

## Examination of Economic Feasibility of Nuclear Weapons in the Republic of Korea

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### 1. Introduction

While the government of Republic of Korea is firmly committed to nuclear nonproliferation, survey result of the attitude of the public shows high percentage of the public being receptive toward possessing nuclear weapons [1-3]. At the same time, when all the negative consequences are hypothesized, South Korean people tend to withdraw their support for nuclear weapons development. [4]. This observation implies that the popular view on nuclear weapons amongst Korean public is in part due to lack of knowledge about overall implications of possessing nuclear weapons. In this regard, pros and cons of nuclear weapons development need to be better characterized and understood by the public to support nuclear nonproliferation culture development. Noting lack of literature on characterizing the economics of nuclear weapons development, this study aims at performing economic feasibility analysis of nuclear weapons development in the ROK. For this purpose, an approach called Index technique based on the US experiences [5] was applied to Korean historical data along with cost-benefit analysis and Multi-Criteria Decision Making Analysis.

### 2. Methods and Results

In this section, methodologies of economic analysis, i.e., cost benefit and multi-criteria decision making analysis are described.

#### 2.1 Scenarios Development

Assessment of the contribution of nuclear weapons to national security [6] in a country requires comprehensive understanding of national security environment and strategies considering a wide variety of factors such as economic, human, environmental and social elements. However, understanding the full spectrum of national security issues requires access to sensitive information. Due to the nature of this study as an academic exercise, simple comparison of the cost-benefits [7] between two scenarios, i.e., the case of defending the country by relying on conventional weapons and the case of nuclear weapon-based national defense was performed. In both cases, the goal is to defend against North Korea's nuclear weapons threat. The first scenario, i.e., defense based on conventional weapons, assumed introducing Kill chain and Korea Air and Missile Defense (KAMD) in response to NK's

WMD in addition to maintaining conventional advanced weapon system including weapons import. The second scenario assumed developing domestic nuclear weapon capability equivalent to North Korean capability. The North Korean equivalent capability was assumed as possessing 10 nuclear weapon warheads for the balance of power. It is further assumed that the capability is based on the use of centrifugal separator enrichment and reprocessing technology similar to the scale of North Korean program. Figure 1 shows some specifics about the two scenarios with specified time frames.

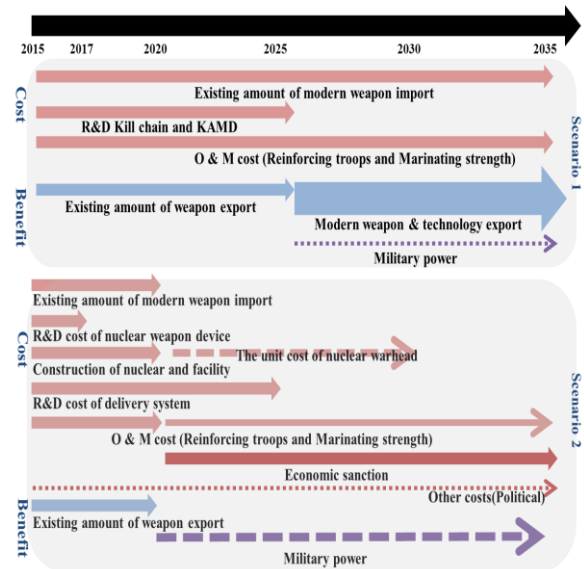


Figure 1. Description of two scenarios

#### 2.2 The Cost of Nuclear Weapon Development

As part of analyzing cost-benefit balance between the two scenarios, the cost of nuclear weapon development needs to be calculated. Estimates of the cost of nuclear-weapons programs can vary widely, depending on the information used, such as the country's technical capacities, existing infrastructure and the extent of the cost consideration [8-12]. In this study, the cost of nuclear weapon development in ROK was estimated using Index technique based on the US nuclear weapon program experiences since 1940 [13]. The index technique provides a convenient means for developing future cost and price estimates from historical data.

