http://ansinet.com/itj

ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 12 (18): 4561-4568, 2013
ISSN 1812-5638 / DOI: 10.3923/itj.2013.4561.4568

Researches on Scheduling Technology in Oil-refining Industry: A Review

[1]Yucheng Wu, [1]Gang Rong, [2]Lianhai Li, [2]Kaixiang Yang and [2]Zhongli Zhang
[1]Department of Control Science and Engineering, Institute of Cyber-System and Control, State Key Laboratory of Industrial Control Technology, Zhejiang University, Hangzhou 310027, China
[2]Zhejiang Supcon Software Co. Ltd., Hangzhou, 310053, China

Abstract: Scheduling optimization in oil-refining industry has been attracted great academic attentions for many years. Most researches on scheduling optimization focus on sub-problems such as crude oil scheduling, production scheduling and blending scheduling and tremendous progress has been made. Meanwhile, the overall scheduling problem which involves multi-stage oil-refining processes is still difficult to handle because of its scale and complexity. This paper reviews the development of modeling strategies and solution approaches of scheduling problems in recent years and gives holistic perspective of researches on scheduling technologies in oil-refining industry.

Key words: Scheduling, optimization, oil-refining, modeling

INTRODUCTION

Oil-refining industry pursues the optimal economic performance by improving capabilities of functions from strategic level to operational level. As a typical process industry, oil refining is characteristic of continuous/batch production modes, existence of materials splitting/blending operations and producing productions with high volume in long campaigns (Kallrath, 2002). Oil-refining industry has small profit margins that reducing production cost is critical to the survival of enterprises in such a competitive economic environment.

Scheduling in oil-refining industry is an arrangement of series operations including oil transportation, storage, processing, blending and distribution within the horizon of several hours to several days. The optimization of scheduling problems can generate an optimal solution to running the process system which may provide opportunities for reducing process cost. Researches on scheduling optimization can date back to 1950s just after linear optimization technology was introduced into the planning in the process industry. Planning and scheduling are similar decision-making process, but the former is usually profit driven in a long campaign while scheduling is production goals oriented at operational level in the production system.

The basis of scheduling is a proper description of the production process. The whole production process is corresponding to the overall problem which is difficult to model and solve because of its large-scale size and complexity. Studies usually decompose the overall problem into sub-problems according to some reasonable assumptions or features such as different production processes. These sub-problems include crude oil scheduling, production scheduling, blend scheduling, pipeline scheduling, oil distribution scheduling and so on.

Although been simplified by making assumptions, the sub-problems may have non-linear and combinational features leading to exponentially growing of computational cost. Furthermore, Scheduling can be treated as tactical level supply chain management, so the problems are becoming much more complicated when considering the coordination between scheduling and other enterprise functions. All these issues call for the efficient modeling and solution approaches which have been made a great progress in last 20 years.

Achieving overall optimal performance of enterprises' operations is one of the most difficult issues which received more and more attentions along with the development of IT technology and the improving efficiency of algorithms. The integration strategy, which from information of every operational level to models of different enterprise's functions, is a solution proposed to put all segments together realizing plant-wide or enterprise-wide optimization through coordination technology. Scheduling optimization has been given more responsibility in the integration context by expanding its scope definition.

Scheduling in most occasions is made based on experiences or simple spreadsheet calculation by schedulers for many years although optimization

Corresponding Author: Yucheng Wu, Department of Control Science and Engineering, Zhejiang University, Hangzhou, 310027, China

technology had been introduced for a long time. State of the art scheduling optimization is still inadequate to apply in real production situation. Lots of open questions still left behind and most of scheduling technologies still stay with researchers in the lab's computers rather than in the factory.

This study does not trying to cover the all the scheduling researches topics but only provides a detailed view of scheduling problems in oil-refinery industry. It is organized as follows. Section 2 will present most of scheduling problems in oil-refining industry in the context of enterprise engineering development, section 3 reviews the main scheduling technology, then we trying to give an overview of current situation of scheduling in real production and discuss some future trends in section 4. Summary will be present in section 5.

