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Modeling tradeoff in ship breaking industry considering sustainability aspects: A system dynamics approach

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Abstract

Ship breaking industry provides incentives for developing countries. Thus, it presents economic catalyst for the country. On the other hand, ship-breaking activity contributes hazardous material that result ecological imbalance for the exposure area. Moreover, ship-breaking process by any standard is dangerous occupation because intoxication by dangerous substances and accident that happened on the plots. In the light of these, economics benefit and social-environmental loss regarding to ship-breaking industry is debatable. This study observes the tradeoff between loss and benefit of ship breaking industry. A model for ship breaking industry considering economics, environmental and social issue was constructed using System Dynamic. Proposed model captures the variable sensitivity while each variable is interacting with another. The result can be considered on regulation and policy implementation regarding to ship-breaking and its aspects, specifically in developing countries

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Keywords: Ship breaking industry, sustainability, tradeoff, system dynamics

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1. Introduction

Since the beginning of 1970's ship-breaking activity become a solution, besides reefing to dispose a ship [1]. However, ship-breaking process is more preferable since it provides economic value of obsolete ships. For the recent years, most of these ships are sent to Asian countries to be scrapped. As well as in Europe, it was long time ago when ship-breaking activity has moved from European region into Asian countries, followed by the raise of the facility and labor cost and the increase of environmental regulation [2, 3].

Since then, ship-breaking industry seems to be important for particular developing country. It is reasonable since it is labor intensive, where the activities provide an extensive human labor due to necessity of on-hand process. The requisite of small investment, large amount of manual labor [4] and less electricity [3] provide economic opportunities for developing country. Therefore it takes place in countries with low-cost labor such as Bangladesh, Pakistan and India. Indonesia also includes in it, with on and off market criteria [2].

Ship-breaking activity can also be considered as green industry, because almost the entire product can be reused, recycled and resold [5,10,13]. Scrap iron resulted from ship breaking can reduce the destruction cost of earth typography due to mining activities. Recent study shows that steel production from hematite ore needs 7400 MJ energy to be proceed, whilst scrapped ferrous will only need 1350 MJ energy. Additionally, the study also shows that CO2 (s) releases from hematite ore processing to become iron are 2200 kg per ton steel, while scrapped ferrous releases only 280 kg per ton steel [4].

However, any of these advantages have not been noticed yet. Previous researches in ship-breaking activity widely discussed about the environmental and social impact as a consequence of the process [4-7]. These studies show that ship-breaking activity contributes a highly waste and pollution for current location where the process done. It was also mentioned that end-of-life ship can be considered as hazardous material, since the ship itself contains several hazardous material. Moreover some other research argued that ship-breaking process by any standard is dangerous occupation due to intoxication from dangerous substances and also accident that could be happened on the plots due to worker who wears no protection equipment [7-10]. Workers are not aware of the danger and hazard which exposed them.

Several studies have been conducted in attempt to provide better process of ship-breaking activity [4, 12, 13]. EU promotes green recycling and green facility to reduce environmental impact and to give better protection for workers. However, green capacity was found to be more expensive compare to traditional ship-breaking process [12-13]. For this reason, ship owner prefers to process their ship using traditional method in order to maximize their profit. On the other hand, green facilities which adopting advanced technology and equipment will require less human labor yet more skilful. This condition will decrease the workforce and potentially increase unemployment for current developing country.

Economics benefit and socio-environmental loss regarding to ship-breaking industry is debatable all over the world. It becomes controversial issue due to serious environmental and social impacts together with the economics importance for several countries. Thus, this research is aimed to capture the tradeoff between each sustainability aspect, includes environmental, social and economic issue. Using system dynamic approach, the model is expected to predict sustainability from ship breaking industry, specifically in developing countries.

2. Ship-breaking industry : An overview

2.1. Brief Process

Ship-breaking activity has already becoming one aspect of ship industry. This activity draws any breaking down of vessel's structure to dismantle the vessels, including the removal of gear, equipment, or any other component of the vessel into part and or pieces. Ship-breaking which also well known as "ship scrapping" has becoming an alternative for ship disposal while on the same the time recapture the value of the scrapped ferrous and other components of ship.

