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The Earth Warming Problem: Practical Modeling in Industrial Enterprises

Susumu Ikenouye

Summary. The earth warming problem will be one of the most difficult problems for industrial enterprises in the world. Heavily energy consuming industries, i.e., steel, power, refinery and chemical, have to establish a powerful management system to deal with the Earth warming problem. The core of this management system is the planning function. The planner should take more complicated criteria into consideration than before. Some of the criteria conflict with each other. At the same time, surroundings of the planning work will be continuously unstable because of political and economical changes in the world. We have to make an effort to implement a planning tool to help planners facing uncertain problems under multi criteria. The idea of modeling is the first step to accomplish a practical planning tool for ordinary planning persons for daily decision making work processes. Mathematical programming approaches are very promising to develop this kind of planning tool.

2.1 Introduction

The earth warming problem has been studied scientifically for many years [3]. Now, this challenging problem is one of the most important issues in the world from both the political and economical point of view. In all countries, governments are faced with the problem how to adopt the system of "Cap and Trade." Especially, energy consuming industries, e.g., steel, power, oil and chemical, are seriously confronted with this problem.

Zoning of the earth warming problem is shown in Fig. 2.1. Obviously, the *earth*, *country* and *enterprise* are basic zones to be modeled. Furthermore, the *complex* of industrial companies is very important in the discussion of emission control. Close connection between factories by fuel/product pipelines and by power lines will make a strong contribution to save energy and to reduce GreenHouse Gas (GHG) in a entire complex.

Management procedures for GHG emissions in each zone should have good simulation functions to estimate how much quantity of GHG will be generated. It is desirable that this simulator embeds optimization techniques. Practical procedures for GHG emission control have to be continuously and robust.

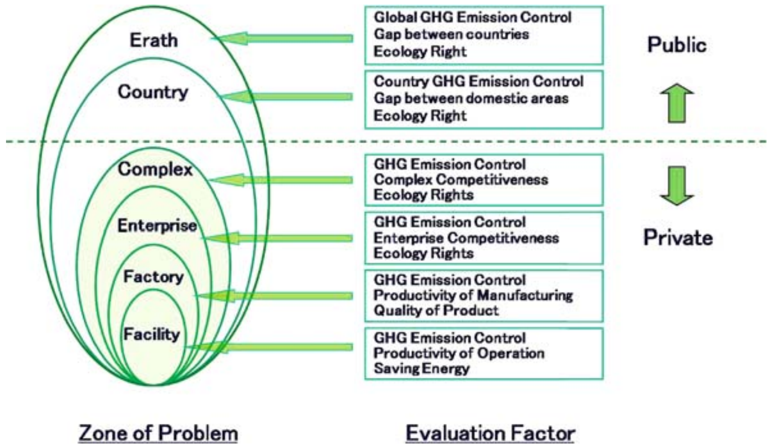

Fig. 2.1. Boundaries of the Earth warming problem

The simulation function has specific evaluation items depending on the character of each zone. Every industrial company has to have simulation functions containing economical metrics and GHG emission metrics. The simulation for production, capital investment and purchase of carbon credit has to be done simultaneously.

The quality of the product is naturally very important for the competitiveness of an industrial enterprise. Until now, there is no good estimation to compare these metrics in simulation and optimization. Good approaches and methods of quality evaluation are expected for a more reasonable simulation.

2.2 Management: What Changes will Affect the Planning Work?

GHG emission control in industrial companies can be done as a management cycle of PDCA (Plan-Do-See and Check) like a financial budget control. A planning tool in phase P should have enough ability to make an optimal plan. The planner has to asses a plan by GHG emission besides economical and technological points of view. In some cases, there will be severe conflicts between economical metrics and GHG emission metrics.

The strongest impact of the change is illustrated in Fig. 2.2. We have to think how to design a new tool of planning in this confliction. In general, operations research (OR) technology offers *multicriteria programming* and *goal programming*, [4, 6]. However, until now, practical applications of both methods cannot be found in real management systems of industrial companies.

