Period

Construction of a repository requires much time as it is built into deep rock. In addition, as a number of the disposal canisters from the restricted area are moved into the disposal hole due to the radiation generated during construction, the construction period is classified into several stages depending on the size of the disposal capacity in order to build the repository in a manner that ensures safety of the workers and cost effectiveness. In addition, a trial operation period was taken into account prior to the commencement of the disposal of the CANDU spent fuel. It is crucial to consider the capacity of the intermediate storage facilities for spent fuel in Korea when constructing above-ground facilities, including packaging facilities. Fig. 8 presents the specific construction periods with respect to a repository.

Fig. 8 shows a total of eight construction stages. The URL stage continues for 10 years, encompassing the URL designing and construction period. The first stage also continues for 10 years. During this period, two CANDU panels and one PWR panel are built. In addition, during the first stage the URL is operated and a trial operation of the repository is undertaken. During the second stage, the CANDU disposal canisters are disposed of for 20 years and at the end of the stage a minimum of 3 PWR panels are built at the other side of the access tunnel.

Stages 3, 4, 5 and 6, each require 7.5 years (for a total of 30 years). During these stages, PWR spent fuel is disposed of and eight panels (two each) are built during each stage. Lastly, the closure stage requires 10 years, when such works as the disassembling of the above-ground facilities and backfilling of the panel tunnels, access tunnels and shaft are undertaken. Therefore, it is assumed that the disposal program would require a total of 80 years.

3.2 Cost Estimation Results of the Korean Case Study

Table 9 summarizes the total costs incurred during each stage required for the construction of the repository, based on the overnight cost estimation method used by POSIVA (Finland) and KAERI with respect to the investment cost and operating cost. The investment cost includes the construction cost and the equipment and system cost. According to the Finnish cost estimates, the total disposal costs are nearly three times the costs of the underground costs. In the Korean case this implies nearly 8 billion Euros for the total disposal cost of the spent nuclear fuel. Figs. 9 to 11 show the constituents of the investment, operating, and closure costs, respectively.

Table 9. Total Costs (MEUR)

Costs	Total (MEUR)	%
Investment	986.27	37.4
Operating	1,469.50	55.8
Closure	180.53	6.8
Total	2,636.20	100

