Chapter 2
Dynamical Modeling of Economy in Global Nuclear Energy Market

Abstract Non-linear dynamical analysis for the global nuclear energy market is investigated. Currently, the market means a different characteristics comparing to the past situation which had been done before two severe accidents as the Three Mile Island nuclear power plant (NPP) accident in the United States and the Chernobyl NPP disaster in the Soviet Union. For the nuclear related facility, the environmental and safety aspects are the important issues of the analysis. Fundamentally, the economic factor is still a critical matter for the commercial trade between two countries, which depends on the energy demand and uranium price. The dynamics simulations show the trend of trade is affected by the several kinds of the aspects. Using system dynamics (SD) method, the event quantification is performed for the event flows, stocks, and feedback where the single and double arrow lines are incorporated.

Keywords Dynamical analysis · System dynamics · Feedback · Nuclear power plant · Simulation

2.1 Introduction

The worldwide energy demand can give a huge market in the nuclear industry. The feature of energy composition shows the steady portion of the nuclear energy. Therefore, the international trade market is affected by several factors which will be modeled in this study. The non-linear dynamical management has been performed in many areas including chemical industry, automobile industry, and some other industries. Especially, the time based algorithm is one of critical issues in the industrial management. The main object of the paper is to find the quantified results for the global export and import in nuclear industry. It, however, is difficult

T. Woo, *Atomic Information Technology*, Springer Series in Reliability Engineering,
DOI: 10.1007/978-1-4471-4030-6_2,

Table 2.1 Estimation of export in South Korea

Year	Number of units (cumulative value)
2009	4
2012	10
2030	80
Total	80

for the simulation to express much tractably due to the linearity of the mathematical expression. So, the easy and non-linear method is needed to show the better explanations.

Recently, South Korean government took the trade order of the advanced power reactor (APR) 1400 to the United Arab Emirates (UAE), which is the new type of nuclear power plant (NPP) for 1,400 MW(e) power [1]. There is some more export plan in Table 2.1; [2]. There is a merit that the nuclear power is a non-carbon production energy source which makes the international trade of NPP be active. So, it is necessary to investigate the systematic estimations. The export and import simulation could be done by the statistical calculations. Presently, nuclear power reactors in operation with a total net installed capacity of 370,187 GW(e) which is seen Fig. 2.1; [3]. 5 nuclear power reactors are in long term shutdown. 56 nuclear power reactors are under construction globally in Table 2.2; [4].

The system dynamics (SD) is used for the quantifications of the marketing in this nuclear industry. The SD was introduced for the non-linear characteristics of the social and economic system. This complex system for dynamical evaluation is tested by SD. The SD has been applied to the organizations by the transitions of the time [5, 6]. Some other papers are also seen as the industrial markets [7–9]. In addition, there are some decision-making related papers [10–14]. The method section explains the method of the study. The calculation for the modeling is shown in the calculation section. The results section describes results of the study. There are some conclusions in the conclusions section. The Sect. 2.2 shows method for the modeling. The calculation for the modeling is given in the Sect. 2.3. The Sect. 2.4 is the results of the study. There are some conclusions in the Sect. 2.5.

2.2 Method

For the simulations to the analytic estimation as well as the quantification, the SD method is applied. The particular problems of the technological implications are quantified by the SD for the variety of factors. In addition, the dynamical decision-making problem could be solved in the complex cases. Vensim package is used for the simulation, which was developed in the Ventana systems, Inc.

