Climate change modeling for nuclear industry using Systems Thinking: Spirit at the University of Maryland

Tae Ho Woo
Department of Mechanical and Control Engineering, The Cyber University of Korea, Seoul 03051, Republic of Korea
Department of Radiation Convergence Engineering, Yonsei University, Wonju 26493, Republic of Korea
**Corresponding author: thw_kor@hotmail.com*

1. Introduction

The climate change is investigated in the aspect of the priority of energy consumptions. Some causes of the climate changes are discussed. Regarding of the carbon productions, nuclear energy is analyzed with other energy sources. The causes of climate change are studied as quantities using relevant mathematical formulas. The simulation modeling is performed using system dynamics (SD) where the simple and easy calculations are performed. The nuclear priority due to the climate change increases, which was done in the previous study (Woo, 2015). The nuclear energy increasing rate with the climate change factor affects to the temperature change which can show the environmental protection as well as energy supply.

It is analyzed for the climate change modeling incorporated with the nuclear power source which is definitely considered as the green energy clearly equivalent with the sustainable renewable energy one. Following the carbon originated global warming nodus, atomic energy has been a realistic and economical source for the industrial adaptations. In this study, the previous study regarding the climate change is modified with the much more adequate algorithm, the game theory with systems thinking idea.

The game theory is applied to the modeling for the quantifications where designed variables are weighted by the game theory factor. That is, each variable could be reevaluated by two opposite quantities in which there are many kinds of cases in the society. For example, the usage of the carbon related energy sources is affected by two contradictable values such as ‘use’ or ‘don’t use’ in the coal or oil resource. Therefore, it is reasonable to make use of the game theory in the nuclear industry that the consumptions of a certain energy are related to the minds of the supplier or consumer. In the calculation of the modeling, the SD is used in the study where the programming is constructed by the Vensim code system. Basic meaning of the climate change modeling is to find out the possibility of the success in manipulating of the global warming scenarios in this paper where the dynamical quantifications are produced. Nuclear energy is a highly promising source, because it is the non-carbon emission energy stuff, especially when considering global energy shortage, the nuclear stuff is important as much as the status of the renewable energies like the solar, wind, and so on.

2. Methods and Results

The game theory is applied to find out the values of the simulations where the interested elements are quantified following the non-zero-sum logic. SD was created by the Dr. Jay Forrester in 1960s for the social humanities matters. Nowadays the scientific and technological applications are very popular in the interested areas such as the energy or reliability stuffs (System dynamics society, 2016). The systems thinking is to describe any systems which could be the human, society, nature, or conception objects (Senge, 1990). This could be expressed by the SD methods using the commercialized software like the Vensim, iThink, Stella, and so on. The powerful contributions of the SD in the systems related technologies have been proved. There are several kinds of tools like the feedback, accumulation, time step, and more skills to show the designed systems. The non-zero-sum method can produce the overlapped image of the event sequences which is different from the zero-sum method of making the zero value after the summations. (Roberts, 2016).

The factors of the climate change are considered as five reasons of Sea, Human, Orbit, Magnetic Field, and Plate Motion as it is studied in the previous study which is in Fig. 1 (Woo, 2015). The Sea is considered as the most important part in the climate change (Bryan, 1986/87). For the formula, assuming ocean radiates and conducts heat away from itself, if the ocean temperature rises above atmosphere average temperature T^*, and A has the positive value. This will cool down as Newton’s Law of cooling (Jiji, 2009; NSF, 2014),

$$T' = -A\,(T - T^*) \tag{1}$$

Regarding Human factor, this is related with the climate through its role in the carbon, water cycles and such mechanisms as albedo, evapotranspiration, cloud formation, and weathering (Spracklen, 2008; Christner et al., 2008; David et al., 1989). It is formulated as the correlation between geometric albedo and diameter is as follows (Dan, 2008),

$$R = (1{,}329 \times 10^{-M/5} / L)^2 \tag{2}$$

where, R is the astronomical albedo, L is the diameter in kilometers, and M is the absolute magnitude. This could be estimated by creating an equation of the water balance of a drainage basin and the equation balances the change in water stored within the basin (W) as (Kendall et al., 1998),

