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EDITORIAL

A preface to the special issue on enterprise-wide optimization

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1 Enterprise-wide optimization

Enterprise-wide optimization (EWO) has become a major goal in the industry due to the increasing pressures for remaining competitive in the global marketplace. Enterprise-wide Optimization is concerned with the coordinated optimization of the operations in the full supply chain, including R&D, sourcing of raw materials, production operations, and distribution of final products. Process supply chains range from those in the petroleum industry to the ones in the pharmaceutical industry, and include manufacturing as a major component. The main objectives in EWO include maximization of profits or minimization of costs, responsiveness to customers, asset utilization, management of inventory levels, and the improvement of a supply chain's ecological footprint. Major operational activities include planning, scheduling, real-time optimization and control. A major challenge that is involved in EWO of process industries is the integrated and coordinated decision-making across the various functions in a company (purchasing, manufacturing, distribution, sales), across various geographically distributed organizations (vendors, facilities, markets), and across various levels of decision-making (strategic, tactical, operational). One of the key features in EWO is the integration of information and decision-making among the various functions that comprise the supply chain of the company. Integration of information is being achieved with modern IT tools. While these tools allow many groups in an enterprise to access the same information, they do not provide comprehensive decision making capabilities for optimization that account for complex trade-offs and interactions across the various functions, subsystems and levels of decision making. In order to realize the full potential of such integrated supply chains, the development of sophisticated decision-support tools based on mathematical programming is needed Grossmann (2012).

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From a mathematical point of view, most of the optimization models that have been developed for Enterprise-wide Optimization correspond to mixed-integer optimization problems, for which both discrete and continuous decisions need to be modeled. A majority of EWO problems are formulated as MILP models, since the description of supply chains relies largely on simple input-output models, while scheduling models are usually expressed in terms of fixed production rates and processing times. However, in recent times, we see an increase in the use of NLP, MINLP and differential algebraic models in order to account for operations such as blending, fluid flow, chemical reactions, and process dynamics. The EWO models are multiscale in nature, inasmuch as they involve both spatial integration of geographically distributed manufacturing facilities as well as temporal integration of long-term strategic decisions with short-term operations and control. Since the multiscale nature of these models gives rise to very large-scale problems, decomposition techniques (e.g., Benders, Lagrangean) become essential for effectively addressing these problems. Furthermore, while initially EWO models are formulated as being deterministic, it is clear that there often exists the need to account for uncertainties, ranging from orders placed and equipment availability in scheduling settings to prices and demands in planning for large-scale supply chains. Problems of the former type are often addressed through robust optimization techniques, since their goal is to ensure feasibility over a range of possible realization for the near-term future. In contrast, for long-term strategic problems, stochastic programming is often used because of its probabilistic view of the future and its focus on optimizing outcomes in expectation, while handling recourse in a more straightforward, yet coarse-grained manner. Finally, it is worth recognizing that EWO problems are also often posed as multi-objective optimization problems, given potential conflicting objectives such as economics and customer satisfaction.

From the above, it is clear that EWO deals with problems that are of great practical significance to engineering and business applications, while giving rise to very challenging mathematical programming problems that require sophisticated and elegant methodologies to tackle them. It is therefore the main purpose of this special issue of *Optimization and Engineering* to present a number of technical papers that address some of the major problems currently emerging in this arena.

2 Recent advances from this special issue

In the general area of planning and scheduling, Zhu et al. (2019) improve the agricultural value chain by proposing an optimization scheme for seed production planning at a regional level that accounts for uncertainty in crop yields. The authors apply their method on a real-life industrial case study and report considerable savings in total costs as well as reductions in land usage.[1] Wenzel et al. (2019) study the operation of production plants that are coupled via distribution networks, formulating an MILP that accounts for inventory coupling and uncertainties in energy

[1] The contribution by Zhu et al. (2019) appeared in the previous (September 2019) issue of *Optimization and Engineering*.

prices and ambient temperature. The authors apply their approach on the real-life case of a petrochemical production site and highlight how a reduction of production costs can be achieved by shifting the loads and operation periods of the processes and energy consuming equipment. Next, Flores-Quiroz et al. (2019) present a column generation approach for planning capacities in industrial power-intensive process networks. The algorithm shows competitive computational performance as compared to a full-space model, and was able to address a realistic instance involving the expansion of an existing air separation plant over a 10-year horizon. Dias and Ierapetritou (2019) introduce a data-driven framework to select production targets that are deemed feasible from both the planning and scheduling points of view. Their framework employs classification methods to analyze the feasible region of the scheduling problem using historical data, and the resulting classifiers are used as models that can be incorporated in the planning problem.

The special issue then turns its attention to the area of problem decomposition, where Allman et al. (2019) discuss the automated use of graph community detection in the context of identifying promising, and often non-intuitive, decompositions for complex optimization models. Their algorithm, dubbed DeCODe, has been implemented in a tool that is offered freely for academic use. Next, Basán et al. (2019) develop MILP formulations for solving complex scheduling problems that arise in the shipbuilding industry and that involve block assembly construction. The authors demonstrate how an iterative algorithm hybridizing these MILP formulations with heuristic solution construction schemes was able to reduce computational times to the point where a real-life case study could be practically addressed.

In the area of optimization under uncertainty, Lappas et al. (2019) present an adjustable robust optimization approach to handle imperfect tasks in the context of multitasking scheduling. The authors use the concept of uncertainty in production yields to model the possibility of product streams that require recycling, and they are able to close the optimality gaps in instances with up to 100 uncertain parameters. Galan et al. (2019a, b) study the hydrogen network operation in a real-life oil refinery, and they use the real-time optimization framework to derive optimal production and consumption targets for the LP layer of the refinery's DMC control system. In addition, the authors follow a two-stage stochastic optimization approach to account for the uncertainty in hydrogen demands that exists due to variations in the types of processed crudes. Shahandeh et al. (2019) study the capacity and expansion planning for bitumen partial upgrading infrastructure. Recognizing the strong economic and commercialization uncertainties in this space, they propose a multi-stage optimization model as well as two solution methods that utilize hybrid stochastic programming and robust optimization principles to accommodate the simultaneous multiplicative presence of time-invariant and time-dependent uncertainty. In the context of oil production planning, Awasthi et al. (2019) present a multiperiod NLP model to determine oil well production profiles, and show that it provides advantages compared to the sequential single period optimization approach. They apply a stochastic programming version of the former model on a case study and report solutions on the Pareto frontier between maximizing expected net present value and total oil production while accounting for uncertainties in oil prices and productivity indices over long term time horizons. Finally, the special issue concludes with a contribution from Sampat and Zavala (2019), who present an axiomatic analysis of various utility allocation schemes and show conditions under which these schemes might lead to allocations that are unfair for the stakeholders. The authors illustrate these results with two case studies to allocate power and soil nutrients.

3 Endnote

We hope that the reader will enjoy this special issue and find the manuscripts contained herein insightful and inspiring for the research and/or practice of Enterprise-wide Optimization. We would like to thank all authors for their contributions to this effort, as well as all referees for their detailed and constructive reviews. Finally, our thanks also go to the Editor-in-chief of *Optimization and Engineering*, Prof. Nikolaos V. Sahinidis, for providing us with the opportunity to compile this special issue and for his support of the EWO area.

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