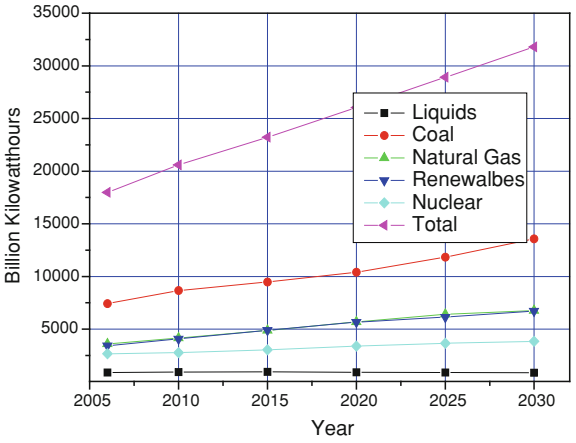


Fig. 2.1 International energy annual 2006

Table 2.2 Under construction nuclear power plants (NPPs) by country

Country	No of units	Total MW(e)
Argentina	1	692
Bulgaria	2	1906
China	21	20920
Finland	1	1600
France	1	1600
India	5	2708
Islamic Republic of Iran	1	915
Japan	1	1325
Republic of Korea	6	6510
Pakistan	1	300
Russian Federation	9	6894
Slovak Republic	2	810
Taiwan, China	2	2600
Ukraine	2	1900
U.S.A	1	1165
Total	56	51855

The SD was described by M. Radzicki, which is a powerful methodology and computer simulation modeling technique for understanding, framing, and discussing complex issues and problems [15]. It is helpful for managers to improve their understanding, which is practicable in all kinds of policy and design areas. The basic block could be expressed by the SD for how and why complex real-world systems behave the way they do during the specified time. The object is to support the understanding to implement much more effective policies. In SD molding, the most important thing is the dynamic behavior of system, where the operator tries to identify the patterns of behavior exhibited by interested system variables, and then builds a model with the characteristics of patterns. The single

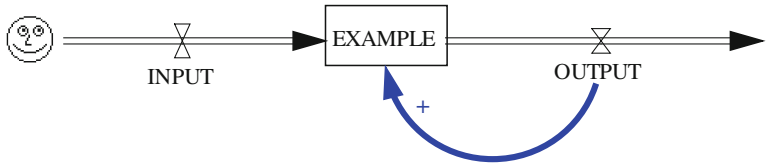


Fig. 2.2 Stock-flow and feedback

and double arrow lines are used for the purpose. Lines mean the event flows and time flows. The important thing is the dynamic behavior of a system, its key physical and information flows, stocks, and feedback structures for SD. There are several characteristics of the SD as Nonlinearity, Stock-flow, Feedback, and Time Paths. In the SD modeling, there are special expressions for the above characteristics. Especially, in the Vensim code, the technical methods are done by single and double arrow lines. All kinds of dynamic behaviors could be happened when flows accumulate in stocks, which are seen as EXAMPLE for accumulation and INPUT/OUTPUT for flows in Fig. 2.2. It is a case like a bathtub where a flow can be thought of a faucet and pipe assembly that fills or drains the stock. It is thought as the simplest dynamical system in the stock-flow structure. Both informational and non-informational object can move through flows and accumulate in stocks for the SD. The feedback loops are often joined together by nonlinear couplings where any object often cause counterintuitive behavior, which is seen as blue color loop in Fig. 2.2. A plus sign means for the addition to EXAMPLE of the feedback value, OUTPUT. Otherwise, if the sign is minus, the feedback value, OUTPUT, is subtracted from the EXAMPLE.

Usually, the Monte-Carlo simulation is performed for the quantifications in the assessment of the social and economic problems. This could be used for the practical operations in the plant and business modeling. This method, however, can express the mathematical values. Otherwise, the SD shows analytical as well as numbering graphs incorporated with dynamical expressions. This advanced method can give the easy understanding of the designed modeling.

2.3 Calculation

The modeling for the real world to the systems thinking world is in Fig. 2.3. There is a paralleled configuration between the real world and the systems thinking world which makes the combinations of the construction in the modeling. It is defined that the systems thinking is any process to problem solving by viewing ‘problems’ as parts of an overall system, which is potentially a contribution to further development of the undesired issue and problem. The SD is expressed by the dynamical feature of the systems thinking.

