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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,
my father Julio, and my mother Francisca.

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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.

Resumo

Oliveira, Fabrício Carlos Pinheiro de; Hamacher, Silvio(orientador). **Gestão da cadeia de Suprimentos 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 decomposição.

Contents

1	Introduction	12
1.1	Objectives	13
1.2	Thesis Organization	14
2	Problem Statement	15
2.1	Problem Description	15
2.2	Mathematical Model	18
	<i>Nomenclature</i>	18
	<i>Model Formulation</i>	21
	First-stage problem	21
	Second-stage problems	22
3	Dealing with Demand Uncertainty using Sample Average Approximation	26
3.1	Sample Average Approximation	27
	<i>Lower bound approximation</i>	28
	<i>Upper bound approximation</i>	29
	<i>Estimating the gap</i>	30
3.2	Scenario generation using SAA	31
3.3	Case Study	33
	<i>Case description</i>	33
	<i>Results</i>	37
3.4	Conclusions	41
4	Scenario decomposition framework for continuous second-stage problem: stochastic Benders decomposition	42
4.1	Mathematical Model	44
	<i>Nomenclature</i>	44
	<i>Model Formulation</i>	45
4.2	Stochastic Benders Decomposition	46
4.3	Accelerating Benders Decomposition	49
	<i>Multi cut framework</i>	50
	<i>Generating stronger cuts</i>	50
	<i>Additional acceleration ideas</i>	54
	Upper bound improving	54
	Trust-region	55
	<i>Algorithm statement</i>	56
4.4	Numerical Experiments	57
4.5	Conclusions	60

5	Scenario decomposition framework for mixed-integer second-stage problem: stochastic Lagrangean decomposition	62
5.1	Mathematical Model	63
	<i>Nomenclature</i>	63
	<i>Model Formulation</i>	64
5.2	Solution Algorithm	65
	<i>Lagrangean Decomposition Approach</i>	65
	<i>Proposed strategy for solving the Lagrangean Dual</i>	68
	<i>Upper bounding procedure</i>	70
	<i>Multiplier updating procedure</i>	71
	<i>Algorithm statement</i>	73
5.3	Risk Management	74
5.4	Numerical results	76
	<i>Example 1</i>	76
	<i>Example 2</i>	81
5.5	Conclusions	85
6	Conclusions	86
6.1	Thesis Contributions	87
6.2	Future Perspectives	89
	Bibliography	91

List of Figures

2.1	Example of a multi-period network investment planning	15
2.2	Piecewise linear representation of nonlinear demurrage cost	17
3.1	Case study distribution network	34
3.2	Case study demand levels	36
3.3	Example of demand scenarios	37
4.1	Schematic representation of the proposed stochastic Benders decomposition	49
4.2	Geometric illustration of cut strength	51
5.1	Schematic representation of the proposed Lagrangean decomposition	69
5.2	Network structure of example 1	77
5.3	Convergence Profile: Subgradient algorithm and sequential formulation	80
5.4	Convergence Profile: Proposed algorithm and sequential formulation	80
5.5	Convergence Profile: Subgradient algorithm and asymmetric formulation	81
5.6	Convergence Profile: Proposed algorithm and different algorithms	81
5.7	Multi-scale approximation representation	82
5.8	Cost distribution for 200 scenarios	83
5.9	Cost distribution for 200 scenarios after risk management	84
5.10	Cost distribution comparison	85

List of Tables

2.1	Model Notation: Sets and subsets	19
2.2	Model Notation: Parameters	20
2.3	Model Notation: Variables	21
3.1	Seaworthiness between locations	35
3.2	Investment portfolio for locations	35
3.3	Summary of model sizes	38
3.4	Experiment results: statistical limits (lower and upper)	39
3.5	Experiment results: estimative of the optimality gap	39
3.6	Investment profiles of solution 3 for $N = 20$, solution 3 for $N = 30$ and solution 2 for $N = 40$	40
4.1	Model Notation	45
4.2	Summary of CPU times(s) - experiment 1	59
4.3	Summary of CPU times(s) - experiment 2	60
5.1	Model Additional Notation	64
5.2	Example 1 Capacity expansion decisions	78
5.3	Example 1 Network design decisions	78
5.4	Summary of CPU times(s)	78
5.5	Deterministic Equivalent Sizes	82
5.6	Summary of CPU times(s)	82

*To choose doubt as a philosophy of life is akin
to choosing immobility as a means of transport-
ation.*

Yann Martel, *Life of Pi*.