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Systems dynamics (SD) strategy for Small Modular Reactor (SMR) marketing – Conquest at the MIT Energy Laboratory (*Pres.* MIT Energy Initiative)

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1. Introduction

As the historic monumental victory of the global nuclear industry, the success of export for the South Korean small modular reactor (SMR) has been studied as the marketing strategy using system dynamics (SD) of MIT [1]. The world's first commercialized SMR, the System-integrated Modular Advanced Reactor (SMART), is planned to build in Saudi Arabia [2-6]. South Korea and Saudi Arabia had agreed that two countries have the three-year preliminary study to review the feasibility of constructing SMART reactors in Saudi Arabia where the cost of building the first SMART unit in Saudi Arabia was estimated at $1 billion [6]. This reactor has the specification as the power is 330 MWt pressurized water reactor (PWR) with integral steam generators and advanced safety features [6]. In the plant design, it is planned for electricity generation of 100 MWe and thermal applications of seawater desalination where the life span is a 60-year operation design and three-year refueling cycle [6]. Regarding of the licensing, the standard design was approved from the Korean regulator in mid-2012 and the Korea Atomic Energy Research Institute (KAERI) has a plan to build a demonstration plant to operate from 2017 [6].

According to the previous study of the marketing strategy of the Canadian small reactor, Safe LOW-POwer Kritical Experiment (SLOWPOKE) reactor had been investigated in 1988 [7]. Therefore, it is interesting to compare SMART and SLOWPOKE. In this work, it is to find out the strategy of the successful marketing of SMART and suggest continuous marketing prospects. There are specifications and parameters of SMART in Tables 1 and 2 [8]. The public acceptance (PA) had been studies as safety-public interpretation, SLOWPOKE safety-experience and process, and economics in the previous paper of the SLOWPOKE, [7] which was about the marketing strategy for the commercial nuclear reactor. It is modified for the mathematical methods by dynamical strategy in which the Chou et al.'s methods are reviewed [9] and then the SD is applied to the work.

2. Methods and Results

The importance of the marketing strategy in the nuclear industry is to analyze the dynamical consequences. Chou et al. [9] studied for the five methodological factors using the decoding network dynamics as network boundary, process, time, events, and conceptual tools for analyzing change. In this work, the graphical configurations were utilized for the concept of roles to analyze change where it is necessary for the capturing and decoding network dynamics to take the dimensions of stability and change [10].

In this paper, the SD method is employed for the applications of the network method which was introduced around 1960s for the business management matters in MIT [11]. Author had worked the SD study with a researcher at the MIT Energy Laboratory (*presently* MIT Energy Initiative) in which the innovative energy researches have been done including SD applications to the nuclear industry. Basically the information of the algorithms is manipulated by the feedback oriented method in the field of the social humanities topics where the level and rates are accompanied with the accumulations of the systems process [11]. In the modeling, each event value has the Boolean values as 0 or 1 in which the values are selected by the random number generation. In the case of the randomly generated value higher than the designed value decided by an operator, it is 1. On the data quantifications, the random number selection and the designed value are decided by the expert judgment. The comparison between the Chou et al.'s network method and the SD method is shown in Fig. 1 where the repeated feedback and multiple connectivity are adjusted. It is the sequence for the repetitions of the feedback configurations incorporated with the multiple connectivity. In Fig. 2, the SD modeling for Product Technology is described where the modeling is composed of Reactor Core System, Nuclear Steam Supply System, Safety System, and Electricity Generator, which means the summations of each element. Furthermore, the Reactor Core System is composed of Nuclear Fuel System, Vessel System, and Fuel Management Technology, which means the summations of each element. The other connections are done in similar ways. Especially, the Reactor Core System is connected with the Safety System and Nuclear Steam Supply System where the Reactor Core System effects on three factors as Product Technology, Safety System and Nuclear Steam Supply System. In Fig. 3, the SD modeling is shown as the Marketing Technology and in Fig. 4, the SD modeling is shown as the Process Technology. The numerical values are obtained in Product Technology, Marketing Technology, and Process Technology. As an example, the Piping System is quantified as random number between 0 and 1. If it is lower than 0.8, the value is 0. Otherwise, it is 1. The other models are analyzed by the similar way. In Fig. 5, the SD modeling shows for Nuclear Marketing. The System is 'if then else (random 0 1 () < 0.3, 0, 1)' and Modeling is 'if then else (random 0 1 () < 0.4, 0, 1)'. The Weight means the feedback loop of the modeling in which the value is 'if then else (random 0 1 () < 0.8, 0.1, 1)'. That is to say, the Nuclear Marketing affects itself by the weighting including the time sequences. In this study, the simulation software is done by the Vensim code system [12]. Since the uncertainty of the events in the NPPs is comparatively higher than those of the other industries, the random sampling-based quantifications are used for the assessment of the futuristic event in which the safety and economic factors are analyzed, especially for the nuclear problems. It is said the nuclear energy is not easy to control, because the accident is extremely significant. Therefore the safety should be treated with the uncertainty of the events.