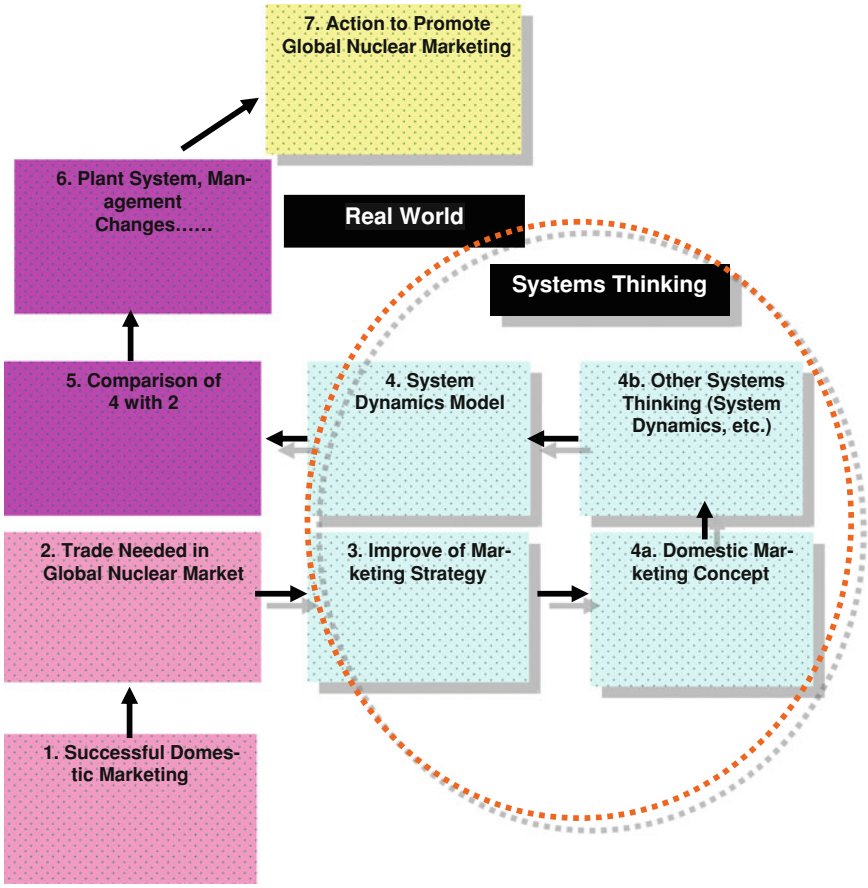


Fig. 2.3 Real world versus systems thinking world

The configuration for the Global Nuclear Marketing Activity is in Fig. 2.4. The main object is to find the possibility of expected plant trade in Table 2.1 which gives the South Korean plan of 80 units export until 2030. The 3 factors are introduced as the technological factor, the political factor, and the diplomatic factor.

The technological factor has 2 aspects which are the funds aspect and the market activity aspect. There are the financial effects of funds in Fig. 2.5 as company factor, economic factor, and government factor. In each factor, there are income, construction capacity, GDP, economy progress, tax income, and leader mind. Especially, the economy progress is organized as Fig. 2.6. It is represented by the plan progress which is summed by production and feedback adjusted consume. These elements are adjusted by economic plan term of 7 years. That is, the strategy of economic plan is changed by every 7 years. So, the numerical value