$$\Delta W = R - MF - S - G \tag{3}$$

In addition, the input is precipitation (R), and the exports are evapotranspiration (which is to be estimated), stream-flow (S), and groundwater recharge (G). For the changes in storage, precipitation, stream-flow, and groundwater recharge are estimated, and the missing flux, MF, can be estimated by rearranging the above equation as follows (Kendall et al., 1998),

$$MF = R - \Delta W - S - G \quad (4)$$

In the cloud formation, it is analyzed by the way of saturation from air (Pidwirny, 2014). In addition, the Human is including the Economy, Politics, Energy, and Resources. Each term has relevant elements as population, GDP, Export-Import, Congress, President, Government, Politician, Oil, Hydro, Coal, Nuclear, Solar, Wind, Food, Water, Air, Soil, and Mineral. Orbital variations is done as slight variations in Earth's orbit lead to changes in the seasonal distribution of sunlight which reaches to the Earth's surface and the distributions (Schwarzacher, 1993). Magnetic field strength is related with the global climate where the strength of Earth's magnetic field could affect to the climate (Courtillot, 2006; SpaceDaily.com, 2013). The plate tectonics is the course of millions of years of the Earth in which the motion of tectonic plates forms the global land and sea areas (Forest, 1999). In the simulation, Orbit, Magnetic Field, and Plate Motion are done by the reasonable random sampling where the expert judgments are incorporated. The other variables as A, H, D, P, ET, Q, and D (other one) are also decided by expert's decision. The strategy of this study is that the human induced carbon gas and the nuclear priority are key issues.

Then, the game theory is described as the subtraction between two random number generations. So, there is the diagram description in Fig. 2 (a) for the non-zero-sum method (Smashing Blogger, 2009) and its modification with SD is constructed as the analogy of Fig. 2 (a) where Element1 minus Elemetn2 means the differences between two elements in Fig. 2 (b). That is, the overlapping area is omitted and the A remains in Fig. 2 (a). The subtraction between two random numbers remains in Fig. 2 (b). This is multiplied to the Nuclear Priority by Climate Change Factor in Fig. 3. The nuclear percentage is changed approximately for 6 % in 2010 to 13 % in 2050 (HSBC, 2011). By the study, the nuclear priority by climate change factor is calculated as nuclear percentage multiplied by climate change factor. Fig. 3 shows the simulation result for nuclear priority by climate change factor.

3. Results

The event connection is described as the causes tree in the Fig. 4. Fig. 5 shows the simulations of the climate change factor. In Fig. 6, there is the graph for nuclear priority by climate change factor where the initial value is 995.76 in 2017 and the last value is 65,586.00 in 2100, which are dimensionless values. These values are compared each other for the meaning of designed characteristics. The nuclear priority due to the climate change increases 65.87 times in 2100.

4. Conclusions

Although the climate change is produced by the carbon usage related stuffs, the managements of the consumptions are very affected by the human actions. So, the complex based analysis is very useful to study like the case of the game theory in this work. The dynamical modeling is formulated with the systems thinking and its related simulations. Fig. 7 shows the protocol for climate change investigation in which the nuclear industry considering the climate factor like the temperature is an important index to find out the priority of nuclear energy. There are some important points in this study as follows;

- The climate change in nuclear industry is investigated.
- Nuclear energy could be the key factor to reduce the global warming.
- Systems technology is used very effectively.
- The study is significantly helpful to the pro-nuclear industry.

Following above work, the worldwide study using the individual nation circumstances should be done as the aspect of the international cooperation, because the climate change of a country clearly affects to the neighbor nations. If the energy is wisely controllable in the fossil fuel, the clean air environment could be constructed as soon as possible. There is the researches description for industrial assessments in the University of Maryland where the climate change is one of the hot topics in the energy studies, which is in Fig. 8.

ACKNOWLEDGEMENTS

Author thanks to Prof. Bial M. Ayyub at the Center for Technology and Systems Management, Dept. of Civil & Environmental Engineering in the University of Maryland for the research spirit in 2013.

REFERENCES

Bryan, K., 1986/87. Man's Great Geophysical Experiment: Can we model the consequences? Oceanus, 29(4), 36-42.