Basically there were no standard for ship-breaking procedure. Each region has its own technique in order to do ship-breaking activity, which depends on the labor skill and the availability of tools and equipment. However, Sarraf M, et al. classified ship-breaking methods into three types; include beaching, dry dock, and afloat/slipway [5]. Beaching is the most used method in several developing countries, since it involve non-mechanized process. Thus, it tends to employ low-skill labor in large numbers. This method usually performs at most developing countries. Dry dock method is mentioned to be the method that meets the requirement of Environmental and Safety Management. Dry dock method is usually adopted in develop country since it requires high capital and investment. On the other hand afloat method is more difficult to do than dry dock, but the cost saving is much greater than dry dock. Turkey ship-breaking industry adopts this method with modification. This procedure needs specific requirement of yard which appropriate to condition of the shore [4].

As mentioned before, ship owner tends to send their obsolete ship to Asian country to optimize their profit. Study shows that up to 90% of ship-breaking process in the world are done in Asian country [2,5,4,7,12,13]. As almost all ship-breaking facility in these countries are lacks of mechanized facilities together with under precarious health and safety working conditions, resulting human cost for ship-breaking industry. Moreover, most of those ship-breaking facilities do not have adequate infrastructure to treat hazardous material resulted from obsolete ship. This leads to high amount of pollution and risk the environmental and people.

In order to provide solution for the environmental problem resulted from ship-breaking and reducing risk for workers cleaner ship-breaking process is then proposed [4,10,13,14]. The recommendation involves environmentally friendly procedure of scrap; include treatment of hazardous waste and material. Besides that, suggestion of proper maintenance working condition and protection of the health and safety of worker were also mentioned. Nevertheless, the cost of ascertaining the recommendation is relatively expensive, though environmentally impact should be more substantial for the next future [5,14].

2.2. Ship-breaking issue

2.2.1. Environmental issue

The main issue in ship-breaking process is mostly about the problem related to waste management and hazardous material resulted from obsolete ships. Ships which were built in over decades and banned today usually contain of oil sludge, bilge and ballast water. Those materials represent danger to the environment. In the light of this, end-of-life ship, which is sent to be scrapped, must contain a mixture of hazardous material. Furthermore, the hazardous materials mostly found in a ship include asbestos, polychlorinated biphenyls (PCBs), and lead. Oil, mercury, antifreeze, solvents, TBT and another material that also considered hazardous were also mention as ship-breaking result [4,5,7,8,12,13]. Those hazardous materials can be found in amounts of material vary depending on the size, type and the age of ship.

Contrary to significant volume of hazardous material and waste from ship-breaking process, most of ship-breaking facilities were lack of infrastructure to treat such materials. Ship-breaker releases those materials directly to the environment without proper process [13]. The existence of waste and hazardous material from ship-breaking contaminate the coastal soil and water environment and thus lead to ecological imbalance. The occurrence of zooplankton and phytoplankton in numbers as well as species

richness was very poor for the affected area. As a result the fishery and other resources were also affected [10].

The aforementioned condition above describes how ship-breaking activities contribute negative environmental impact and therefore, it becomes a contra, not only for environmentalist but also government in countries with strict environmental regulation such as European Region. Environmental issue became reason of ship-breaking activity was moved from European Region. Moreover the cost of labor and environmental cost is very high in accordance to the environmentally policies [2].

2.2.2. Social issue

Ship-breaking facility, especially in developing country performs unsafe work environment due to inadequate safety devices and proper working equipment. Several studies found that most workers haven't formally trained to deal with toxic materials as well as shortage of Personal Protective Equipment (PPE) in general and appropriate PPE in particular area [5,10]. Many of them are die or get injured on the spot because of accident such as explosion and accident due to the lack of safety measures [4, 10,13].

Moreover, hazardous material exposure to the workers in long term leads to sickness and death. Some cancer types and asbestos related disease will occur 15 – 20 years later [8,10]. On the other hand there are no insurance for health or life in case of illness happen. Ship-breaker will only compensate for the accident happen on the spot [7]. Though it was found in many cases that ship-breaker not fully compensate for injury or death caused by accident on the ship-breaking process [9].

2.2.3. Economics issue

In the countries where ship-breaking occur, scrap iron and other reusable item are considered to be resource instead of waste. Therefore, ship-breaking activity provides important contribution to the development of local economy. It was mentioned that a great number of under privileged people are locally dependent on this industry. The industry provides huge number of working opportunity for low-skill labor, both directly and indirectly. Direct labor are people who works on ship-breaking spot, while indirect labor are people who engaged downstream of ship-breaking industry [17]. The highly need of labor force for doing the process make provides economic catalyst for the country. Furthermore, recapture the value of part and component of the ship, which mostly made up from metal, promising a considerable profit for the actor of the business and provide tax revenue for related government [4].

