Pontifícia Universidade Católica
do Rio de Janeiro

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Petroleum Supply Chain Management under Uncertainty: Models and Algorithms

TESE DE DOUTORADO

Thesis presented to the Programa de Pós–Graduação em Engenharia de Produção of the Departamento de Engenharia Industrial , PUC–Rio as partial fulfillment of the requirements for the degree of Doutor em Engenharia de Produção

Advisor: Prof. Silvio Hamacher

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To my wife Jeniffer,
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Abstract

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In this thesis we investigate the investment planning problem for the petroleum supply chain under demand uncertainty. We formulate and solve a two-stage stochastic programming model that seeks to accurately represent the particular features that are inherent to the investment planning for the petroleum logistics infrastructure.

The incorporation of uncertainty in this case inevitably increases the complexity of the problem, which becomes quickly intractable as the number of scenarios grows. We circumvent this drawback by relying on Sample Average Approximation (SAA) to control the number of scenarios required to reach a prespecified level of tolerance regarding solution quality. We also focus on efficiently solving the stochastic programming problem, exploiting its particular structure by means of a scenario-wise decomposition. Following this idea, we propose two novel approaches that focus on decomposing the problem in a way that it could be efficiently solved.

The first algorithm is based on stochastic Benders decomposition, which we further improve by using new acceleration techniques proposed in this study. The second is a novel algorithm based on Lagrangean decomposition that was designed to deal with the case where we have integer variables in the second-stage problem. The novel feature in this algorithm is related with the hybrid strategy for updating the Lagrange multipliers, which combines subgradient, cutting-planes and trust region ideas. In both cases, we have assessed the proposed approaches considering a large-scale real-world instances of the problem. Results suggests that they attain superior performance.

Keywords

Petroleum supply chain management. Strategic planning. Optimization under uncertainty. Stochastic programming. Decomposition strategy.

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Resumo

Oliveira, Fabrício Carlos Pinheiro de; Hamacher, Silvio(orientador). **Gestão da cadeia de petróleo sob incerteza: modelos e algoritmos**. Rio de Janeiro, 2012. 97p. Tese de Doutorado — Departamento de Engenharia Industrial, Pontifícia Universidade Católica do Rio de Janeiro.

Nesta tese é abordado o problema de planejamento de investimentos para a cadeia de fornecimento de petróleo sob incerteza. Neste contexto, um modelo de programação estocástica de dois estágios é formulado e resolvido. Tal modelo busca representar com precisão as características particulares que são inerentes ao planejamento de investimentos para a infra-estrutura logística de petróleo.

A incorporação da incerteza neste contexto inevitavelmente aumenta a complexidade do problema, o qual se torna rapidamente intratável conforme cresce o número de cenários. Tal dificuldade é contornada baseando-se na aproximação por média amostral (AMA) para controlar o número de cenários necessários para atingir um nível pré-especificado de tolerância em relação à qualidade da solução. Além disso, é considerado o desenvolvimento de técnicas que resolvam de maneira eficiente o problema, explorando sua estrutura especial, através de decomposição por cenários. Seguindo esta ideia, propõe-se duas novas abordagens para decompor o problema de forma que o mesmo possa ser eficientemente resolvido.

O primeiro algoritmo é baseado na decomposição estocástica de Benders, a qual é aprimorada usando-se novas técnicas de aceleração propostas. O segundo consiste de um novo algoritmo baseado em decomposição Lagrangeana que foi projetado para lidar com o caso onde temos variáveis inteiras no problema de segundo estágio. A característica inovadora desse algoritmo está relacionada com a estratégia híbrida utilizada para atualizar os multiplicadores de Lagrange, combinando subgradientes, planos de cortes e regiões de confiança. Em ambos os casos as abordagens propostas foram avaliadas considerando um exemplo de grande escala do mundo real e os resultados sugerem que os mesmos apresentam desempenho superior quando comparados com outras técnicas disponíveis na literatura.

Palavras-chave

Gestão da cadeia de suprimentos de petróleo. Planejamento estratégico. Otimização sob incerteza. Programação estocástica. Estratégias de decomposi cão.

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To choose doubt as a philosophy of life is akin to choosing immobility as a means of transportation.

Yann Martel, *Life of Pi.*