A table of objective criteria will contain the following crucial factors:

- *Economics*: sales, income, cost, depreciation expenses, capital investment, debt, return on asset (ROA)

Fig. 2.2. Big change in management system

- *Environment*: GHG, CO_2, carbon credit
- *Technology*: production effectiveness, quality of product

In any way, through real work of planning, the planner has pay attention to all metrics above mentioned. We have to try to find a good method to include these metrics as objectives for planning.

2.3 Modeling: How to Make a Practical Model for the Earth Warming Problem?

2.3.1 Structure of the Model for the Industry

Heavily energy consuming industries, such as, steel, power, oil and chemical have specific models for mathematical calculations. In general, this models are a combination of process flow models and network models. A long term model is likely to be of multi periods.

Criteria of such a model contains metrics as mentioned before as possible. From the point of mathematical programming, all of these metrics introduced are target constraints. In each case study, one of the constraints will be the objective. In some case, a set of constraints will form multiobjectives.

The model we discussed is an abstract one and it will be divided into several models to be solved by methods of OR. AS a whole, the model will be a complex of sub models and methodologies.

2.3.2 The Model Type for Planning Work of an Industrial Company

The following three types of models are very effective for practical planning work:

1. Enterprise-wide model of single term (single-period model)
2. Enterprise-wide model of road map (multiperiod model)
3. Process and network model as a social model

All models are for long-term planning, annual planning and longer time scale. Shorter time scale plans, such as, monthly plan, production scheduling and process control plan, provably have other aspects in technology and engineering points of view.

Enterprise-Wide Model of Single Term

The first model is applied for enterprise-wide planning in a single term. The planner will use this model in the case study of an annual business plan and a production plan including judgment on investments for facility and purchasing carbon credits. This model contains the selection problem. Integer variables should be used for the selection of capital investment and purchase of carbon credits.

Enterprise-Wide Road Map Model

The second model covers several time periods. A Road Map Plan of GHG emission control as the Kyoto Protocol in 1997 [2, 7] has been discussed for several years. This model is almost the same as a connected single-term model of Sect. 2.3.2. The decision problem which investment should be selected and when it will be done can be modeled as a mixed-integer linear programming (MIP) problem. However, it will be very difficult to solve a single-term enterprise-wide model as one monolithic model. In every time period, the

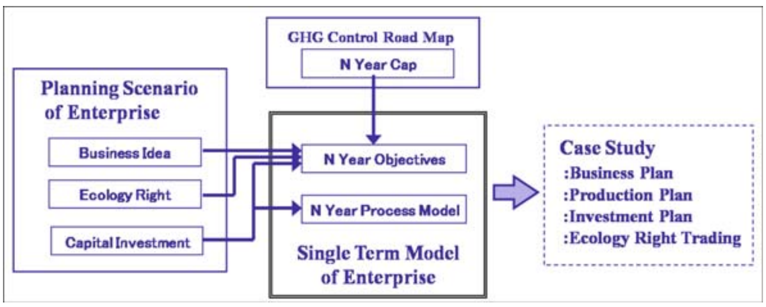

Fig. 2.3. Single term planning including GHG emission control

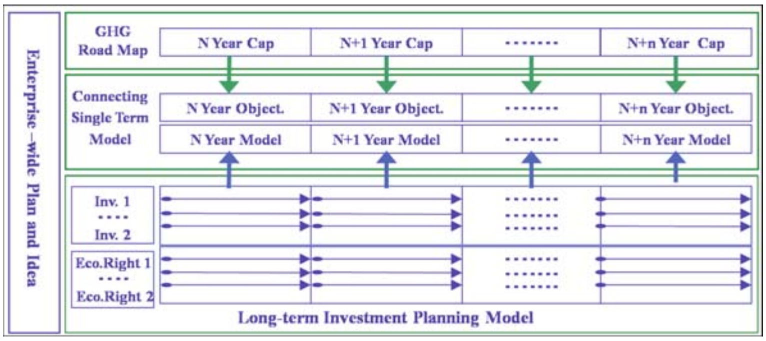

Fig. 2.4. Configuration of enterprise road map model

production process model has to be modified by adding all candidates of investments for the process flow. We have to find another idea to solve this complicated large-scale problem.

The planning work to deal with Road Map Plans like the Kyoto Protocol should consider a forecast for the coming 5 years or more. The planner has to face very strong uncertainty in any situation. So, this model shall be modified very often. We need good remodeling functions to perform the planning work smoothly.