3. Methodology and Model Development

3.1. Methodology

System dynamics approach is applied to model the ship-breaking trade off. This method is expected to provide better understanding of the problem, since ship-breaking industry is particularly complex with highly uncertainty. System dynamics is able to identify the relationships among variables in the system and demonstrated the variables behaviour that affects one another. Moreover, it is also able to demonstrate the effect of interaction among variable to overall model [18].

The model development was done in three steps. First step is to develop the system structure which will draw the character of its behaviour. This represents by building causal loop diagram. Second step is expanding it by develop the flock stow diagram to demonstrate the natures of dynamic behaviour of the structure. The last step is to simulate and evaluate the model structure. In this research, stock and flow diagram will be simulated using the Ventana Simulation software (Vensim).

3.2. Model Development

A causal loop diagram is constructed to capture the interaction of economics, social and environmental issue related to ship-breaking industry. For better understanding, the major assumptions should be mentioned first as follows; (1) Environmental issue will only consider the environmental loss as direct impact of ship-breaking activity, without considering its environmental benefit regarding to 'green industry', (2) The model does not consider the international regulation, due to lack implementation in real condition.

Figure 1 draws the feedback loop between main variable generally. As the main motivation of ship-breaking occurrence in developing country is the economics benefit, the model put three benefits that contribute to local economic, consist of benefit for the government, the business, and people. It shows that there are positive feedback for government and people from the business profit of ship-breaking industry. Positive feedback means that for every incremental profit gained by the business, the government will provide more benefit from the tax of the business, as well as the economics benefit for employee in form of working opportunity.

On the other hand, the existing of ship-breaking industry in developing country, which is lack of infrastructure for waste management and working safety, contributes to environmental loss and human risk. Therefore the arrow from both variables shows negative feedback toward economics benefit. The more profit gain by the business, means lessen investment and cost for safety and working equipment and waste management. Thus, ship-breaker shifts the cost in order to provide ship owner a competitive price of obsolete ship, increasing volume of ship demolition to the country. The figure also shows how the environmental loss and human risk will influence the benefit for government. It gives negative impact since the people and environmental become the responsible of the government. In the case of ship-breaking loss is higher than the benefit, government in form of regulation, have authorization to adjust the capacity of ship-breaking thus reducing the productivity and profit indirectly and vice versa. The same interaction occurs for variable of human risk and economics benefit for people, except that people do not have power to overcome this situation instead of accept it.

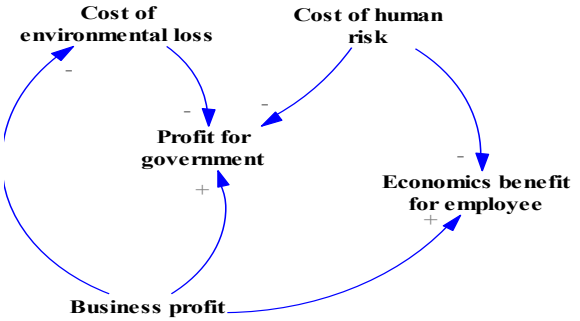

Fig. 1. Model structure of ship-breaking trade-off

4. Result and Discussion

The model structure of ship-breaking trade off in Figure 1 has been used to create system structure and generate system behavior. The system design and simulation result will be discussed and analyzed in this section.

4.1. System Dynamic Model

Stock and flow diagram which ilustrates relationship of elements in the ship-breaking process will be used as dynamic system simulator in this simulation study. The flow diagram of ship-breaking process consists of three sub-models to represents the economics, environmental, and society aspects. Written bellow are the explanations of each flow diagram.