The cost was estimated by considering inflation effects, availability of labor and materials, countries' infrastructure capacity and technological advances. The US spent \$ 2 billion (cost in 1945) for 2 warheads

through Manhattan project and ultimately spent \$ 640 billion (cost in 2014) for about 7700 warheads. Based on this information, the learning rate can be estimated at about 72%. Moreover, as the ROK is the one of NPP export countries having mature NPP technologies, the cost of nuclear weapons development could be lower, although enrichment and reprocessing capability do not exist in the ROK. According to Global Innovation Index [14] which is to quantify technology innovation level considering human factor, ROK ranking is similar to US. This means that it is appropriate to apply US nuclear weapon cost data into the ROK situation as a base case. Based on these assumptions, the cost of developing a single nuclear warhead including production of nuclear materials and operating and maintenance cost is estimated at about \$2.2 million.

### 2.3 Cost Benefit Analysis

As part of cost-benefit analysis, two mutually exclusive public-works scenarios were assumed. In Scenario1, capital investment was indicated as the annual amount of weapon import in 2014, while the benefit is related to weapons export by the ROK [18-19]. The scenario also requires preparing Korea Air and Missile Defense (KAMD) and killing chain system for preventing NK nuclear weapon attacks [21-22]. In contrast, the cost of scenario 2 contains Research and Development (R&D) cost of nuclear warhead and delivery system [20]. Comparisons of costs and benefits between the two scenarios are presented in the Table 1 [23-26]. Each project was evaluated based on a standard project period of 20 years including research, development and construction periods. The Minimum Attractive Rate of Return (MARR) represents the real discount rate considering nominal discount rate and inflation rate at 2 % per year. It also assumed that there will be economic sanction to the ROK if the country decides to develop nuclear weapons and will be applied after 5 years of project initiation. To evaluate the cost benefit analysis of two scenarios, the values of given data were converted into future worth.

Table I: Cost and benefit of two scenarios (Scenario 1: Conventional weapons-based defense; Scenario 2: Nuclear weapons-based defense)

		Scenario 1		Scenario 2	
Cost	The annual amount of weapon import	\$1627 million / year	R&D cost of nuclear weapon device	\$ 134 million (R&D period: 2 years)	
			The unit cost of producing a nuclear warhead	\$ 2.1528 million/ 1 warhead during 1 year	
			Capital Investment on construction of Nuclear facility	\$ 201 million (Construction period: 5 years)	
	Capital investment on building the kill chain and KAMD	\$ 27789.8 million (R&D period: 10 years)	R&D cost of Delivery system (one ballistic missile)	\$ 53200 million (R&D period: 10 years)	
	Annual operating and maintenance costs	Reinforcing troops	\$ 14.2 million/year	Reinforcing troops	\$ 7.810 million
		Maintaining strength	\$ 9.9 million/year	Maintaining strength	\$ 5.445 million
	Other costs	ROK-US alliance	no change(positive benefits)	Damage on ROK-US alliance (risks on military)	\$ α
		Damage on economic growth	no change (maintaining \$ 1000 billion)	only remaining 10% of total trade volume	\$ 900 billion under economic sanction
		Further security threat	Conflicts on china, international relationship \$ β	remaining 90% of total trade volume	\$ 100 billion under economic sanction
	Additional Benefit	The annual amount of weapon export	\$600 million/year	In reality, we cannot export nuclear weapon	\$γ (military power)
Benefit		Responsible power to North Korea's asymmetric warfare capacity			
Results			Minimum sanction	Maximum sanction	
	Cost(Future worth): \$ million	\$ 69,847.70	\$ 1,820,777.94	\$ 156,565,497.94	
	Benefit (Future worth): \$ million	\$ 21,148.24	\$ 4,201.50	\$ 4,201.50	
	Conventional B-C ratio	0.302776469	0.002307531	2.68354E-05	
Incremental ΔB/ΔC(I-II)		-0.009678706			