OVERVIEW OF SCHEDULING PROBLEMS IN REFINING INDUSTRY

Oil-refining involves multi-stage processes which can be used as basis of decomposition strategies for defining scheduling problems. The processes from the shipment of crude oil to the product distribution are roughly separated into several stages which are crude oil process, production process and blending and distribution process and the overall scheduling problem can be decomposed into sub-problems in consist with these process. Since the definition of the process segment is arbitrary, other scheduling problem can be defined based on the interest of the industry or academia, the example is pipeline scheduling problem. The decomposition strategy reduces the size and complexity of scheduling problems effectively but leads to suboptimal or even unfeasible solutions of whole refinery operations. Therefore the plant-wide scheduling problem is always concerned though it is still a hard nut to crack.

Scheduling is one of functions of enterprise which interconnect with each other. ISA-95 (ISA, 2010) has defined enterprise's functional hierarchy from the view of system integration. There are three layers which are Business Planning and Logistics where functions such as SCM, planning, accounting belong, Manufacturing Operations and Control where scheduling belongs and Process Control which including three types of batch, continuous and discrete. Most of functions of all three layers are coupled with scheduling and their relationship has been concerned in system synthesis through integration, coordination techniques. In recent years, the concept of Enterprise-wide Optimization (EWO) has been proposed and discussed (Grossmann, 2005). EWO not only optimizes functions but also concerns their interactions through integration.

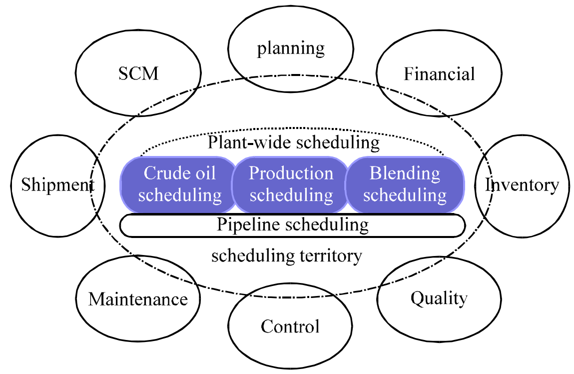

Fig. 1: Scheduling problems definition in oil-refining industry

Figure 1 describes the scheduling problems definitions mentioned above. The view from left to right presents the multistage of oil-refining processes which begin with shipment and ends inventory. The middle functions are crude oil scheduling, production scheduling, blending scheduling, pipeline scheduling and plant-wide scheduling which belong to typical scheduling territory. The top-down view from planning to control is a hierarchy in consistent with ISA-95 standard. The overlapping zone between scheduling territory and other functions can be new definitions of scheduling problems such as SCM optimization incorporated with scheduling and integration of planning and scheduling which already have received great attentions. With the development of enterprise engineering, scheduling territory will greatly expand its boundary along with many new scheduling problems emerging. The following parts will briefly present some recent research progress in these fields from left-right view and top-down view in Fig. 1.

Scheduling problems of multistage refining process: The overall scheduling problem has been decoupled into several sub-problems based on some reasonable assumptions in left-right view in Fig. 1. They are crude oil scheduling, production scheduling, bending scheduling and pipeline scheduling which belonging to typical scheduling territory.

Crude oil scheduling problem: Typical crude oil operations involve shipment of crude oil by vessels, unloading crude oil from vessels to storage tanks at ports, transportation of crude oil from storage tanks to charging tanks located in refineries through pipelines, mixing crude oil to meet the properties specification and feeding it into CDU for further processing.