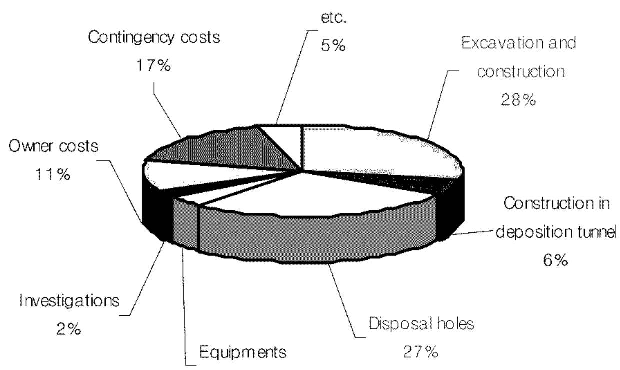

Fig. 9. Investment Costs

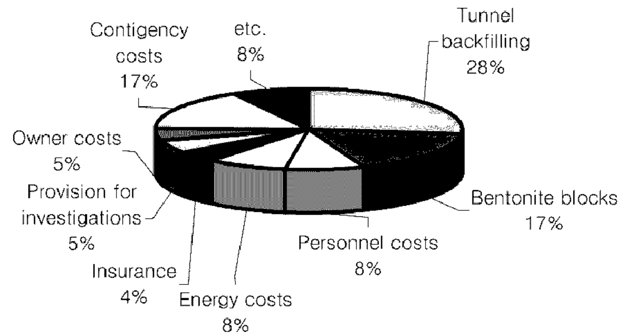

Fig. 10. Operating Costs

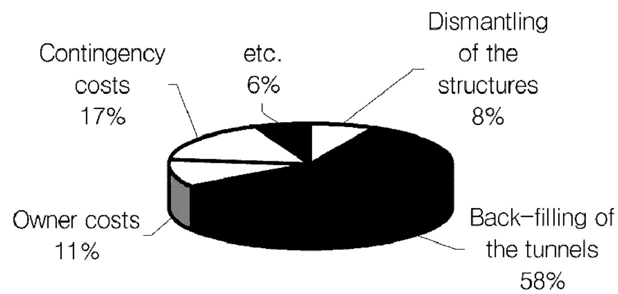

Fig. 11. Closure Costs

Table 10. Dominant Design Variables

Category	Dominant cost drivers	Dominant design variables
Investment costs	Tunnel excavation Volume	A cross sectional area of a tunnel, Tunnel length
	Disposal hole excavation Volume	A cross sectional area of a disposal hole, Disposal hole depth
Operating costs	Tunnel backfilling Volume	A cross sectional area of a tunnel, tunnel length
	Bentonite dimensions	Buffer radial thickness, height

Table 10 shows the dominant design variables in terms of the underground facilities of a HLW-repository.

3.3 Sensitivity Analysis

In this case for a cost estimation, cash flow should be considered for a long period of time as the construction of the repository was assumed to be 80 years. Fig. 12 shows the cash flow for the underground facilities of a HLW repository.

Figs. 13 and 14 show the sensitivity of the escalation and the interest rate, respectively, at the point of completion of the repository.

3.4 Results for a Single Layer Vs. a Double Layer

Disposal tunnels can be constructed in two levels, as illustrated in Figs 16 and 17, instead of one level, as shown in Fig. 15. The double layer alternative, which was divided into two equal parts with vertical and horizontal single layer options, was drafted by assuming that the depth of the layers are 400 and 500 meters, respectively.

Fig. 18 shows the difference in the dominant costs between the single layer and the double layer plans. It was found that the single layer option is the most economical alternative due to the excavation volume of the central tunnel and the backfilling cost.