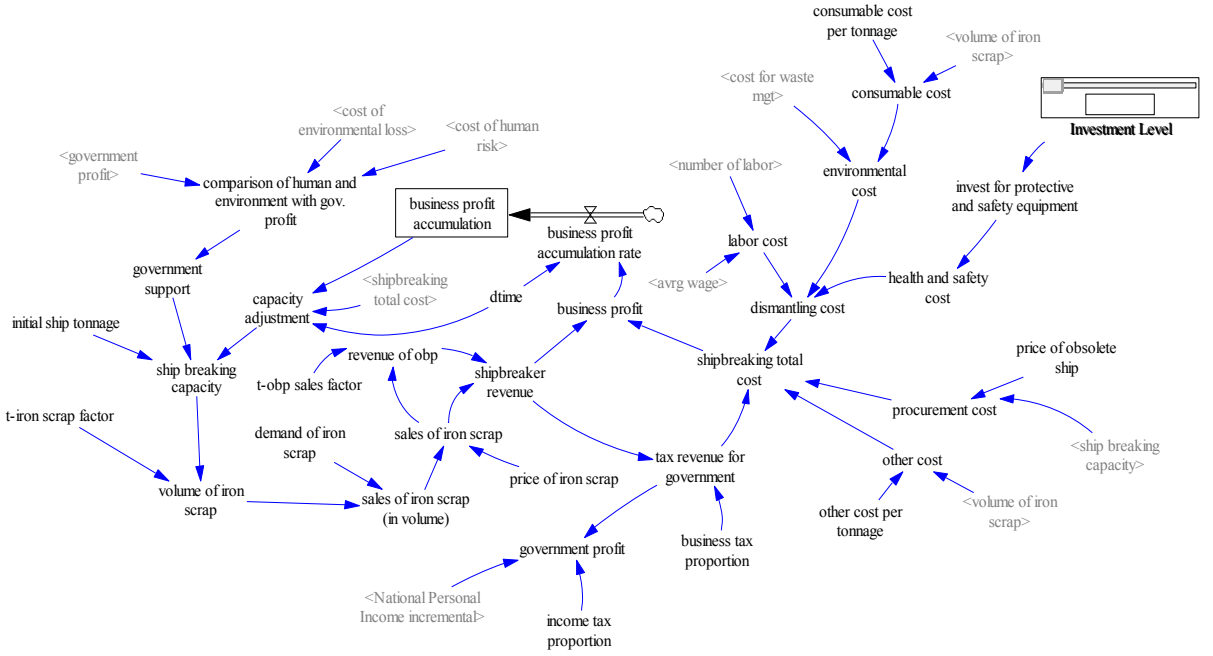

Fig. 2. Flow diagram of economic aspect

Table 1. Equation in economic aspect flow diagram

No.	Variable	Formulation	Unit
1.	ship breaking capacity	initial ship tonnage * capacity adjustment * government support	tons/year
2.	business profit	Ship breaker revenue – ship breaking total cost	$/year
3.	ship breaking total cost	dismantling cost + procurement cost + other cost + tax revenue for government	$/year
4.	ship breaker revenue	revenue of obp + sales of iron scrap	$/year
5.	initial ship tonnage	9.5e+006	tons/year
6.	capacity adjustment	comparison of business profit accumulation and shipbreaking total cost to adjust ship-breaking capacity	Dmnl
7.	government support	comparison of human and environment with government profit to adjust ship-breaking capacity	Dmnl
8.	government profit	(income tax proportion * National Personal Income incremental) + tax revenue for government	$/year

4.1.1 Economics Aspect

Figure 2 shows sub-model of economic aspect from ship-breaking industry. It is consist of revenue and cost of ship-breaking process. Ship-breaking revenue is earned from sales of iron scrap and other-by-products. Ship-breaking total cost is all cost needed to do the ship-breaking process consist of dismantling cost, procurement cost, tax, and other cost which include transportation cost and beaching cost. The profit can be generated by substract the revenue to cost. The amount of profit along with government support

will effect the increase of shi-breaking capactity. The government support is set based on the comparison of environmental cost and human risk cost to the government profit. Environmental cost will be explained in sub-model of environmental aspect. Human risk cost and government profit are included in sub-model of social-aspect. Table 1 shows the formulation which represent connection between variable in the model.

4.1.2 Environmental Aspect

Figure 3 describes the loss suffered by environment from hazardous materials which have not been properly processed. The amount of unprocessed hazardous materials affected by level of ship-breaker company willingness to spend cost more in waste management. The higher the willingness level means the lower the environmental cost loss and it is contrary with the cost of waste management. However government support to increase the ship-breaker capacity will be the advantage point of the minimum environmental loss cost. The equation which represent connection between variable in this flow diagram is listed in Table 2.

