

Planning and Integration of Refinery and Petrochemical Operations



Contents

Preface IX

Part One Background 1

1	Petroleum Refining and Petrochemical Industry Overview 3
1.1	Refinery Overview 3
1.2	Mathematical Programming in Refining 5
1.3	Refinery Configuration 7
1.3.1	Distillation Processes 7
1.3.2	Coking and Thermal Processes 8
1.3.3	Catalytic Processes 9
1.3.3.1	Cracking Processes 9
1.3.3.2	Alteration Processes 9
1.3.4	Treatment Processes 10
1.3.5	Product Blending 10
1.4	Petrochemical Industry Overview 11
1.5	Petrochemical Feedstock 12
1.5.1	Aromatics 12
1.5.2	Olefins 13
1.5.3	Normal Paraffins and Cyclo-Paraffins 13
1.6	Refinery and Petrochemical Synergy Benefits 14
1.6.1	Process Integration 14
1.6.2	Utilities Integration 15
1.6.3	Fuel Gas Upgrade 16
	References 16

Part Two Deterministic Planning Models 19

2	Petroleum Refinery Planning 21
2.1	Production Planning and Scheduling 21
2.2	Operations Practices in the Past 23

2.3	Types of Planning Models	24
2.4	Regression-Based Planning: Example of the Fluid Catalytic Cracker	24
2.4.1	Fluid Catalytic Cracking Process	25
2.4.2	Development of FCC Process Correlation	27
2.4.3	Model Evaluation	31
2.4.4	Integration within an LP for a Petroleum Refinery	31
2.5	Artificial-Neural-Network-Based Modeling: Example of Fluid Catalytic Cracker	36
2.5.1	Artificial Neural Networks	36
2.5.2	Development of FCC Neural Network Model	37
2.5.3	Comparison with Other Models	39
2.6	Yield Based Planning: Example of a Single Refinery	44
2.6.1	Model Formulation	46
2.6.1.1	Limitations on Plant Capacity	46
2.6.1.2	Material Balances	46
2.6.1.3	Raw Material Limitation and Market Requirement	47
2.6.1.4	Objective Function	47
2.6.2	Model Solution	48
2.6.3	Sensitivity Analysis	49
2.7	General Remarks	52
	References	53
3	Multisite Refinery Network Integration and Coordination	55
3.1	Introduction	55
3.2	Literature Review	57
3.3	Problem Statement	60
3.4	Model Formulation	61
3.4.1	Material Balance	62
3.4.2	Product Quality	63
3.4.3	Capacity Limitation and Expansion	64
3.4.4	Product Demand	65
3.4.5	Import Constraint	65
3.4.6	Objective Function	65
3.5	Illustrative Case Study	66
3.5.1	Single Refinery Planning	66
3.5.2	Multisite Refinery Planning	69
3.5.2.1	Scenario-1: Single Feedstock, Multiple Refineries with No Integration	70
3.5.2.2	Scenario-2: Single Feedstock, Multiple Refineries with Integration	71
3.5.2.3	Scenario-3: Multiple Feedstocks, Multiple Refineries with Integration	72
3.5.2.4	Scenario-4: Multiple Feedstocks, Multiple Refineries with Integration and Increased Market Demand	74

3.6	Conclusion	75
	References	77
4	Petrochemical Network Planning	81
4.1	Introduction	81
4.2	Literature Review	82
4.3	Model Formulation	83
4.4	Illustrative Case Study	84
4.5	Conclusion	87
	References	88
5	Multisite Refinery and Petrochemical Network Integration	91
5.1	Introduction	91
5.2	Problem Statement	93
5.3	Model Formulation	95
5.4	Illustrative Case Study	99
5.5	Conclusion	105
	References	106
Part Three Planning Under Uncertainty 109		
6	Planning Under Uncertainty for a Single Refinery Plant	111
6.1	Introduction	111
6.2	Problem Definition	112
6.3	Deterministic Model Formulation	112
6.4	Stochastic Model Formuation	114
6.4.1	Approach 1: Risk Model I	114
6.4.1.1	Sampling Methodology	115
6.4.1.2	Objective Function Evaluation	115
6.4.1.3	Variance Calculation	116
6.4.2	Approach 2: Expectation Model I and II	117
6.4.2.1	Demand Uncertainty	117
6.4.2.2	Process Yield Uncertainty	118
6.4.3	Approach 3: Risk Model II	119
6.4.4	Approach 4: Risk Model III	120
6.5	Analysis Methodology	121
6.5.1	Model and Solution Robustness	121
6.5.2	Variation Coefficient	122
6.6	Illustrative Case Study	123
6.6.1	Approach 1: Risk Model I	124
6.6.2	Approach 2: Expectation Models I and II	125
6.6.3	Approach 3: Risk Model II	126
6.6.4	Approach 4: Risk Model III	133
6.7	General Remarks	133
	References	137

7	Robust Planning of Multisite Refinery Network	139
7.1	Introduction	139
7.2	Literature Review	140
7.3	Model Formulation	142
7.3.1	Stochastic Model	142
7.3.2	Robust Model	144
7.4	Sample Average Approximation (SAA)	146
7.4.1	SAA Method	146
7.4.2	SAA Procedure	147
7.5	Illustrative Case Study	148
7.5.1	Single Refinery Planning	148
7.5.2	Multisite Refinery Planning	153
7.6	Conclusion	159
	References	159
8	Robust Planning for Petrochemical Networks	161
8.1	Introduction	161
8.2	Model Formulation	162
8.2.1	Two-Stage Stochastic Model	162
8.2.2	Robust Optimization	163
8.3	Value to Information and Stochastic Solution	165
8.4	Illustrative Case Study	166
8.4.1	Solution of Stochastic Model	167
8.4.2	Solution of the Robust Model	168
8.5	Conclusion	170
	References	171
9	Stochastic Multisite Refinery and Petrochemical Network Integration	173
9.1	Introduction	173
9.2	Model Formulation	174
9.3	Scenario Generation	177
9.4	Illustrative Case Study	177
9.5	Conclusion	181
	References	181
	Appendix A: Two-Stage Stochastic Programming	183
	Appendix B: Chance Constrained Programming	185
	Appendix C: SAA Optimal Solution Bounding	187
	Index	189