In the SD modeling, the simulations are including the connectivity loop as well as dynamical sequences where the causal loop is considered as the event connectivity. In this study, the Reactor Core System is connected twice. This is shown as the results obtained by the graphical dynamic features. The period is the 60-year in the program, which is different from the previous study [1], because the life time of the plant is reflected. That is, it is considered whether or not a life cycle of the operations can effect on the marketing. In the quantification, Time step is done one time for a half year, which means that the calculation is done every half year. The logic of the Time step is one of importance characteristics in SD, because the result is affected by the time step. For the case of level function, the shorter time step produces higher values due to the accumulations of the each value where the more important event could be calculated in shorter time step. In Fig. 6, the results for modeling are done as Product Technology, Marketing Technology, Process Technology, and Nuclear Marketing. The outputs are obtained by the comparative values where no dimension and unit are in the graphs. Therefore, the higher value means the higher possibility of the marketing in NPPs. In evaluation of the results, on the 8^{th} year, there is the highest value as 290 when the marketing is in the highest possibility time, which is seen in the Nuclear Marketing graph. Due to this result, it is suggested to prepare to make the exportation of the SMR. This modeling is taken by the many elements of the SD algorithm, which is originated from the MIT Sloan School of management in Fig. 7 [13]. Current MIT Energy Initiative could give the implications in the nuclear research prospections shown in Fig. 8 [14].

3. Conclusions

The highly cognitive networking based dynamical modeling was discussed where the system is treated by a complex and non-linear way. The linear networking of the interested issue was changed by the SD algorithm where the feedback and multiple connections are added to the original networking theory. The non-linear method has shown the complexity of the marketing strategy, especially for the NPP which is the very expensive and safety focused facility. There are some marketing strategies based on the modeling as follows,

1. Product Technology: It is needed to improve the integrity of the safety as well as the economy in power productions.
2. Marketing Technology: Aggressive sales promotions could succeed in the global competitions against Japan, France, and some other potential marketers.
3. Process Technology: Creative R&Ds and education programs are proposed for infrastructure enhancement.

In addition, it is expressed by the operator who decides the functions in the modeling and the time step which decides the calculation frequency. Hence, the complex algorithm is shown by the modeling designs. In the applications, this method could be applicable to the other industries where the safety and economic factors are highly focused.

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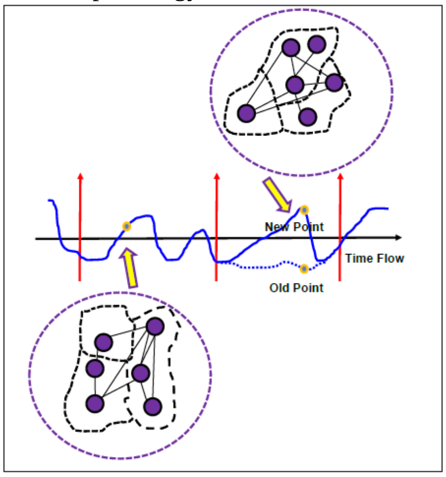


Figure 1. SD for Nuclear Marketing with feedback loop with multiple connectivity.

