INTEGRATED SCHEDULING FOR COLD MILL PLANTS: AN APPLICATION OF STEELPLANNER® MODULES AT SIDERAR

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Summary

In this paper we describe a solution developed by AISystems for capacity planning optimisation at Siderar, Argentina.
The solution combines several mathematical techniques in order to consider complex production constraints like campaign constraints, plant work calendar, maintenance constraints, inventory constraints, orders due dates, products alternative routings.
Expected results are lower production costs, lower and better stock mix, optimal resource usage.

Keywords
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Introduction

Siderar is the largest steel company in Argentina. It is a fully integrated producer that makes coke, pig iron and steel from raw materials, in order to manufacture rolled sheets and coated products. Currently Siderar reaches production levels of 2.4mt annually.
AISystems is a Belgian company specialized in software development and implementation for decision support in the areas of production planning and supply chain optimisation specifically for the steel industry.

In order to improve Siderar' s current performances, both in terms of customer service and productivity, AISystems and Siderar started a first R&D project in 2000.
A general overview of that project is outlined in [1]. We followed a pragmatic approach splitting the problem in two layers, with different levels of aggregation and granularity.

The result of the project was a fully integrated Planning and Scheduling solution, that is marketed since 2003 under the name of Material Flow Coordinator®, as a member of the SteelPlanner® suite of products. A general description of Material Flow Coordinator's® way of working and functionalities can be found in [2].

Recently we have focused on improving the flow synchronization layer, also called capacity planning.
The result is a new optimisation module integrated within MFC. This module is called Capacity Planning Optimiser (CPO).

In this paper, we describe the CPO capabilities, with reference to Siderar project issues.

Project scope

Overview of the capacity planning problem

Siderar production is organised in five sites (see figure 1): San Nicolas (integrated hot and cold plants), Ensenada (cold plant), Canning, Haedo and Varela (finishing plants).

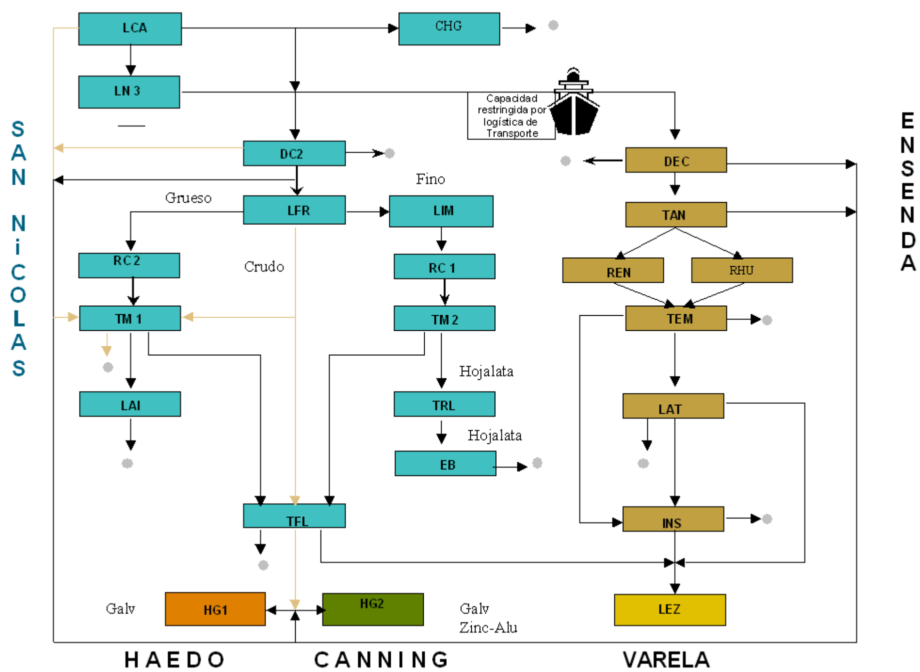

Figure 1: Most important production units in Siderar sites. San Nicolas site includes the hot area: continuous caster (not represented) and hot strip mill (LCA). San Nicolas cold plant includes the pickling line (DC2), the cold mill (LFR), annealing lines (RC1 and RC2), temper mills (TM1 and TM2), inspection line (LAI), trimming line (TRL), Estañado immersion line (EB), trimming and inspection line (TFL). Ensenada cold plant includes the pickling line (DEC), the cold mill (TAN), annealing lines (REN and RHU), the temper mill (TEM), the aplanado-tensionado line (LAT) and the inspection line (INS).
Finally, the three other sites (Haedo, Canning and Varela) include the coating finishing lines.

From a capacity planning point of view, orders are expressed in terms of requirements for product families.