Fig. 2.4 System dynamics (SD) model for global nuclear marketing activity

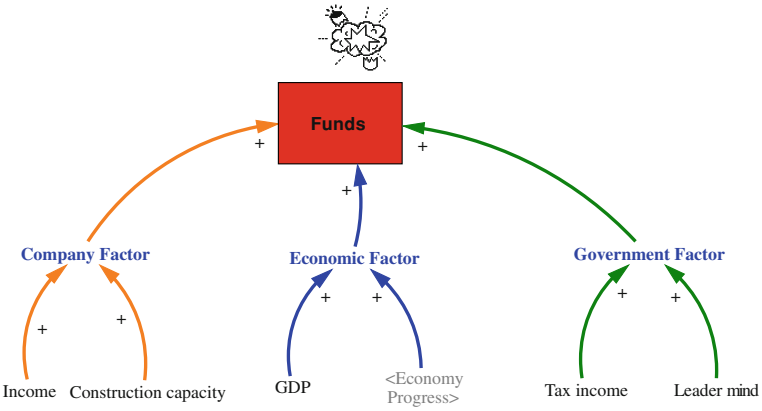


Fig. 2.5 System dynamics (SD) model for funds

is changed by every term. The value of production is accumulative as double line arrow as it is explained above. For each basic element, the quantifications are done by the Monte-Carlo quantifications.

By a similar way, there are the new promotion effects of marketing in Fig. 2.7 as market and uranium price. In each factor, there are manpower, marketing situation, mining, and refining. Especially, the marketing situation is organized as Fig. 2.8. It is represented by summations by supply and feedback adjusted

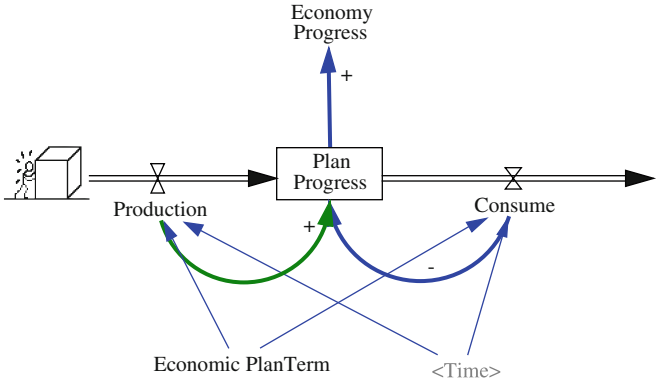


Fig. 2.6 System dynamics (SD) model for economy progress

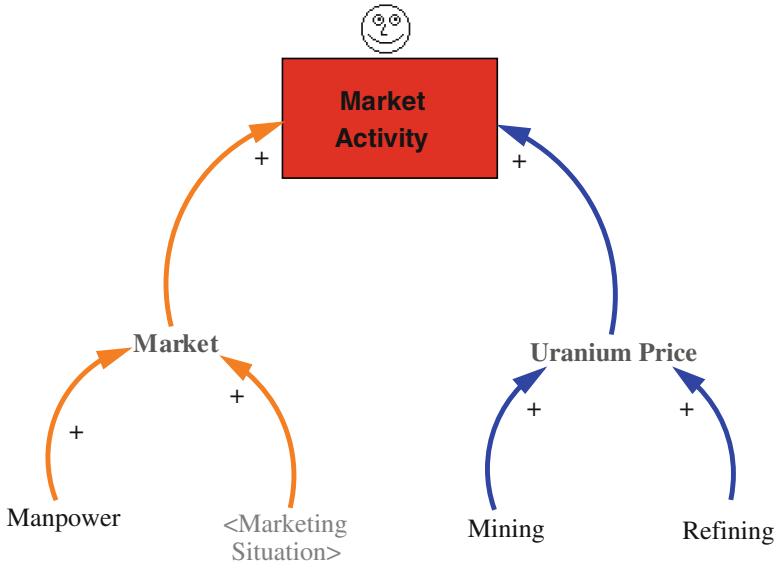


Fig. 2.7 System dynamics (SD) model for market activity

demand. These elements are adjusted by balance term of 5 years. That is to say, the market stability is changed by every 5 years. Therefore, the numerical value is changed by every term. The value of production is accumulative as double line arrow as it is explained above. In Fig. 2.9, there are the causal loops for the modeling where the connections of the events are seen by the event flows. For each basic element, the quantifications are done by the Monte-Carlo quantifications.