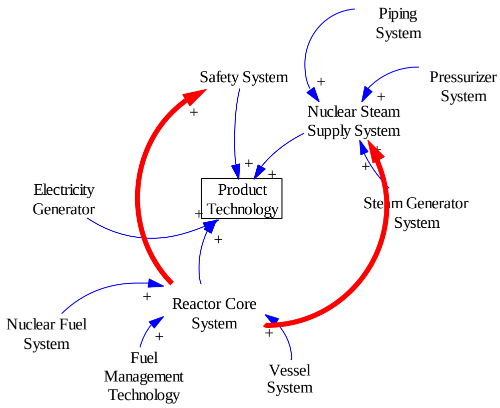


Figure 2. SD for Product Technology.

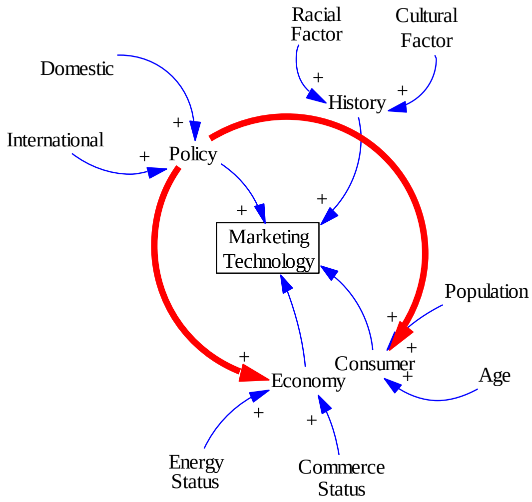


Figure 3. SD for Marketing Technology.

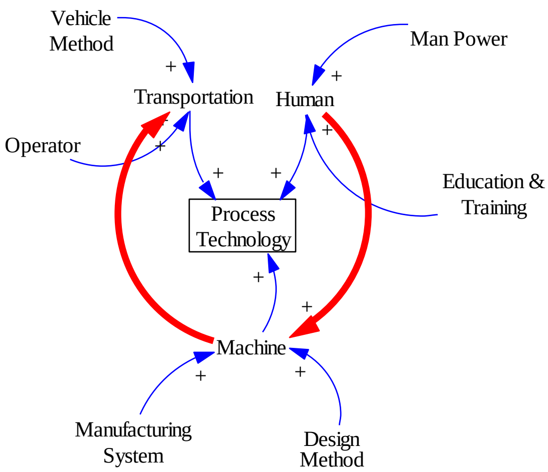


Figure 4. SD for Process Technology.

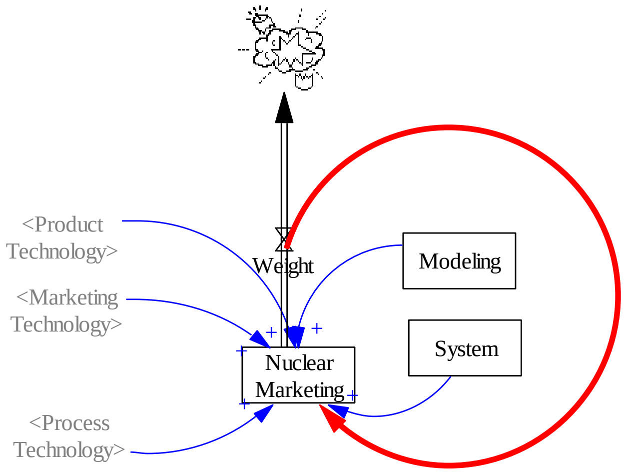
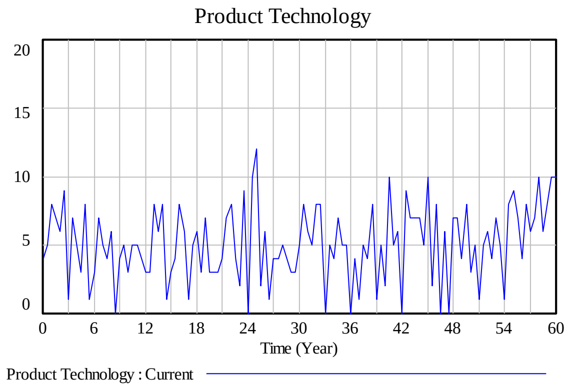
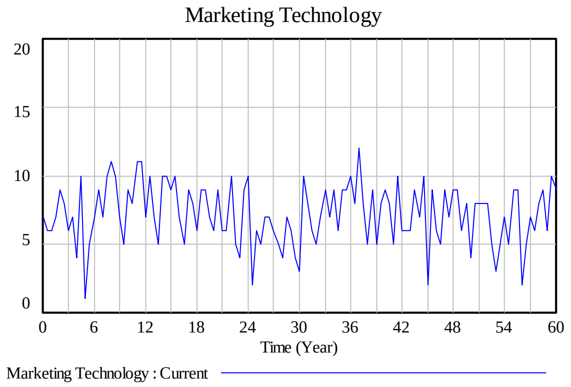