Crude oil scheduling is to ensure the continuity of crude oil supply from vessels to CDU according to the monthly production plan and shipment plan. There are several key infrastructures serve crude oil scheduling: vessels, storage tanks, charging tanks, pipelines and CDU. Crude storage tanks are required because vessels arrival is intermittent while CDU charging crude oil is continuous, Meanwhile, charging tanks are used as a buffer to crude oil mix which component specification should meet the demand of CDU production plan (Lee *et al*., 1996). Pipelines connecting storage tanks to charging tanks are another important infrastructure which may be treated as special tanks for their big capacity while transferring the crude oil. Once the information of scheduled vessels arrivals and CDU production plan are available, crude oil scheduling determines vessels unloading schedule, crude oil allocation schedule, crude oil transferring schedule and CDU schedule. To lower the cost of crude oil operations, mathematical model are established to find optimized solutions. Shah (1996) and Lee *et al*. (1996) have established MILP models on the base of time discretization. Jia and Ierapetritou (2004) has introduced continuous-time modeling technology into crude oil scheduling optimization problem. Considering the properties constrains of crude oil mixing process, Moro and Pinto (2004) and Reddy *et al*. (2004) have build MINLP model for scheduling optimization and developed MILP-based solution approaches to find solutions.

Production scheduling problem: Production include operations of CDU and other production units such as FCC, VDU etc. One or more CDU take charge of distillation of mixed crude oil and produce desirable distillates which include gas, naphtha, light distillates, heavy distillates and bitumen. The distillates are partly delivered to intermediate tanks for further process: Naphtha and light distillates are sent to pools to blend final products (such as gasoline, diesel) and some heavy distillates may be sent into Fluidize-bed Catalytic Cracker (FCC), vacuum distillation unit, coking unit or hydro treating unit to produce intermediate products with suitable composition.

Production scheduling determines which mode of each production unit is adopted at each point in time to meet the demand of production plan while considering the capability of production units and capacity of intermediate tanks. Modes of production units are mainly specified by which products produced and material consumed and changeovers between modes usually lead to product degrading or disturbances. To guarantee the continuous production process of the units, a great deal of intermediate tanks is used as buffers. Great deal of process units, tanks and pipelines along with their complex physical or logical connections make description of detailed production process extremely difficult. Production scheduling defines detailed schedules of which mode will be used at each time point and when changeovers occur in a short horizon based on monthly production plan.

To describe the complex production process, STN (State Task Network) and RTN (Resource Task Network) has been introduced into refinery production process modeling. Pinto *et al*. (2000) and Gothe-Lundgren *et al*. (2002) have established MILP model to optimizing the production scheduling. Jia and Ierapetritou (2004) has developed a continuous-time model for production process. Nystrom *et al*. (2006) has developed a decomposition approach to find a optimal solution.

Blending scheduling problem: Typical blending process involve operations of feeding intermediate products with a given recipe into blend headers to produce final products and holding products in tanks or direct transferring to market according to shipment plan. The products usually are gasoline and diesel which yield 60~70% of total refinery's profit, so blending operations is urgent to be optimized.

Blending scheduling has two responsibilities to guide the whole process. The first one is to ensure the quantity of specified products been produced to meet demands of production and shipment plan, which belongs to traditional scheduling problem. The second one is to calculate or optimize blending recipes to reach the goal of quality demands of final products, which is a typical pooling problem.

To optimizing the blending operations, Glismann and Gruhn (2001) has developed a hierarchical structure to integrate the scheduling problem which is a MILP model based on RTN process representation and recipe optimization which is NLP model, also an iterative approach has presented to find the solution. Jia and Ierapetritou (2003) has established MILP model based continuous-time representation which based an assumption of fixed recipe. Mendez *et al*. (2006) has put forward an algorithm to simultaneously optimize operations scheduling and off-line blending.

Other scheduling problems: Except above mentioned scheduling problems, pipeline scheduling is getting to be noticed by academics because of the fact that pipelines run through the whole oil refinery and play a key role of transferring crude oil to refinery as well as product to market. Although crude oil scheduling is considering flow rate of pipelines as a constraint, but its more regular model has established by Neiro and Pinto (2004) through general model framework. Magatao *et al*. (2004) has developed a

MILP model based on discrete-time representation to deal with product pipelines scheduling. Rejowski and Pinto (2008) build a novel model of the pipelines system scheduling problems which mainly focus on pipelines operations of product transferring based on continuous-time representation.