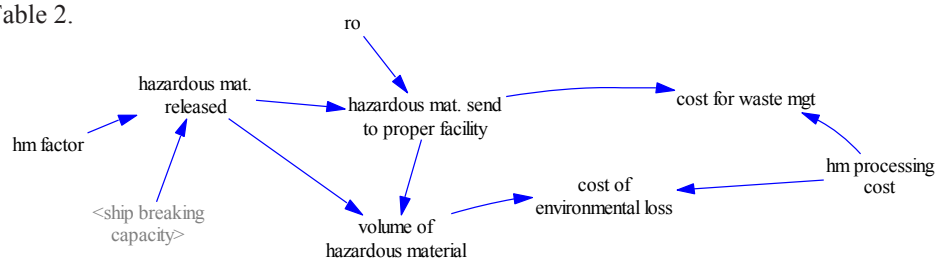

Fig. 3. Flow diagram of eenvironmental aspect

Table 2. Equation in environmental aspect flow diagram

No.	Variable	Formulation	Unit
1.	cost of environmental loss	hm processing cost * volume of hazardous material	$/year
2.	hm processing cost	RANDOM UNIFORM(4, 11.1 , 0)	$/tons
3.	volume of hazardous material	"hazardous mat. released" - "hazardous mat. send to proper facility"	tons/year
4.	hazardous mat. send to proper facility	ro * "hazardous mat. released"	tons/year
5.	ro	willingness level of ship-breaker to send volume of hm to waste facility	Dmnl

4.1.3 Social Aspect

Figure 4 represents the social aspect of ship-breaking industry. It simulates the effect of ship-breaking process to the National income and government profit. National income is generated from multiply of number of empolyee work at the ship-breaker industry to average wage. The higher National income means the higher profit to government which come from the tax.

However, the increasing of National income is not the only social aspect of ship-breaking industry. The risk of worker which work in unhealthy and unsafe environment will be another side of it. The level of human risk in this industry is affected by the investment in health and safety infrastructure. The higher the investment level, human risk cost will be lower. Minimum cost of human risk will affect government support level in order to increase ship-breaking capacity. List of equation in this flow diagram can be seen in Table 3.

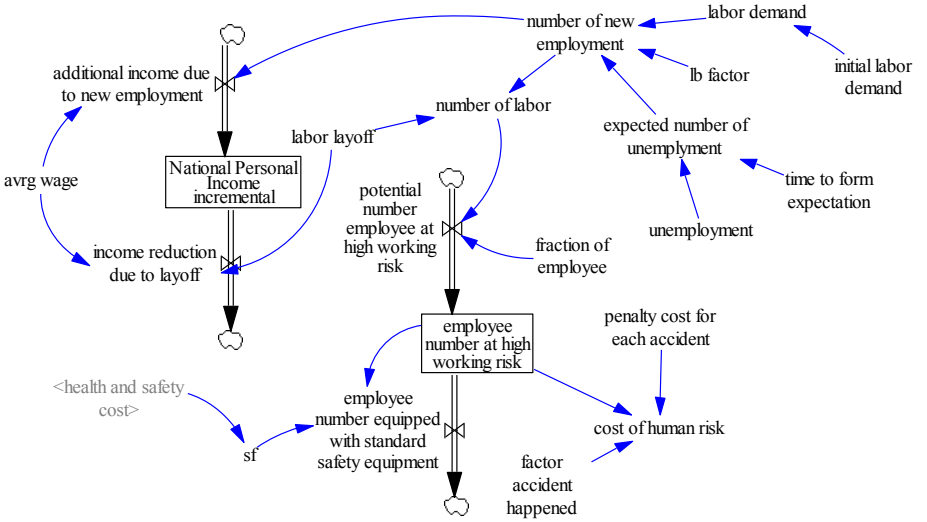

Fig.4. Flow diagram of social aspect

Table 3. Equation in social aspect flow diagram

No.	Variable	Formulation	Unit
1.	number of labor	number of new employment - labor layoff	person/year
2.	National Personal Income incremental	additional income due to new employment - income reduction due to layoff	$
3.	employee number at high working risk	potential number employee at high working risk - employee number equipped with standard safety equipment	person
4.	cost of human risk	employee number at high working risk * factor accident happened * penalty cost for each accident	$/year

4.2 Model Validation

Model validation is an important step in system dynamic. This process will be based on Barlas [18] validation classification. The model in this research is consider as causal-descriptive model. Therefore, the most appropriate validation method is structure validity. Theoritical and empirical test was done during model development to validate the structure. Vensim provide “check model” and “unit check” as tools to do model structural check to ensure the consistency and relathionship in model. The result of vensim validation can be seen in appendix. Validation of structure oriented behavior test is done by doing extreme and behavior sensitivity test by comparing the significancy difference ship-breaking capacity resulted by different level of willingness to process hazardous materials and level of health and safety investment.