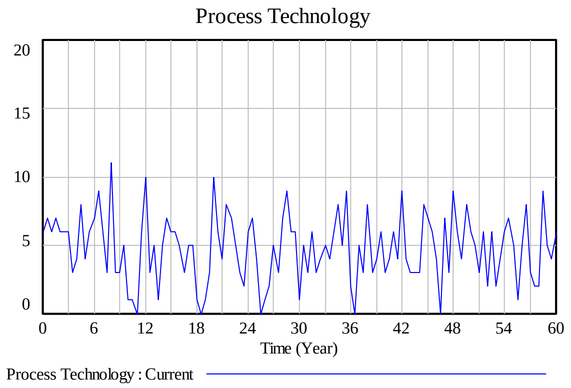
Figure 5. SD for Nuclear Marketing.



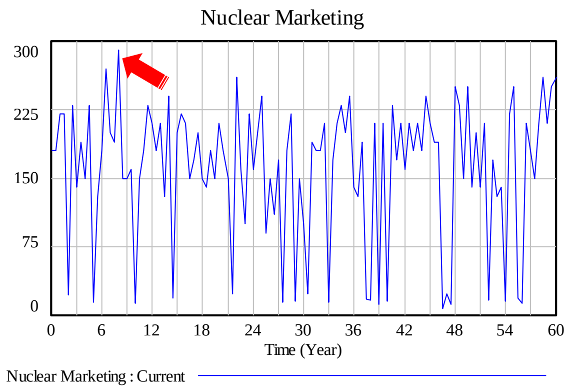
(a)



(b)



(c)



(d)

Figure 6. Results for modeling, (a) Product Technology, (b) Marketing Technology, (c) Process Technology, and (d) Nuclear Marketing.

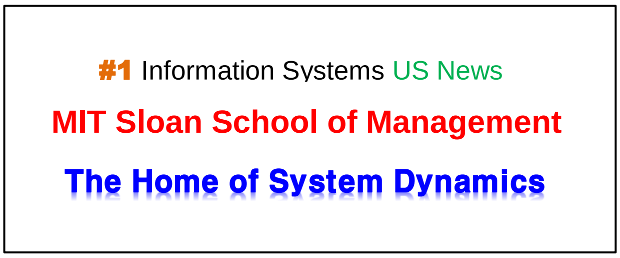


Figure 7. SD in MIT.

Figure 8. Four fields of nuclear energy in MIT Energy initiative.

Table I. Specifications of SMART

Specification	Value
Thermal Power	330 MWth
Electric Power	100 MWe
Refueling Period	36 months
Design Lifetime	60 years
Fuel Type	17x17 Square
Fuel Material	UO_2 Ceramic (< 5 w/o)
Number of Fuel Assembly	57

Table II. Parameters of SMART

Parameter	Value
Core Thermal Power	330 MWth
Design Pressure/Temperature	17/360 MPa/^{o}C
Operating Pressure	15 MPa
S/G Inlet Temperature	323 ^{o}C
S/G Outlet Temperature	295.7 ^{o}C
Flow Rate	2090 kg/sec
Steam Pressure	5.2 MPa
Steam Temperature	298 ^{o}C