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An integrated model of supply network and production planning for multiple fuel products of multi-site refineries

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Abstract

An integrated model of supply network and production planning is proposed for the collaboration among refineries manufacturing multiple fuel products at different locations. The simulation and optimization based on the model indicate the following. The distribution costs can be reduced by relocating distribution centers as well as by reconfiguring their linkages to various markets. Moreover, the multiple fuel products manufactured need to be segregated during storage and transportation to be able to satisfy the demands of the various markets. The production planning, therefore, should be an integral part of the supply-network planning, and vice versa. Specifically, the proposed integrated model is for the nationwide supply of multiple fuel products manufactured by the individual refineries. The efficacy and usefulness of the integrated model is illustrated with an example involving three refineries and four varieties of fuel products.

Keywords: Supply network; Multi-site refineries; Collaborative production

1. Introduction

Efficient supply networks have become indispensable for marketing diversified products to meet the varied demands of global customers. A number of major oil refineries and chemical manufacturers producing various fuel and chemical products in large quantities have forged a merger of their operations to manufacture and/or market these products. Such a merger renders it possible to facilitate the acquisition of raw materials, the distribution of intermediates and the delivery of products.

The planning of integrated production has been studied for multi-site refineries and petrochemical complexes where the products are delivered through the fixed networks of pipelines (Jackson & Grossmann, 2003; Neiro & Pinto, 2004; Schulz, Diaz, & Bandoni, 2005). It is highly likely that further integration of supply networks will reduce the distribution cost; this involves reconfiguring the linkages to markets through relocated distribution centers (Melkote & Daskin, 2001; Wu, Zhang, & Zhang, 2006).

The linkages between distribution centers and markets should be planned separately for different fuel products. They need to be segregated during transportation and storage to satisfy the demands of the various markets under different conditions. Meanwhile, the production rates of individual refineries depend on the properties of crude oil, the cut points of distillation units, and the modes of blending operation (Brooks, Van Walsem, & Drury, 1999; Jia & Ierapetritou, 2003; Li, Hui, & Li, 2005; Mendez, Grossmann, Harjunkoski, & Kabore, 2006; Moro, Zanin, & Pinto, 1998). Accordingly, the production planning should be integrated into supply-network planning to enable the production to respond effectively to fluctuations in market demand.

This study aims at establishing an integrated model of supply network and production planning for fuel products. Specifically, the distribution centers are relocated according to a mixed-integer model for profit maximization. Moreover, this mixed-integer model is coupled with the non-linear production

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Nomenclature

Indices

i	refineries
j	distribution centers (DC's)
k	markets
p	products
s	intermediate streams

Sets

$\boldsymbol{I}$	set of refineries
$\boldsymbol{J}$	set of DC's
$\boldsymbol{K}$	set of markets
$\boldsymbol{P}$	set of products
$\boldsymbol{S}$	set of intermediate streams

Parameters

$\mathrm{Cap\_cdu}_i$	capacity of CDU at refinery i (tonne/day)
$D_{k,p}$	demand for product p at market k (bbl/year)
F_j	unit fixed operating cost of DC j (won/bbl)
$\mathrm{G\_fcc}_i$	weight transfer ratio of the gasoline stream from FCC at refinery i
$\mathrm{Op\_cdu}_i$	unit operating cost of CDU at refinery i (won/tonne)
$\mathrm{Op\_fcc}_i$	unit operating cost of FCC at refinery i (won/tonne)
P_{crude}	price of crude oil (won/tonne)
P_{MTBE}	price of MTBE (won/tonne)
P_p	price of product p (won/bbl)
$\mathrm{Re\_fcc}_i$	weight transfer ratio of the recycle stream from FCC at refinery i
S_j	annual throughput capacity of DC j (bbl/year)
SD_i	stream days per year at refinery i
TB_p	barrels per 1 tonne of product p (bbl/tonne)
V_j	unit variable operating cost of DC j (won/bbl)
$\mathrm{XC}_{i,j}$	unit transportation cost from refinery i to DC j (won/bbl)
$\mathrm{YC}_{j,k}$	unit transportation cost from DC j to market k (won/bbl)