4.3 Result

The model is simulated in some conditions to show the behavior of system; to know its impact condition to ship-breaking capacity and business profit. The different conditions are given to ship-breaker

willingness to process harzardous materials, investment level of health and safety infrastructure, business tax propotions. The scenarios show the envolvement ship-breaker and government to obtain high profit as well as minimize environmental loss and human risk. The highest and lowest willingness in processing harzardous materials and health and safety infrastructure investment level will be the reference scenarios. Alternarive scenarios are made by modifiy some conditions between the two scenarios. By reffering to all scenarios result the best trade-off obtained on the condition which listed in Table 4.

Table 4. Equation in social aspect flow diagram

No.	Variable	Unit	Value		
			Highest	Trade-off	Lowest
1.	ro (willingness to process hazardous materials)	Dmnl	1	0.5	0
2.	Investment level	$/year	9.25M	6.75M	0
3.	business tax proportion	Dmnl	0.1	0.05	0.1

Figure 5 and 6 in sequence demonstrate cost of human risk and environmental loss at the three scenarios above. Figure 7 and 8 represent the comparison of business profit and government profit among three scenarios. The trade-off scenario lower the human cost 95.24% in average from the lowest scenario and the environmental loss minimize 54.72% in average. On the other hand business profit are 31.72% in average compare to the lowest scenario. It is also the higher profit among three scenario which are caused by the government reward by lowering the business tax proportion.

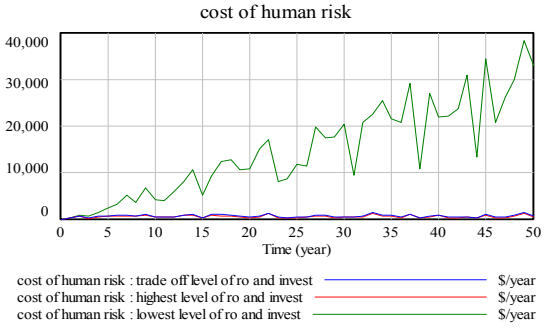

Fig. 5. Cost of human

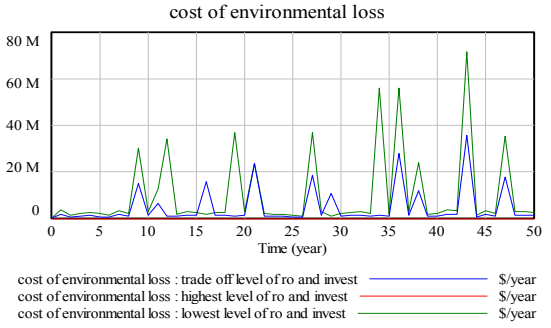

Fig. 6. Cost of environmental loss

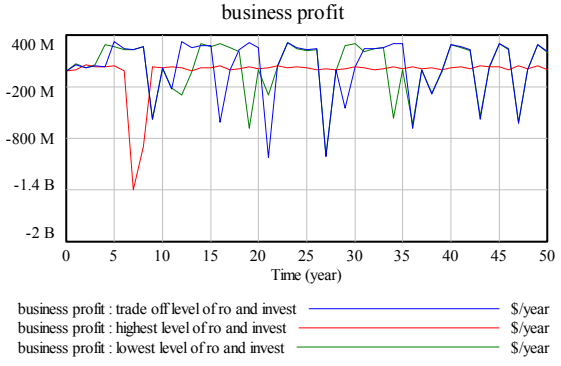

Fig. 7. Ship-breaker industry profit

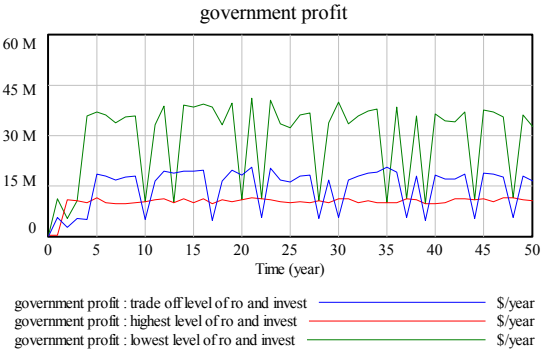

Fig. 8. Government profit

5. Suggestion

This study could be considered as a pilot study of trade-off among economics, environment, and social aspects in ship-breaking industry. It could be the tools for the decision maker in this industry both government and ship-breaker to find the most optimal condition to earn high profit and still consider the environmental loss and the risk for human who involved in the industry. However, there are several areas where further research is still required. Considering ship-breaking as green industry, the model can be expanded by includes environmental benefit variable. Moreover, it is essential to consider the existence of international regulation related to ship-breaking activity in order to provide complete picture about ship-breaking.

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