Although each scheduling problem of these sub-systems has been discussed for many years, but the fact is that scheduling in real refinery does not always comply with those assumptions which make problems smaller and simpler by decoupling the original overall problem. Zhang and Zhu (2000) decomposed overall optimization problem into site-level problem and process-level problem and developed an integrative approach to find overall optimal solution by solve the two level problems respectively. Berning *et al.* (2002) presented an integration system solution by developing a collaborative mechanism of planning and scheduling of supply chain. Jia and Ierapetritou (2004) has decomposed overall problems into crude oil scheduling problem, production scheduling problem and blending scheduling problem and established continuous-time model respectively did not discuss the integration of the three problems. Zhang and Zhu (2006) has further developed decomposition strategy for overall problem optimization based on their previous work. Overall scheduling problem is still one of the most difficult problems due to its size and complexity.

Scheduling Problems from Top-down Hierarchical View: Enterprises always pursue overall optimum economic performance therefore most of operational functions such as planning, scheduling and real-time control are required running in optimal mode. Enterprise-wide optimization emerged in process system engineering, which focuses on optimizing the operations with integrating the information and decision-making among various functions (Grossmann, 2005). As one of the most important functions of oil-refining process system, scheduling coordinating or integrating with other functions to acquire overall optimized result has attracted more and more attentions. Researches on scheduling optimization have expanded scopes to from operational level to enterprise level during last ten years.

Planning and scheduling integration: Planning and scheduling belongs to decision making process and responsible for supply chain management and plant-wide logistics. Planning is used to create production, distribution, sales and inventory plans according to customer and market information while scheduling defines the precise timing and sequencing of individual operations as well as the assignment of the required resources over time based on operational plans (Kallrath, 2002). Although the refining industry has realized simultaneous optimization of planning and scheduling will make enterprise more competitive, the integration of planning and scheduling is a difficult multi-scale optimization problem because the two level models lie in different time scale and dealing with different problem size. Two major approaches has been used to integrate planning and scheduling optimization problems, the one is performing planning and scheduling simultaneously over common time grid and the other is using two-level decomposition procedures which upper level is planning problem and lower level concerns scheduling problem (Grossmann, 2005). Das *et al.* (2000) has developed a prototype system that integrating aggregating production plan and master production schedule through a common data model. Van den Heever and Grossmann (2003) has put forward a strategy to integrate production planning and reactive scheduling of a supply network.

Scheduling and other functions integration: Except planning functions, scheduling is needed to integrate or coordinate with other functions for enterprise synthesis and optimization. Varma *et al.* (2007) has investigated the impact of enterprise-wide coordination on enterprise performance, sustainability and growth prospects and defined cross-functional coordination as the integration of strategic and tactical decision-making processes involving many functions of enterprise. Scheduling is a tactical decision-making process and usually treated as operational level SCM which interconnects with other business functions. Guillen *et al.* (2006) has presented an example by integration financial decision optimization into planning/scheduling of supply chain. Research territory on scheduling will be expanded or re-defined with further development of enterprise engineering.

SCHEDULING OPTIMIZATION TECHNOLOGY

Scheduling optimization technology is a branch of Operational Research (OR), which includes modeling technology and solution approaches. The objective system or process usually needs a representation for modeling. State-Task Network (STN) is such a uniform representation for the batch production process which brought forward by Kondili *et al.* (1993) and has been further developed. The latest work (Pinto *et al.*, 2008) has discussed STN and its derivations form the viewpoint of batch plants design. The oil refining process which is characterized as continuous production has not a uniform representation by far and modeling is based on simple production flowsheet. Pinto *et al*. (2000) presented a typical unit representation which can be applied to every process unit in a refinery. Neiro and Pinto (2004) has further developed the representation and generalized it as a modeling framework for planning and scheduling of supply chains.