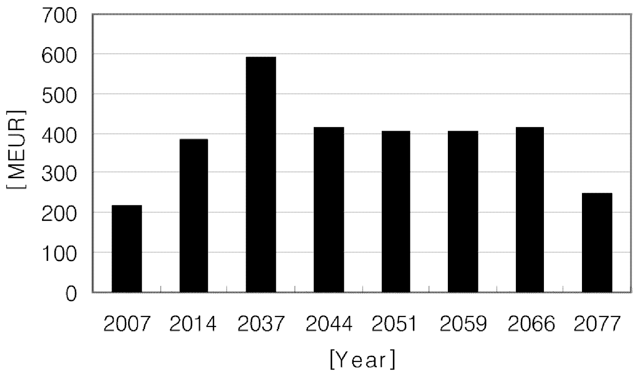

Fig. 12. Cash Flow for the Underground Facilities of a Repository

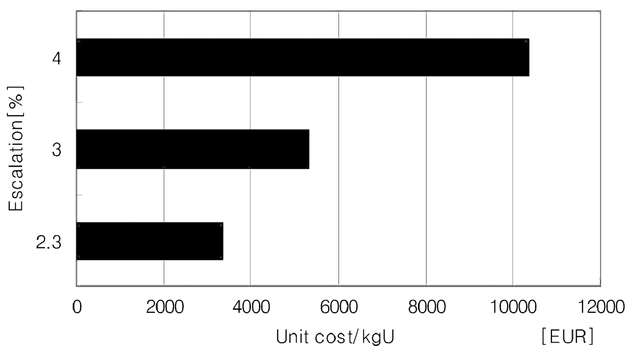

Fig. 13. Sensitivity of an Escalation

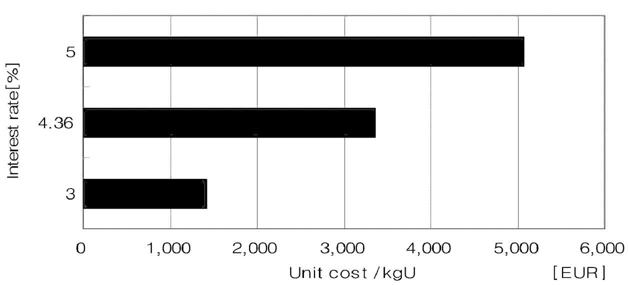

Fig. 14. Sensitivity of the Interest Rate

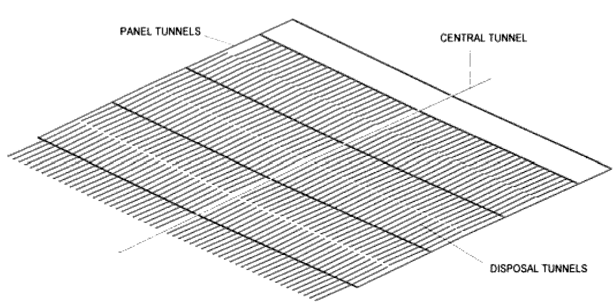

Fig. 15. Single Layer Alternative of the Repository

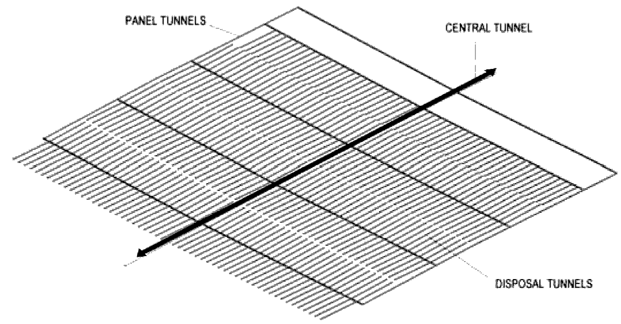

Fig. 16. Double Layer (Horizontal division)

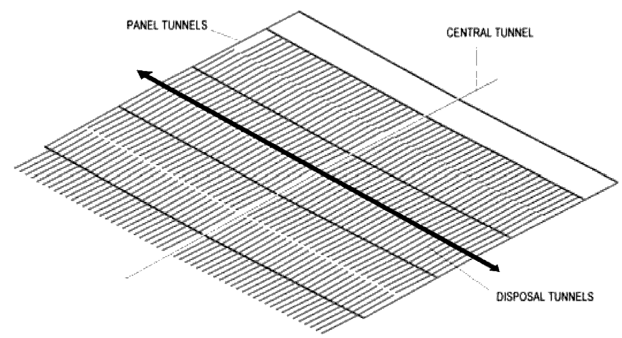

Fig. 17. Double Layer (Vertical division)

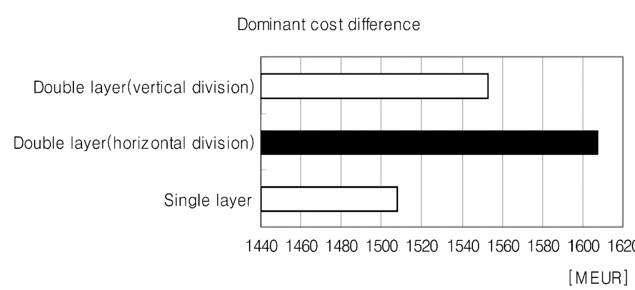

Fig. 18. A Comparison of the Cost for the Single Layer and Double Layer Options

4. CONCLUSIONS

In comparisons of single layer and the double layer options, it was found that the single layer option was the most economical alternative due to the central tunnel excavation and backfilling cost.

According to the sensitivity analysis undertaken in this study in terms of the escalation and interest rate, it was found that these economic variables affect the total cost significantly, as the construction of a repository requires approximately 80 years.

Finally, the disposal unit cost was estimated to be 222 EUR/kgU, which appears viable. However, this cost is the result of a case study, thus if a disposal concept for Korea is to be completed, the cost may change. In addition, it is essential to take all economic variables, repository site costs and safeguard costs into consideration when estimating such a cost in the future.

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