Variables

$\mathrm{MTBE}_{i,p}$	flowrate of MTBE that is added in the blending of product $p \in \{\mathrm{G\#93, G\#90}\}$ (tonne/day)
$\mathrm{qF}_{i,s}$	flowrate of intermediate stream s at refinery i (tonne/day)
$\mathrm{qF}_{i,s,p}$	flowrate of intermediate stream s split to produce product p (tonne/day)
$\mathrm{qP}_{i,p}$	production rate of product p at refinery i (bbl/year)
W_i	integer variable for the number of operating CDU's at refinery i
$x_{i,j,p}$	quantity of product p delivered from refinery i to DC j (bbl/year)
X_j	binary variable for the establishment of DC j
$y_{j,k,p}$	quantity of product p delivered from DC j to market k (bbl/year)
Z	profit (won)
Z'	profit of the integrated model (won)

model developed by Li et al. (2005). A real-world example is presented to demonstrate the usefulness of the integrated model.

2. Development of integrated model

Linking the models of supply network and production planning for manufacturing and marketing fuel products leads to an integrated model. Such a model can be deployed to determine the optimal production rates at the refineries, the locations of distribution centers and the transport routes to markets for maximizing profit.

2.1. Network planning

In the first sector of a typical refinery-supply network as illustrated in Fig. 1 with the one existing in South Korea, the fuel products are transported from the refineries to the distribution centers (DC's) by different means including pipelines (P/L's), vessels (VSL's), railroad train containers (RTC's), and/or tank trucks (T/T's). This gives rise to a network, comprising the refineries, DC's and the linkages among them.

In the second sector, the fuel products are delivered from DC's to the markets where the aggregated or individual demands of gas stations reside. The delivery in this sector usually involves T/T's: they can readily reach the markets with diverse demands. In either sector, the unit transportation cost depends on the means of transportation and the delivery distance.

The network model is formulated as a mixed-integer problem of network reconfiguration where the locations of candidate DC's and the production capacities of the refineries involved are known. The objective is to maximize the profit, which is

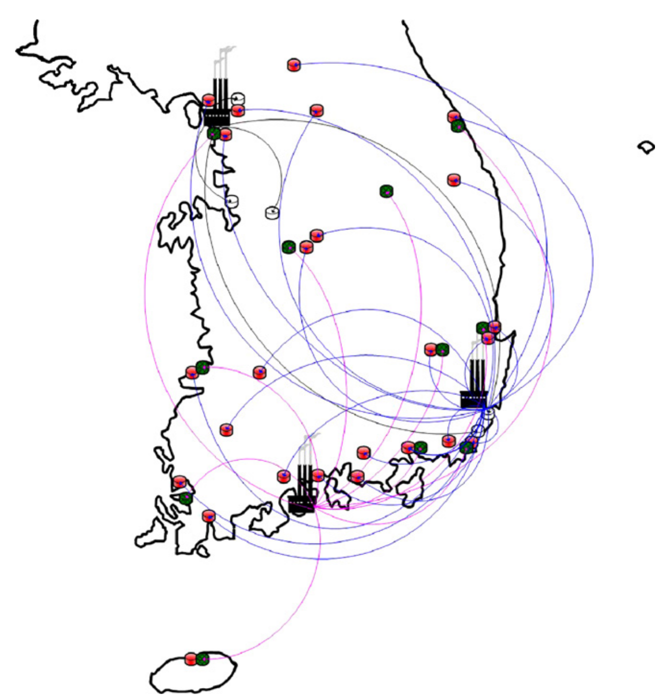

Fig. 1. Network linking the multi-site refineries to the distribution centers (DC's) in South Korea: three refineries denoted by plant icons ( ) and DC's belonging to them denoted by red tanks ( ), white tanks ( ) and green tanks ( ).