of electricity for a set of prosumers, aims to maximize his/her profit. At the lower level, prosumers (considered as acting together) aim to maximize the revenues from selling power/minimize what is paid to the producer when their production does not satisfy their power need.

3 - Convex hull pricing in markets with non-convex offers and AC OPF
Nicolas Stevens

Non-convexity is an unavoidable difficulty in electricity markets, that arises from (i) the inherent non-convexity of the physical laws governing the power grids as well as (ii) from the market orders that include binary decisions — the commitment decisions in the US-style markets or the so-called block bids in the EU-style markets. Besides the computational challenges that emerge from these non-convexities, their economical implication is that an equilibrium price supporting the market dispatch is not guaranteed to exist anymore. Fifteen years ago, a pricing model called Convex Hull Pricing has been proposed as a promising solution, exhibiting several desirable properties. This triggered a vivid debate in the academic literature as well as in the industry, among American ISO first and more recently also emerged in the European NEMOs discussions. This presentation investigates the convex hull pricing approach, provides an algorithmic solution to compute it and discusses its application in EU and US markets.

4 - Mixed-Integer Nonlinear Optimization for District Heating Network Expansion
Marius Roland, Martin Schmidt

We present an MINLP for computing optimal expansions of tree-shaped district heating networks given a number of potential new consumers. We state a stationary and nonlinear model of all hydraulic and thermal effects in the network as well as nonlinear models for consumers and the network's depot. For the former, we consider the Euler momentum and the thermal energy equation. For the thermal aspects, we develop a novel approximation. The expansion decisions are modeled by binary variables for which we derive additional valid inequalities. Finally, we present a case study in which we identify three major aspects that strongly influence investment decisions: the estimated average power demand of potentially new consumers, the distance between the existing network and the new consumers, and thermal losses in the network.

■ TF-48

Tuesday, 18:30-20:00 - Virtual Room 48

Lot-sizing

Stream: Lot Sizing, Lot Scheduling and Production Planning
Invited session
Chair: *Nabil Absi*

1 - Addressing the multistage integrated procurement and lot-sizing problem with demand fulfillment, backlogging and service levels
Caio Tomazella, Maristela Santos, Douglas Alem, Raf Jans

In this article we address the Multistage Integrated Procurement and Lot-Sizing Problem with multiple customers and backlogging. We were motivated by the case of a manufacturing company from Brazil that assembles refrigeration equipment, using raw materials purchased from overseas suppliers and in-house fabricated products. The objective of our study was to find solutions that are both cost efficient and that optimize service levels. Knowing that, in traditional cost minimization models, the backlog penalties are mostly intangible costs which are hard to estimate, we present models that optimize service levels while keeping the operational costs within a budget. Furthermore, we incorporate demand fulfillment decisions considering service levels for each customer separately. The results of our experimentation show that the proposed models are viable alternatives that surpass the need of using backlog costs, since they improve service levels when compared to the cost minimization models and can also be used to enforce service equity between customers. We analyze the trade-off between service levels, showing that it is possible to enforce equity by maximizing the lowest service level among the different customers without deteriorating global service levels. We also show how the models behave when the budget is tightened and propose adaptations of the models to maximize service levels considering customer and product importance, and to consider demand shortage as lost sales.

2 - Reformulations for the economic lot sizing problem with remanufacturing under demand and return uncertainty
Fernando Islas, Pedro Piñeyro, Carlos Testuri

In the economic lot-sizing problem with remanufacturing, the demand for a final product can be also satisfied by remanufacturing used products returned to the origin. Considering that demand and returns quantities are generally uncertain, we developed two stochastic variants of the problem according to whether manufacturing and remanufacturing are in separated or dedicated production lines. Stochastic mixed-integer linear programming reformulations are provided for both variants, assuming a finite discrete time planning horizon and finite probability space represented by scenario trees. The reformulations are mainly based on two different approaches: the facility location problem and the strengthening of the formulation by incorporating path valid inequalities. In addition, the path inequalities are combined to generate tree inequalities to further strengthen the formulations. A relax-and-fix heuristic is also proposed fot the case of large instances. We performed several computational experiments for the case of separate production lines, since it is the most complex variant of the two considered. Some key findings from the experiments are that the tree inequalities can improve the linear programming relaxation of the reformulations, and that the performance of the reformulations decrease as the number of periods increases. In addition, we note that the relax-and-fixed heuristic suggested shows promising results for large instances of the problem.

3 - Production Planning Applied to a Lattice Slabs Factory
Caroline de Arruda Signorini, Silvio de Araujo, Sônia Cristina Poltroniere, Gislaine Mara Melega

This study looks at the production planning of lattice slabs integrated to the optimization problem of the use of molds, motivated by a factory in Brazil. Lattice slabs are precast concrete structures composed of precast joists with steel latticed bars on a base of concrete. In the joists' production process, it is used a limited number of molds, which are divided into sections of equal lengths. The production planning of lattice slabs is weekly, and the production process starts with the preparation of the molds. Next, each mold is filled with concrete. The steel bars previously cut into the length of the items are used as reinforcement, being inserted into the still liquid concrete base. Subsequently, the items are removed from the molds, resetting the production cycle. Based on this production process, and considering the main concern of the studied factory related to the waste of steel bars during the cutting process and the minimization of the inventory level, we propose a mathematical model, which is an integrated lot-sizing and cutting stock problem, to minimize the inventory and production costs, subject to capacity and inventory constraints. We based the data set on real information obtained from a lattice slab local factory and also from specialized websites. The proposed model is solved by the Column generation procedure to generate the cutting patterns used in the production and a rounding procedure is applied to find an integer solution.