The result of analysis As shown in Table 1, the result of conventional benefit-cost (B-C) ratio, for both scenarios was found to be lower than 1. This means two scenarios are both unacceptable from the view of economical feasibility. Furthermore, using Incremental B-C Analysis, Scenario 1 was found to be more beneficial than Scenario 2. This means that development of nuclear weapons in the ROK has little economic benefits. This result did not include the consideration of political effect on ROK-US alliance and resulting degradation of the security environment. In addition, current estimate did not consider the influence of α, β, γ parameters given in Table 1 because of the difficulties in accessing their values But even if their influences were included, and the general trend of the result is expected to be valid as the cost of Scenario 2 was found to be so high. Therefore, nuclear weapon development program will not be desirable from the economics point of view.

As this result comes with many assumptions and limitations, further work, a Multi-Criteria Decision Making method, was also performed.

### 2.4 Multi-Criteria Decision Making (MCDM)

In the cost benefit analysis described in the previous section, only military defense budgets were considered.

However, in reality, cost-benefit analysis requires the consideration of various internal and external factors such as the effect of international economic sanction and declining national status in the international system should be considered. This indicates that nuclear weapons development is a multi-attribute decision. Accordingly, analysis based on the use of the MCDM method was made for various aspects of national security. The decision criteria used included economic security, military security, human security, environmental security, social security and political security including domestic and international aspects [27]. Table II describes categories of national security used in the analysis and factors affecting the evaluation of each security category. Although there may be many factors to be considered for assessing each security category, only the main factors related to nuclear weapons program [28-30] were selected in the study. For example, one of key factors in the development of nuclear weapons program is the leadership of a country. When a national leader leads the program with strong motivation and will, a backdrop of widespread poverty and unmet basic needs can be overlooked and bypassed as shown by countries like North Korea.

Table II: Categories of national security and factors affecting each category

	Categories	Factors affecting the category
National Security	Political security	Leadership, democracy or dictatorship, international relationship
	Economic security	GDP per capita, Total trade volume, export, import, electricity production, the volume of crude
	Environmental Security	Global warming, Environment contamination caused by nuclear test
	Social Security	Nuclear weapon free world
	Human Security	Population, perception of danger of WMD
	Military Security	Troops, the amount of weapon import and export

It is difficult to assess relative importance or value of each of the factors in the respective security category. Only the economic security category can be assessed in monetary units. Economic value is also established through an item's use value (properties that provide a unit of use, work or service) and/or esteem value (properties that make something desirable). As "use value" and/or "esteem value" defy precise quantification in monetary terms, this paper resorted to the use of these values in exercising the multi-attribute techniques. Table III and Table IV represent the ranking values of each factor and the results of MCDM analysis for the two scenarios. All attributes, collectively, were assumed sufficient for selecting the "best" alternative. Differences in the values of each attribute category should be meaningful for the purpose of performing the exercise.

For security category, values ranging from 1 to 4 were assigned based on the examination of the expected

consequences of the decision in the given scenario. The value 4 means highest level of security. Therefore higher total score combining the values of all security categories is desirable for improving overall national security. For example, if the ROK government follows Scenario 2, an international economic sanction is likely to be imposed. As international trade dependence of the ROK is very high (~ 90 % of total commerce volume which was \$1000 billion in 2014), total trade volume of the ROK will be reduced by 90% because of the sanction [31-33] resulting in the assessed value of 1 in the economic security category. In case, ranking of scenario 2 is almost one point while scenario 1 is almost four points. The sanction will also affect domestic electricity production and the related energy security situation of the country. Thus the sanction is estimated at resulting in the value of 2 in electricity production under Scenario 2.

The factors affecting human, environmental and social security category are related to the country's prevalent belief among the public and culture. As the ROK, has excelled in the role of middle power state recently by following international norms and duty, following Scenario 2 will certainly result in degradation of that status. Therefore following Scenario 2 was assumed to result in the value of 2 in human, environmental, and social security category.