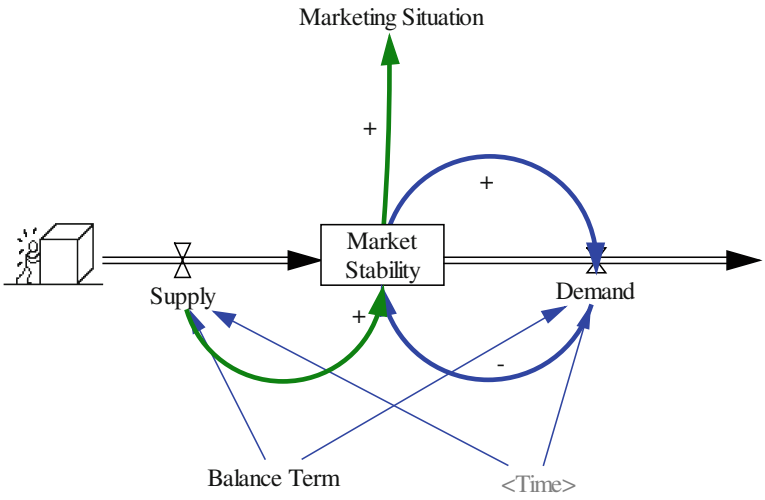
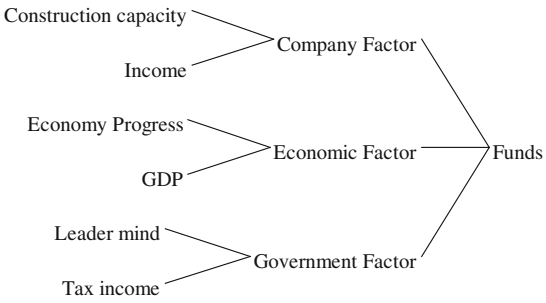
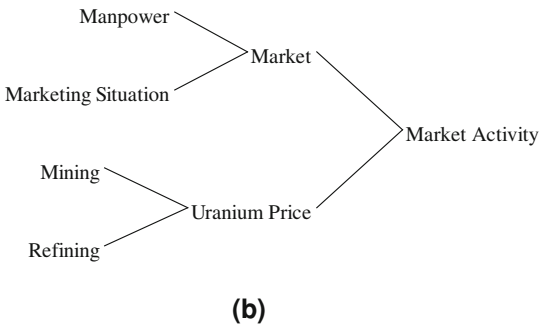