Model features of scheduling problems: All oil-refining scheduling problems mentioned in section 2 have common features of modeling formulation which Kelly (2003) has summarized that they have three main dimensions, which are quantity, quality and logic. He decomposed the scheduling optimization problem into two optimization sub-problems: a logistics problem which is grouped quantity and logic dimension and a quality problem. The logistics problem can be modeled as MILP and solved using Successive Linear Programming (SLP) and quality problem is usually classified as pooling problems which is non-linear and optimal solution is not provably found. The basic formulation of scheduling optimization model is as follows:

The objective of scheduling models is to minimize the deviation from the pre-determined operational plan or minimize the cost which is the sum of material cost, inventory cost, changeover cost, operating cost, transportation cost and so on. Mainly constraints of the models include:

Balance constraints: Indicating the balance of material flow and its components of each process unit and tank.
Capability constraints: involving the production capability of process units, maximum flow rate of pipelines and capacity of tanks.

Demand and supply constraints: Referring market demands and supplying availability. They are usually decomposed into operational level time frame.

Logic constraints: Including rules, allocation, sequence, run-mode changeover of each unit and so on. Most of them are binary variables leading to bilinear equations of the constraints.

Modeling technology of scheduling problems: There are several technologies used for scheduling problems modeling, which are mathematical programming, simulation and heuristic method. From the optimization view, rigid mathematical programming is a main tool of modeling job. All these mathematical models can be classified into two groups which are discrete-time model and continuous-time model. Otherwise, scheduling model also can be classified into deterministic and non-deterministic model considering if the uncertainty involved in the production process.

Discrete-time and continuous-time: Discrete-time representation model of scheduling problems is based on the discretization of the time horizon into a number of time intervals, which leads to inaccuracy of model and an increase of problem size. To conquer the limitations, continuous-time based model has been developed to provide potential for accurate modeling and solution approaches (Floudas and Lin, 2004). Discrete time formulations slice time into intervals of equal or unequal durations where each operation of each unit such as beginning and ending of a task only occurs on the border of these predefined time grids. When the time horizon or the problem size increases, the model contains a large number of discrete variables of resulting combinational complexity. Although the continuous time formulations can reduce the size of model, modeling of discrete-time representation is still attractive because resource constraints are much easier to handle and formulations are tight in general under this approach (Pinto *et al*., 2000).

Continuous time modeling received great attentions in recent years because of its advantage of model size and accuracy. Almost every scheduling problem in oil refining industry has been modeled using this approach. Continuous time modeling also slices time but it is done by optimization and the time for the intervals of operation happened is variables in the MILP. Following the continuous time representation a number of alternatives have appeared in the literature targeting the reduction of computational complexity of the resulting model. There are formulations using global time intervals that coincide with the discrete time representation, global time points that uses a common time grid for all resources, unit-specific time events that utilizes different event points for different units in the production facility, as well as synchronous/asynchronous time slots that use a set of predefined time slots of unknown duration. Floudas and Lin (2004) classify continuous-time modeling into two categories based on the type of processes. The first one focuses on sequential processes based on the concept of time slots and the second one aims at general network-representation processes that allow merging/splitting task to happen.

Scheduling under uncertainty: Considering uncertainties in scheduling modeling has got more and more attentions in recent years because deterministic models, which parameters are supposed to know in advance, could be infeasible in reality. Pistikopoulos (1995) has classified uncertainty of production process into four categories: model inherent uncertainty, process inherent uncertainty, external uncertainty and discrete uncertainty. The most common sources of uncertainty in refinery are process-inherent uncertainty such as parameters of processing time and equipment availability and external uncertainty coming from demand amount, due date, price of materials etc.

