SIMULATION MODELS FOR ENVIRONMENTAL RESOURCE PLANNING OF MANUFACTURING SYSTEMS

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EXTENDED ABSTRACT

To reduce the greenhouse gas emission, Cap-and-Trade (C&T) program has been widely implemented around the world. Known as emission quotes trading, C&T is a market-based program for controlling CO2E emission. Under such a program, emission generating companies (e.g. manufacturers) in a region are allocated emission allowances to offset their emission needs. Initial allowance is usually allocated free through a regulatory agency, and then be traded later among the generating companies through transactions at a regional emission trade market (RETM). Participating companies can also make green improvement to reduce emission level to satisfy their emission needs and sell the surplus (e.g. in the form of certified-emission-quotes) to gain revenue via the market.

The complexity or difficulty of such decisions under C&T conditions comes in several aspects. First as a required participant in RETM an enterprise faces more operational constraints and must fulfill new obligations that are dictated by multiple exogenous factors, i.e. following rules and regulations set by government agencies (for the purpose of control and operation of a RETM), e.g. estimating emission-needs and accepting emission allowance, obeying transaction regulation, participating in compliance/monitor-report-verification (MRV), etc. These exogenous functions are usually designed and controlled by policy makers (governmental agencies) and involved with complicated logic and inconsistencies. This "macro-system structure" significantly influences the decision behavior of individual companies (e.g. as they play the role of potential buyer or seller of emission quotes through interactions via a RETM). Consequently participating enterprises operate significantly different under the conditions of C&T. This leads to second aspect of complexity: operation managers face greater challenge in resource planning decisions. In addition to traditional production resource (e.g. labor and raw materials), they now have to plan and acquire environmental resource (e.g. emission quotes or EQ) to meet their emission needs generated by production/service; and balance between production economy and CO2E reduction. More specifically managers need to choose from purchasing EQ (via trading at a RETM), or reducing emission level via self-purification (SP), or carrying over surplus emission quote (SEQ) to meet the required emission for the planning period. Previous studies have revealed following characteristics in this decision-making process: (1) market price of EQ follows a random fluctuation; (2) the abatement cost of performing SP to reduce emission level increases as accumulated emission reduction increases, i.e. the more reduced, the more difficult to reduce; and (3) there exist trade-offs between decision alternatives that may lead to significant cost-saving. Consequently it is critical for managers to decide how to satisfy the emission needs of planning periods via different options available under C&T. Finally and unfortunately there are multiple risks associated with these decisions. For instance, when a generating company considers buying EQ from market, it has to face at least three types

of risk: random fluctuation of market price of EQ, risk of performing SP to reduce its emission needs, or the risk of paying penalty if it cannot fulfill the emission reduction target. When it acts as a potential seller (having surplus EQs), the risks include the fluctuation of market EQ price and unpredictable demand change that drives the change of production capacity. The costs of these risks can be so high that decision maker must assess their impact (and compare these costs with the cost of mitigation) before any final action is taken.

Apparently these risks influence enterprise's decisions significantly and are driven by complicated exogenous factors that change dynamically and stochastically. This has raised important questions such as: How to characterize the risk factors and the decision-making process under the joint (and marginal) application of these risks? How to assess accurately the impact of the risks on system performance and evaluate the effectiveness or efficiency of different mitigation strategies (in terms of both production economy and environmental sustainability)? Unfortunately few studies have addressed these issues from a production enterprise perspective when it is confined under the C&T conditions. The challenge is to build a robust model that adequately represent the characteristics (e.g. uncertainties and dynamics) of the environmental resource planning process (under C&T conditions) and allow the analysis that effectively characterizes the relationship between the decision inputs (specification of decision options and risk factor attributes) and decision outputs (system's performance measures) under various combinations of system conditions (e.g. C&T policies), risk profiles, and mitigation strategies. Such a model is useful for both practical decision making and theoretical analysis.

The purpose of this study is to develop a discrete-event simulation model to conduct experimental analysis on manufacturing enterprise's decisions in planning environmental resources (via interactions with a regional emission quotes trade market) subjected to the conditions associated with a C&T program and under the impact of multiple risks, evaluate the system performance, and characterize the distribution of system outputs corresponding to the various combinations of decision option and risk profile, which are useful in deriving managerial suggestions for decision improvement.

The work of this study is reported (through the poster) as follows. First we introduce the conceptual modeling of the decision-making process described above, focusing on the logical design of decision maker under each decision option and risk factors associated with the option. The emphasis is given to the autonomous evaluation of the risk and the final impact (as a result of the decision and the risk) on the system performance. We then describe the implementation of proposed conceptual framework, via the development of a discrete-event simulation model through ARENA© software. Finally we present limited experimental results collected via the simulation analysis that was designed mainly for the verification of the implemented model functions. The issues of validation (of the model) are also discussed (e.g. via empirical studies with the partners from industries and governmental agencies). Finally we conclude the study and discuss the challenges of modeling and validation. It is noted that due to the limit of space as a poster, the descriptions presented in the poster are unavoidably too abstract to satisfy readers' interest. More detailed information will be available in a full journal paper that is under the development.