Christner, B.C., Morris, C.E., Foreman, C.M., Cai, R., and Sands, D.C., 2008. Ubiquity of biological ice nucleators in snowfall, Sci. 319 (5867) 1214.

Courtillot, V., Gallet, Y. Le Mouël, J.-L., Fluteau, F., Genevey, A., 2006. Are there connections between the Earth's magnetic field and climate? Ear. and Pla. Sci. Lett. 253, 328-339.

Dan, B., 2008. Conversion of Absolute Magnitude to Diameter for Minor Planets. Department of Physics & Astronomy (Stephen F. Austin State University).

David, W.S., and Tyler, V., 1989. Biotic enhancement of weathering and the habitability of Earth, Nat. 340, 457-460.

Forest, C.E., Wolfe, J.A., Molnar, P., Emanuel, K.A., 1999. Paleoaltimetry incorporating atmospheric physics and botanical estimates of paleoclimate, Geo. Soc. of Ame. Bull. 111 (4), 497–511.

HSBC, 2011. Global Economics & Climate Change, Energy in 2050. HSBC Bank Plc, London. UK.

Jiji,L. F., 2009. Heat Convection, 2nd Ed., Springer-Verlag Berlin Heidelberg, Germany.

Kendall, D., McDonnell, J.J., 1998. Isotope Tracers in Catchment Hydrolog, Elsevier Science B.V., Amsterdam, Netherlands.

NSF, 2014. The El Niño / Southern Oscillation. Department of Mathematics, IDEA: Internet Differential Equations Activities, http://www.idea.wsu.edu/El-Nino/.

Roberts, E., 2016. Non-Zero-Sum Games, Charles Simonyi Professor of Computer Science, emeritus, Stanford University, Stanford, USA, http://cs.stanford.edu/people/eroberts/courses/soco/projects/1998-99/game-theory/nonzero.html.

Schwarzacher, W., 1993. Cyclostratigraphy and the Milankovitch Theory, Elsevier Science Publishers B.V., Amsterdam, The Netherlands.

Senge, P.M., 1990. The Fifth Discipline, Currency Doubleday, USA.

Smashing Blogger, 2009. Original Sin: Part 5, A Game Theoretic Summary of Sin in the Malthusian World, for LiteThemes.com.

SpaceDaily.com, 2009. The earth's magnetic field impacts climate: Danish study.

Spracklen, D. et al., (2008). Boreal forests, aerosols and the impacts on clouds and climate. Phil. Trans. Roy. Soc. A, 366, 4613-4626.

System dynamics society, 2016. Introduction to system dynamics, Albany, USA, http://www.systemdynamics.org/what-is-s/.

Woo, T.H., 2015. Modeling for climate change in the aspect of nuclear energy priority: Nuclear power energy-based convergence social-humanity analysis, Transactions of the Korean Nuclear Society Spring Meeting Jeju, Korea, May 7-8, 2015.

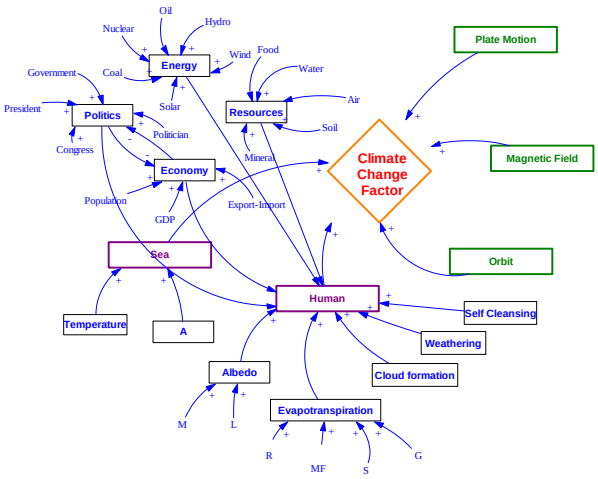
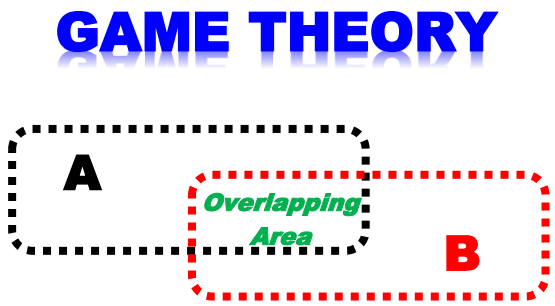
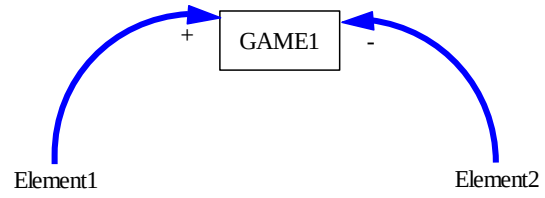