A family of products is a set of final items sharing enough similarities so that they can be aggregated within a single entity at the capacity planning level.
In this project, we have identified about 200 product families.
Each product family has an associated technical recipe, i.e. a description of intermediate processes and possible routes through plant lines in order to achieve the finished good. A product family may have alternative recipes, i.e. several possible routes though the lines and/or several possible intermediate material designs.
For example, line LAT and LIF are alternative for a large variety of products in Siderar's implementation.

Time is bucketized; typically buckets have duration of one day and the horizon we consider is about 3 months.

Basically, the goal of the capacity planning is to determine, for every line, the flows of each product family to be produced in every bucket.

The solution (i.e. the set of flows) must fulfil three objectives, which are in competition:

1. Requirements for finished goods must be satisfied within their due date
2. Intermediate inventory constraints must be respected. These constraints can be minimum/target/maximum levels for every product family or aggregation of product families. Typically:
    a. Minimum levels are safety stock levels requested for every product family, to be respected in every bucket
    b. Target levels are given in some buckets (e.g. the last day of each month) for every product family
    c. Maximum levels represent the physical capacity of the stockyard to be respected every day and are given at the global level.
3. Production constraints have to be respected.

The last point (production constraints) is very important and critical in the steel industry. Next section focuses on it.

About production constraints

Campaigns

Some production units have campaigning constraints, for example the San Nicolas and the Ensenada cold mills. A campaign on a line is a set of families that can be continuously processed without stopping the machine. On the other hand, going from a product family in a campaign to a product family in a different campaign, requires a machine set-up. Beyond this idle time, a campaign transition also has a direct cost.
Some campaigns may have minimum/maximum duration and/or rhythm constraints (in tons and/or hours).
For example, on Cold Mills we have campaigns of ultra-thin, thin and thick material. The thick material campaign has a minimum duration of 8000 tons, a max duration of 3 days and must be planned not more than 4 times a week.

Shift policies

Most production units have a calendar describing the workers availability (also called shift policy).
For example, typically on San Nicolas Temper line workers are available from Monday morning 6 a.m. until Saturday afternoon at 2 p.m., whereas on the remaining lines workers are available every day of the week.

Maintenances
Production units need to stop from time to time for maintenance. For lines where this maintenance period is more than a day the stops are planned well in advance and must be imposed in the capacity plan.
For some other lines, maintenances are not strictly imposed and can be planned within the capacity plan provided that some rhythm constraint is respected. This is the case, for example, of the Hot Strip Mill where maintenance of 16 hours is required with a periodicity of 14 days.

Formulation of the Capacity planning problem

The Capacity Planning problem can be formulated as follows: Given:

- A time bucketization
- A plant description in terms of lines and families of products with technical elaboration (intermediate materials design and possible routes)
- A set of requirements for finished product families (weight, family, due date)
- Inventory constraints
- Campaigning constraints where it applies
- Shift policies on different lines
- Imposed maintenances and/or maintenances rules where it applies

Find the set of flows, per line, per bucket, per product family to be produced in order to fulfil the requirements and respect the constraints.
Some optimality criteria can also be included like work-in-progress minimization, throughput maximization, JIT policy, and idle time minimization.

Methods

To tackle the complexity of the capacity planning problem, we worked out a solution based on a mix of exact techniques (linear and integer programming) and metaheuritstics (simulated annealing).

A very important aspect of the proposed solution is its flexibility, due to two important features of the solver:

1. The solver can be applied to any subset of plant lines, the remaining lines being already solved or not. This allows for example to configure a classic “pull” strategy, line-by-line, or area-by-area (where “area” is a group of nearby lines), starting from downstream finishing lines to upstream ones.
2. The solver can work with some additional constraints generated in a previous resolution step. For example, one can run the solver a first

time in order to roughly balance the load between alternative lines, without considering campaigning constraints; then, the total calculated flow (weekly, or monthly) can be imposed in the next run, where campaigns constraints are considered and good campaigns patterns are built; finally, these campaign patterns can be imposed in a third run, in which the detailed daily flows for every family are calculated within each campaign.

Of course, the solution can also be obtained in a single global step, considering all constraints at the same time and the result is more likely to be better than in a step-by-step approach.
However, experience shows that users highly appreciate participating to the construction of the solution in a multi-step mode, because they improve their insight in the problem.

Results and perspectives
The MFC-CPO module is currently being integrated in the existing MFC environment, covering the five Siderar' s sites. The benefits expected from this implementation are:

- Lower and better stock mix, given by tight flow synchronization between production lines.
- Lower production costs, given by optimal campaign transitions
- Optimal resource usage, given by alternative routes flow balancing

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