Scheduling under uncertainty can be classified into reactive scheduling and preventive scheduling (Li and Ierapetritou, 2008). Reactive scheduling deals with the problem of modify the original scheduling policy or generate scheduling policy on time when uncertainty occurs and preventive scheduling generates robust scheduling policy before the uncertainty occurs. Preventive scheduling could be further classified as stochastic scheduling, robust scheduling, fuzzy programming method and Sensitivity analysis and parametric programming method. Sahinidis (2004) reviewed the optimization problems under uncertainty and discussed the methodology dealing with aforementioned uncertainty problems. Planning and scheduling problems under uncertainty in oil refining industry have been discussed (Adhitya *et al*., 2007).

Solution approaches: Mathematical models of scheduling problems are inherent large-scale and non-linear which lead to computational complexity. MILP/MINLP is wildly used to formulate scheduling problems for optimization. For MILP problems, general purpose solver software such as CPLEX or OSL is effective tool which uses the Branch-and-Bound algorithm. MINLP problems usually decomposed into a NLP sub-problem and a MILP master-problem by using of decomposition technology such as Benders Decomposition (BD) and Outer Approximation (OA) (Bergamini *et al*., 2008).

Along with algorithms improving, decomposition is a fundamental technique in large-scale optimization issue. Decomposition of variables and constraints in optimization model usually can rapidly gain a near-optimal solution. Wu and Ierapetritou (2003) have summarized some heuristic-based decomposition approaches for the efficient solutions, which are time decomposition, required production method and resource-based decomposition. Kelly (2002) and Kelly and Zyngier (2008) have proposed a several novel decomposition strategies for process modeling.

Although mathematical programming is very powerful for optimization modeling of scheduling problems, a feasible solution often cannot be obtained in reasonable time in spite of above mentioned algorithms and strategies used. Constraint programming (CP) (Maravelias and Grossmann, 2004) and other heuristic searching algorithms has been proposed in recent years, but seldom used to solve scheduling problems in oil-refining industry.

DEVELOPMENT SITUATION OF SCHEDULING TECHNOLOGY

Scheduling technology in practice: Scheduling optimization technologies have been developed at academic institutions for many years, but their implementations are rare in practice. This awkward situation could be determined by reasons as follows:

Simplified problems definition: Modeling the scheduling problems is based on some assumptions which can reasonably reduce the size and complexity of problems but not always in consist of real situation, which leads to solution infeasible in reality. Meanwhile production process is uncertain in nature although theories dealing with uncertainty have made much more progress but they are still far beyond practice

Modeling and algorithms approaches efficiency: Scheduling models of real scenario are usually featured combinational, non-linear even becoming typical NPC problems, Furthermore, uncertainty is another great obstacle to the application of scheduling optimization. Current modeling strategies or algorithms are still incapable of conquering the difficulty.

The gap between scheduling and planning as well as other business functions; planning, scheduling and control have different underlying models, different solution algorithms and different sets of users (Shobrys and White, 2000). The integration of these functions is a fundamental need to tackle the real scheduling problems. But there are so many sophistic factors including human and company behaviors make current integration don't work well.

Scheduling business package such as Aspen ORION, RPMS have put into practice in oil-refining industry. They are mostly interactive tools providing scheduling modeling, simulation and optimization techniques to support the scheduler, which are great assistants of users in this traditional human experiences dominant filed. By far, they still cannot replace the human as a decisions maker because of complicated situation in real scenarios considering mentioned reasons.

Future of Scheduling research: To make scheduling technology more practical, further improvement of modeling and algorithms is always one of the key issues in the future development of scheduling technology. Besides this, other trends emerged along with the increasing demand of enterprises. Traditional scope of scheduling problems and current technology are not enough to meet the demands. Enterprises seek overall solution not only coming from on scheduling problems but other functions or goals which are interacted with scheduling. Loos and Allweyer (1998) has presented the scheduling requirements such as feasibility of the schedule, interactive and graphical interface, frequent update and integration to business system. To meet these demands, scheduling optimization scope has been expanded and is worthy of receiving more attentions. (Berning *et al*., 2002; Guillen *et al*., 2006) have discussed supply chain management incorporating scheduling optimization.