Fig. 1. Climate change factor with human factor.



(a)



(b)

Fig. 2. Modeling for the game theory.

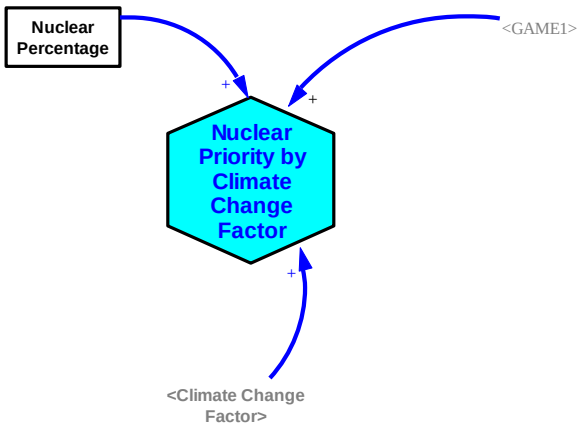


Fig. 3. Graph for nuclear priority by climate change factor.

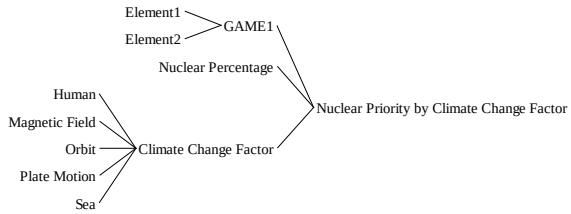


Fig. 4. Graph for causes tree.

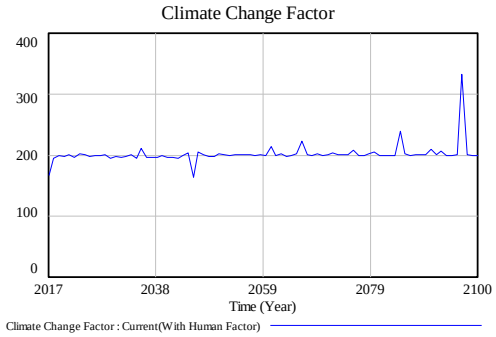


Fig. 5. Graph for climate change factor.

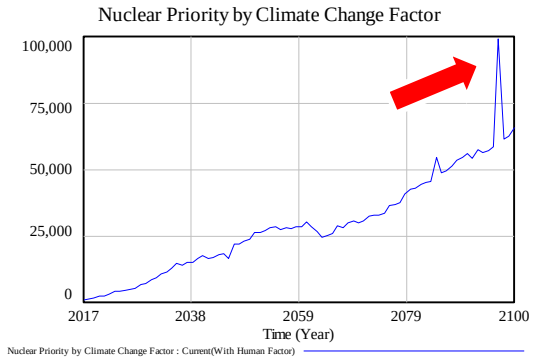


Fig. 6. Graph for nuclear priority by climate change factor.

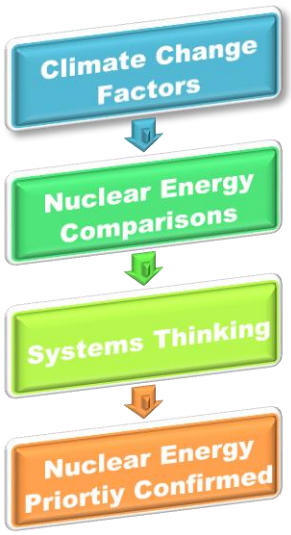


Fig. 7. Protocol for climate change factors in nuclear industry.

Fig. 8. Researches for industrial assessments in the University of Maryland.