Process and Network Models as Social Models

This model is a combination of a process flow model and a network model. Process flow models are very popular as refinery models like PIMS of Aspentech [1]. Network models are just like logistic models. They show power transmission lines, fuel, steam, water and other utilities. The structure of a process and network model is good for an industrial complex to simulate and to control GHG emission. Usually, a typical complex is composed out of power plant, refinery, steal and petrochemical. All these industries are consuming a lot of energy and are generating huge GHG.

Process and network models are composed by a set of elements connected in a network. Each element shows one company or one factory. This element is a production process flow model that can be solved as standalone mathematical model with multicriteria objectives.

Every element in a process and network model is an independent company. This model is able to simulate in detail the cooperation of companies as one independent company. This ability is very useful to evaluate competitiveness of a specific area or country.

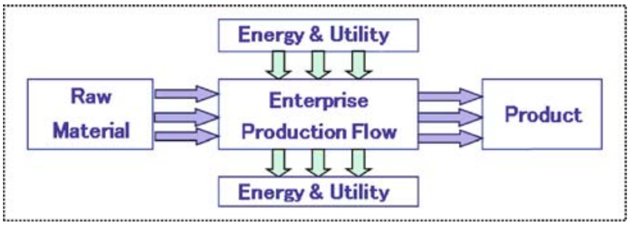

Fig. 2.5. Element (enterprise) of process and network model

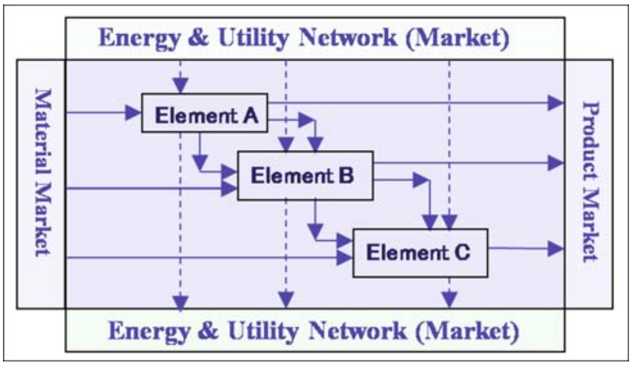

Fig. 2.6. Process and network model

2.4 Problems When Applying to Real World

2.4.1 Practical Multipurpose Programming

Large and complicated models like a Road Map Plan of GHG emission control is not so easy to apply in ordinary planning of practical management work. Planning work processes cannot be covered by any IT system and by any OR methods completely. The problem of earth warming is not explained by scientific approach enough. So, many points remain unsolved for the coming years. Most processes of decision making will be done by planner. As mentioned before, the mathematical model that we discuss has several submodels that could be solved by a steady mathematical method like linear programs (LPs) or MIPs.

Multicriteria optimization models for GHG emission control is a new idea. There is no deep experience of application in real work. For the time being, practical solution for planning work of GHG control is still heuristic way supported by OR methods partially.

2.4.2 Effort in OR

Decomposition methods will have a large influence to produce practical solutions. The planner can easily understand what happens in the calculation processes. Visual modeling tools are also helpful to illustrate and interpret the model. The planner should judge by adopting heavy criteria and a clear understanding of interdepending relationships between submodels and each criteria.

Mathematical effort to solve models having contradiction and uncertainty is very important and essential. Multicriteria programming, goal programming and stochastic programming [5, 8] are expected to be more easily to use in ordinary work.

From the point of view that practical solutions for planning work are still heuristic, decomposition of how to solve this problem should be considered carefully. Mathematical programming, connected with other methods like constraint programming and rule base system or metaheuristics, may yield efficient hybrid method, able to solve large-scale real world problems.

2.5 Conclusion

Our understanding of the Earth warming problem will change continuously from now on. As a consequence, in the work of enterprise management, the planner has to prepare basic and natural methods to cope with the situation changing in the world. Although, there a clear ideas and methodologies for solving multicriteria optimization problems with conflicting goals, there are no off-the-shelf models and solvers available. The very first, important step is to develop a reasonable model. Nature and characters of the problem must be analyzed to find a way for appropriate modeling and solving.

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