CONCLUSIONS

This study has presented a holistic view of scheduling problems definition, scheduling technology development, current situation and the future trend of development. Oil-refining industry involves complex processes and operations which are decomposed into sub-systems to study respectively. Most of these problems have been reviewed and then investigate the current scheduling technology including modeling techniques and solution approaches. Finally the current situation and some future development trends of scheduling optimization technology are summarized.

ACKNOWLEDGMENT

The authors would like to thank for the support by the National High Technology Research and Development Program (863 Program) of China (No. 2009AA043204, No. 2012AA040307).

REFERENCES

Adhitya, A., R. Srinivasan and I.A. Karimi, 2007. A model-based rescheduling framework for managing abnormal supply chain events. Comput. Chem. Eng., 31: 496-518.

Bergamini, M.L., I. Grossmann, N. Scenna and P. Aguirre, 2008. An improved piecewise outer-approximation algorithm for the global optimization of MINLP models involving concave and bilinear terms. Comput. Chem. Eng., 32: 477-493.

Berning, G., M. Brandenburg, K. Gursoy, V. Mehta and F.J. Tolle, 2002. An integrated system solution for supply chain optimization in the chemical process industry. OR Spectrum, 24: 371-401.

Das, B.P., J.G. Rickard, N. Shah and S. Macchietto, 2000. An investigation on integration of aggregate production planning, master production scheduling and short-term production scheudling of batch process operations through a common data model. Comput. Chem. Eng., 24: 1625-1631.

Floudas, C.A. and X. Lin, 2004. Continuous-time versus discrete-time approaches for scheduling of chemical processes: A review. Comput. Chem. Eng., 28: 2109-2129.

Glismann, K. and G. Gruhn, 2001. Short-term scheduling and recipe optimization of blending processes. Comput. Chem. Eng., 25: 627-634.

Gothe-Lundgren, M., J.T. Lundgren and J.A. Persson, 2002. An optimization model for refinery production scheduling. Int. J. Prod. Econ., 78: 255-270.

Grossmann, I., 2005. Enterprise-wide optimization: A new frontier in process systems engineering. AIChE J., 51: 1846-1857.

Guillen, G., M. Badell, A. Espuna and L. Puigjaner, 2006. Simultaneous optimization of process operations and financial decisions to enhance the integrated planning/scheduling of chemical supply chains. Comput. Chem. Eng., 30: 421-436.

ISA, 2010. ANSI/ISA-95.00.01-2010 (IEC 62264-1 Mod) Enterprise-control system integration-Part 1: Models and terminology. http://www.isa.org/Template.cfm?Section=standards2&template=/Ecommerce/ProductDisplay.cfm&ProductID=11225.

Jia, Z. and M. Ierapetritou, 2003. Mixed-integer linear programming model for gasoline blending and distribution scheduling. Ind. Eng. Chem. Res., 42: 825-835.

Jia, Z. and M. Ierapetritou, 2004. Efficient short-term scheduling of refinery operations based on a continuous time formulation. Comput. Chem. Eng., 28: 1001-1019.

Kallrath, J., 2002. Planning and scheduling in the process industry. OR Spectrum, 24: 219-250.

Kelly, J.D. and D. Zyngier, 2008. Hierarchical decomposition heuristic for scheduling: Coordinated reasoning for decentralized and distributed decision-making problems. Comput. Chem. Eng., 32: 2684-2705.

Kelly, J.D., 2002. Chronological decomposition heuristic for scheduling: Divide and conquer method. AIChE J., 48: 2995-2999.

Kelly, J.D., 2003. Next-generation refinery scheduling technology. Proceedings of the 2003 NPRA Plant Automation and Decision Support Conference, September 21-24, 2003, San Antonio, TX., USA.

Kondili, E., C.C. Pantelides and R.W.H. Sargent, 1993. A general algorithm for short-term scheduling of batch operations- I. Milp formulation. Comput. Chem. Eng., 17: 211-217.

Lee, H., J.M. Pinto, I.E. Grossmann and S. Park, 1996. Mixed-integer linear programming model for refinery short-term scheduling of crude oil unloading with inventory management. Ind. Eng. Chem. Res., 35: 1630-1641.