In the political security category, factors such as leadership, northeast geopolitics, soft power effect and international relationship are expected to be important. The scenario 2 followed by the ROK will certainly make troubles among Japan, China, USA and others. In this case, Scenario 2 is judged to have resulted in as the value of 1 for the soft power and geopolitics category and 3 for the international relationship category.

In terms of military security, both scenarios should improve national security against the threat from North Korea; so both scenarios have the value of 4. However, missile defense system could result in making uncomfortable relationship with China and the result of nuclear weapons development is becoming a target of nuclear or terrorists attack. In addition, nuclear weapons development by the ROK will have a triggering effect on nuclear proliferation in Northeast Asia.

In this assessment exercise, the resulting numerical value of each element may not be significantly meaningful but the relative difference should be noted.

By using the assessed values of Table III and the equation (1), aggregate score of each scenario was calculated. For a category with multiple attribute subcategories, the mean value for the category was used. The results is shown in Table IV. In this process, the values of each security category was combined by using the assigned weight values (following the so called, Additive weighting Technique). The values of weights were given based on the survey performed among Korean public [2].

The results indicate that maintaining the present policy of conventional weapons-based national defense

with the development of KAMD is more desirable than introducing nuclear weapon program.

Table III: Ranking values of each factor in two scenarios

Categories		Scenario 1	Scenario 2
Human Security	Population(2012)	50,004,000	
	Perception of danger of WMD	4 (totally understand)	2 (understand but can not giving up nuclear weapon)
Environment security	Environment contamination caused by nuclear weapon test	4 (totally understand)	2
Society security	Nuclear weapon free world	4 (totally understand)	2
	Culture effect (i.e Korean wave)	4	2
Political security	leadership	3	4
	Soft power effect	4	1
	Northeast geopolitics	4 (good relationship, open)	1
	International relationship	4	3
Economy Security	GDP per capita(2013)	\$ 23838	
	Total trade volume(2013)	4 \$1000 billion (trade dependence 90%)	1 \$100 billion (UN sanction)
	Electricity production	4 (4224 billion KWh)	2 (the amount of electricity will be decreased)
	Crude	4 (872415*1000barrel)	1 (0 barrel)
Military Security	Response force to North Korea	4	4
	Decreasing potential threat risks	3	2 (Risk will be increased)

$$Rating = \frac{\text{outcome being made dimensionless} - \text{worst outcome}}{\text{best outcome} - \text{worst outcome}} \quad (1)$$

Table IV: The results of MCDM of two scenarios

	Weighting factor	Scenario 1		Scenario 2	
		Ranking	Score	Ranking	Score
Human Security	10	1	10	0.3333	3.3333
Environment security	5	1	5	0.3333	1.6665
Society Security	5	1	5	0.3333	1.6665
Political security	20	0.9167	18.334	0.4167	8.3334
Economy Security	30	1	30	0.1111	3.3333
Military Security	30	0.8333	24.999	0.6666	19.998
Total score	100		93.333		38.323

### 3. Conclusions

In this study, the scenario of nuclear weapons development against North Korean nuclear threat was compared with conventional weapons-based defense strategy. The comparison was based on cost benefit analysis and qualitative multi-criteria decision analysis. Results indicate that nuclear weapons development is not a desirable option. However, as this work was a rather simplistic academic exercise, further work is needed to support the outcome of the study. Outcome of these investigations would be useful for communication with the public regarding the need for nuclear weapons for national defense and to develop nuclear nonproliferation culture in the ROK.

### 4. Future works

To clarify the impact of the assumed scenarios for a realistic appraisal, examinations of issues on the international dimension should be implemented. Nuclear weapon is not only for the purpose of national security but is also related to international security and global peace. Future works should also explore the role of a changing security environment. In addition, sensitivity analysis needs to be performed as many of the factors and values under consideration remain uncertain. Also further work is needed as to the feasibility of using economic terms to analyze national security issues.

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