Fig. 2.8 System dynamics (SD) model for market situation

Fig. 2.9 Causal loop.
a Funds. **b** Market activity





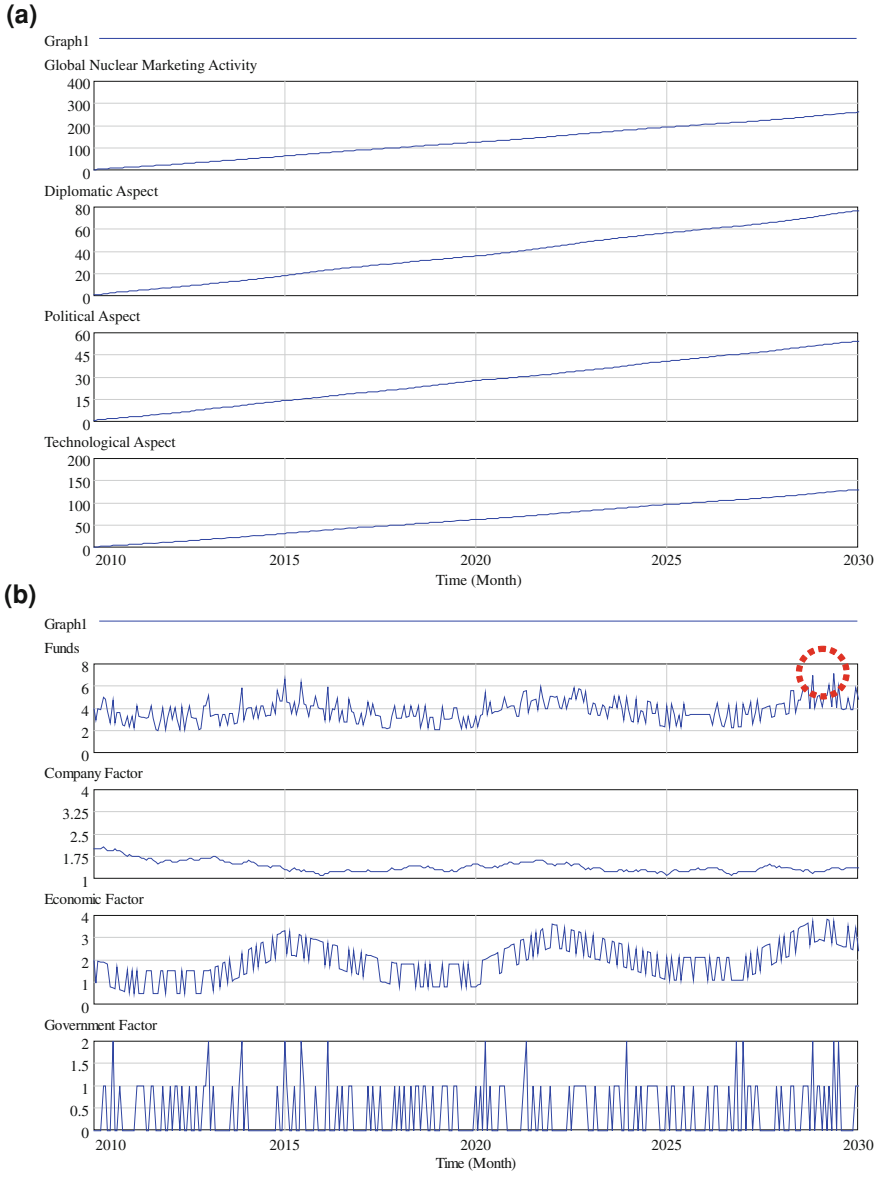


Fig. 2.10 Quantification of model. **a** Global nuclear marketing activity. **b** Funds. **c** Plan progress. **d** Marketing activity. **e** Market stability

