Optimization of Petroleum Supply Chain with Integrated Model of Tactical Planning and Operational Refinery Scheduling Under Uncertainties

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Abstract

Petroleum is a basic industry with high energy consumption and high resource occupation. Researching it with the concept of “supply chain management (SCM)” is an effective way to arrange the complicated system optimally. The petroleum supply chain, consisting of many different entities, is a complex network. The scope of this study is concerned with the midstream and downstream of it, taking account of tactical and operational decision-making levels as well. Which means that the processes of crude oil procurement, manufacture, product distribution and transportation between any two entities are covered in this supply chain. Spatial integration of these process is discussed at the tactical level including all entities, whereas temporal integration between tactical and operational level is focused on manufacture process by an iterative integration approach. Manufacture process is taken as the core of this supply chain, and detailed separation and reaction units in refineries are considered. The mathematic model of the two decision-making levels are proposed, in which uncertainty is incorporated at each decision level respectively.

Firstly, a finite scenario based two-stage stochastic mixed integer linear programming (MILP) model is proposed to optimize the multi-period and multi-echelon petroleum supply chain in tactical decision-making level under uncertainties of products demand as well as price. The model considers environmental impact by taking CO₂ emission reduction into account in the economic objective via carbon tax. The entities in the model are regarded as “black box”, to simplify the complicated system in tactical decision-making level. A relative reliable optimal result can be obtained by the model in a medium-term horizon to facilitate the plan and management of the petroleum supply chain. But, there are gaps between medium-term tactical planning and short-term operational refinery scheduling for the complicated connected units network and uncertainties such as changes of raw materials supply and maintenance of operation units of refinery. As a result, planning made by
tactical decision-making level may not be satisfied by operational refinery scheduling process, leading to confusion of management and financial loss accordingly. For this, an operational refinery scheduling model is presented and integrated into the tactical planning model to optimize the petroleum supply chain synergistically. The operational refinery scheduling is also described as a finite scenario based two-stage stochastic mixed integer linear programming (MILP) model.

The integrated model is solved by GAMS software to optimal the total revenue with a rolling horizon strategy in the case. The costs considered in tactical level consist of procurement cost, production cost, inventory cost, transportation cost, surplus penalty, backlog penalty as well as carbon tax in the medium-term period, while include unit operational cost and inventory cost of each refinery in operational level in a short-term period. Solving this model, the optimal and feasible purchase scheme, production scheme, inventory scheme, transportation scheme, distribution scheme and the detailed operational scheme of various units in refineries under uncertainties can be obtained. In theory, the objective of maximizing total revenue of the supply chain can be achieved by adopting above schemes in realistic petroleum industry process. Contrasting the result of tactical planning model and integrated model, the optimal planning scheme of each segment is different. Although the optimal revenue of tactical planning descends, the refinery scheduling can be guaranteed to operation feasibly in current condition. The result of integrated model is more significant for supply chain management of petroleum industry.