Li, Z. and M. Ierapetritou, 2008. Process scheduling under uncertainty: Review and challenges. Comput. Chem. Eng., 32: 715-727.

Loos, P. and T. Allweyer, 1998. Application of production planning and scheduling in the process industries. Comput. Industry, 36: 199-208.

Magatao, L., L.V.R. Arruda and F. Neves Jr., 2004. A mixed integer programming approach for scheduling commodities in a pipeline. Comput. Chem. Eng., 28: 171-185.

Maravelias, C.T. and I.E. Grossmann, 2004. A hybrid MILP/CP decomposition approach for the continuous time scheduling of multipurpose batch plants. Comput. Chem. Eng., 28: 1921-1949.

Mendez, C.A., I.E. Grossmann, I. Harjunkoski and P. Kabore, 2006. A simultaneous optimization approach for off-line blending and scheduling of oil-refinery operations. Comput. Chem. Eng., 30: 614-634.

Moro, L.F.L. and J.M. Pinto, 2004. Mixed-integer programming approach for short-term crude oil scheduling. Ind. Eng. Chem. Res., 43: 85-94.

Neiro, S.M.S. and J.M. Pinto, 2004. A general modeling framework for the operational planning of petroleum supply chains. Comput. Chem. Eng., 28: 871-896.

Nystrom, R.H., I. Harjunkoski and A. Kroll, 2006. Production optimization for continuously operated processes with optimal operation and scheduling of multiple units. Comput. Chem. Eng., 30: 392-406.

Pinto, J.M., M. Joly and L.F.L. Moro, 2000. Planning and scheduling models for refinery operations. Comput. Chem. Eng., 24: 2259-2276.

Pinto, T., A.P.F.D. Barbosa-Povoa and A.Q. Novais, 2008. Design of multipurpose batch plants: A comparative analysis between the STN, m-STN and RTN representations and formulations. Ind. Eng. Chem. Res., 47: 6025-6044.

Pistikopoulos, E.N., 1995. Uncertainty in process design and operations. Comput. Chem. Eng., 19: 553-563.

Reddy, P.C.P., I.A. Karimi, R. Srinivasan, 2004. A novel solution approach for optimizing crude oil operations. AICHE J., 50: 1177-1197.

Rejowski Jr., R. and J.M. Pinto, 2008. A novel continuous time representation for the scheduling of pipeline systems with pumping yield rate constraints. Comput. Chem. Eng., 32: 1042-1066.

Sahinidis, N.V., 2004. Optimization under uncertainty: State-of-the-art and opportunities. Comput. Chem. Eng., 28: 971-983.

Shah, N., 1996. Mathematical programming techniques for crude oil scheduling. Comput. Chem. Eng., 20: S1227-S1232.

Shobrys, D.E. and D.C. White, 2000. Planning, scheduling and control systems: Why can they not work together. Comput. Chem. Eng., 24: 163-173.

Van den Heever, S.A. and I.E. Grossmann, 2003. A strategy for the integration of production planning and reactive scheduling in the optimization of a hydrogen supply network. Comput. Chem. Eng., 27: 1813-1839.

Varma, V.A., G.V. Reklaitis, G.E. Blau and J.F. Pekny, 2007. Enterprise-wide modeling and optimization-An overview of emerging research challenges and opportunities. Comput. Chem. Eng., 31: 692-711.

Wu, D. and M.G. Ierapetritou, 2003. Decomposition approaches for the efficient solution of short-term scheduling problems. Comput. Chem. Eng., 27: 1261-1276.

Zhang, N. and X.X. Zhu, 2000. A novel modelling and decomposition strategy for overall refinery optimisation. Comput. Chem. Eng., 24: 1543-1548.

Zhang, N. and X.X. Zhu, 2006. Novel modelling and decomposition strategy for total site optimisation. Comput. Chem. Eng., 30: 765-777.