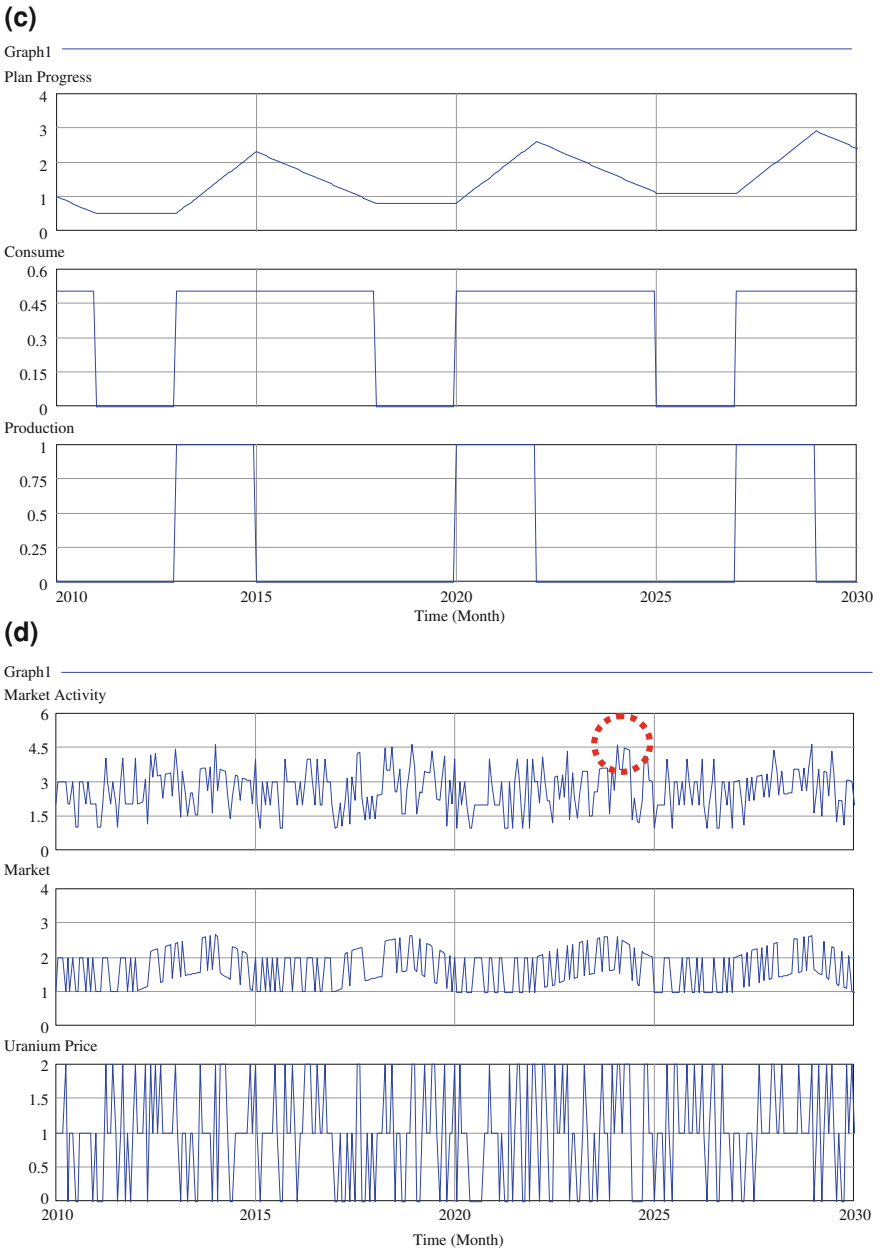


Fig. 2.10 (Continued)

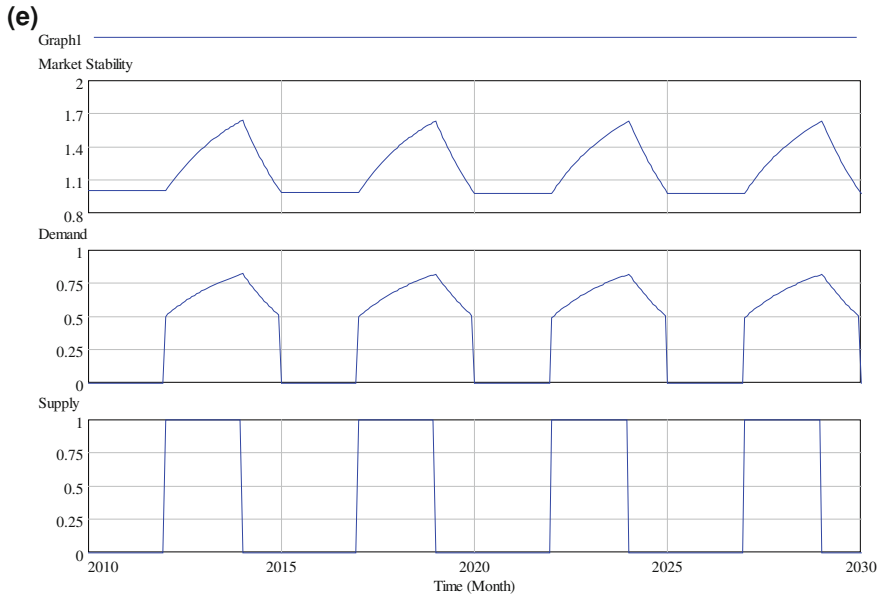


Fig. 2.10 (Continued)

2.4 Results

There are 5 kinds of the results in the Fig. 2.10. Figure 2.10a shows the summation of 3 factors. The maximum value is in the year 2030, which has the value of 86.70 times (=260.11/3.00) higher than the initial value. This figure shows the comparative values. Figure 2.10b shows the funds which have the biggest factor on 2028.8. There is the plan progress in Fig. 2.10c. The values are increased and the cycle of trend is 7 years. The reason of the cyclic change is due to the economic plan term of 7 years. Figure 2.10d shows the market activity has the biggest factor on 2024.0. There is the market stability in Fig. 2.10e. The values are increased and the cycle of trend is 5 years. The reason of the cyclic change is due to the balance term of 5 years.

2.5 Conclusions

For the performance for the global nuclear marketing activity, the dynamical simulation has been done from 2010 to 2030. By the classification of the 3 cases, the technological factor, the political factor, and the diplomatic factor, the numerical values are obtained. The technological aspect has the most important factor among them. There are small effects for the funds and the market activity,

although the diplomatic aspect and the political aspect are important things in the global nuclear marketing activity. The summarized points in this modeling are as follows;

- Non-linear dynamical management has been performed in the global nuclear marketing activity of the NPP.
- Using SD, there is an effective analysis of the global marketing.
- The time feedback algorithm, SD, is applied to the marketing decision-making case.
- Several uncertainties could be applied for the dynamics quantification in the marketing strategy.
- Very tractable quantification is obtained by a computer package.

Some significant issues for marketing could be studied in the further work. In the global economic crisis, the extensive strategy of the marketing is proposed. Furthermore, the real time monitoring by SD could be useful for the operation to prohibit the immediate price change in the world market.

Acknowledgments Author thanks to the Dr. S. M. Kwak in Systemix, Co. for the research discussions.

References

1. CNN. Financial Times (2009) S. Koreans win $20B UAE nuclear power contract
2. MBN news (2010) Estimation of export in South Korea
3. EIA (2006) International energy annual 2006
4. IAEA (2010) The power reactor information system (PRIS)
5. Forrester J (1961) Industrial dynamics. Productivity press, Cambridge
6. Forrester JW (1969) Urban dynamics. Pegasus Communications, Waltham
7. Kanungo S, Jain V (2008) Modeling email use: a case of email system transition. Syst Dyn Rev 24(3):299–319
8. Eskinasi M, Rouwette E, Vennix J (2009) Simulating urban transformation in Haaglanden, the Netherlands. Syst Dyn Rev 25(3):182–206
9. Walther G, Wansart J, Kieckhfer K, Schnieder E, Spengler TS (2010) Impact assessment in the automotive industry: mandatory market introduction of alternative powertrain technologies. Syst Dyn Rev 26(3):239–261
10. Eberlein RL (1989) Simplification and understanding of models. Syst Dyn Rev 5(1):51–68
11. Kampmann CE (1996) Feedback loop gains and system behavior. Proceedings of the 1996 international system dynamics conference Boston, Albany, New York
12. Mojtahedzadeh MT (1997) A path taken: computer-assisted heuristics for understanding dynamic systems. PhD dissertation, Rockefeller College of Public Affairs and Policy, State University of New York, Albany
13. Liehr M, Grobler A, Klein M, Milling PM (2001) Cycles in the sky: understanding and managing business cycles in the airline market. Syst Dyn Rev 17(4):311–332
14. Schmidt MJ, Gary MS (2002) Combining systems and conjoint analysis for strategic decision making with an automotive high-tech SME. Syst Dyn Rev 18(3):359–379
15. Radzicki M, Taylor R (1997) U.S. Department of energy's introduction to system dynamics, a systems approach to understanding complex policy issues, version 1. Sustainable Solutions, Inc., Como