Steel service centers - advanced planning and scheduling with SteelPlanner®

SteelPlanner is a suite of programs that tackle some of the main challenges in steel service centers, namely capacity and campaign planning, inventory management, and alternative processing line optimisation. Programs are available which handle the assignment and cutting plan optimisation of a common stockyard, a global supply chain solution, including campaign and flow balancing over alternative production lines, and scheduling optimisation of parallel production lines.

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A steel service center buys steel products (coils) in large quantity from producing mills and holds the material in inventory until sold to a customer. In addition it will perform additional processing as required, then load and deliver the steel to the customer. Service centers usually offer varying degrees of material pre-processing which involves surface coating such as galvanising and painting, and cutting services, such as sawing, shearing and slitting, or finally re-shaping the flat steel into shapes such as pipes and tubes. *Figure 1* shows a typical material flow.

Today, over 30% of all industrial steel products pass through service centers. Some of these are independent companies, whereas others are related to or owned by the primary steel producers. The most difficult challenge of every steel service center is to balance coil inventory, production capacity and delivery times. Coil inventory should be as small as possible to reduce inventory cost, but high enough to provide enough input material to feed the processing lines. Production capacity should match the demand of the market and be in equilibrium with the accepted orders. The promised delivery dates of the accepted orders have to meet the available processing capacity and the production plan for that capacity.

This challenge is complicated by several production constraints. Some processing lines (coating lines) have to be organised in exclusive campaigns where only orders matching similar production conditions can be scheduled in the same campaign. The production capacity is also subject to the plant work calendar and the maintenance interventions of the processing lines. Inventory levels and transport capacity are not infinite.

Service center processing lines are usually smaller and cheaper than those at steel plants, and very often multiple parallel processing units co-exist *(see Fig. 2)*. ▷

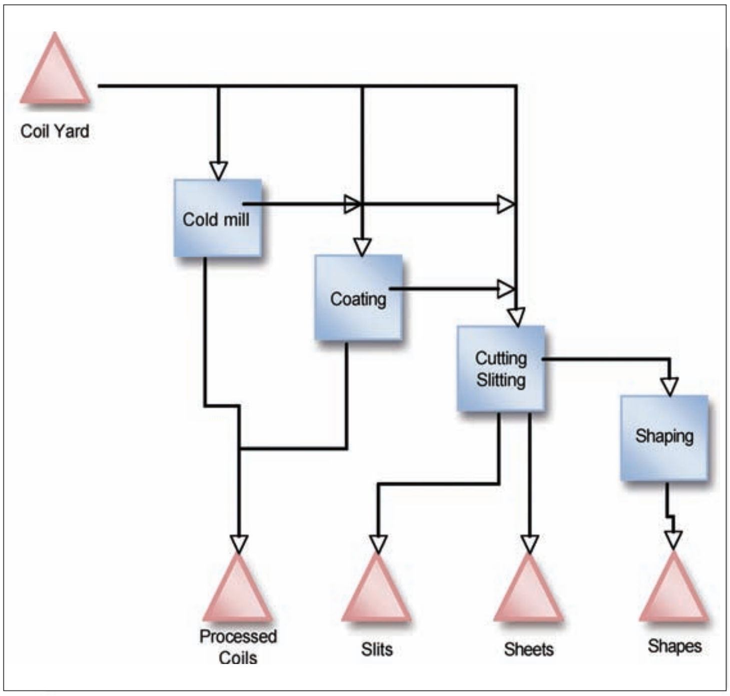

Fig.1 **Typical material flow in a steel service center**

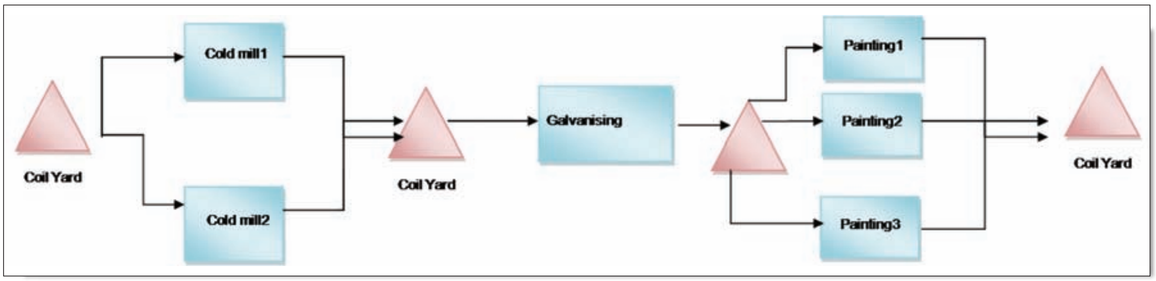

Fig.2 **Parallel processing lines**

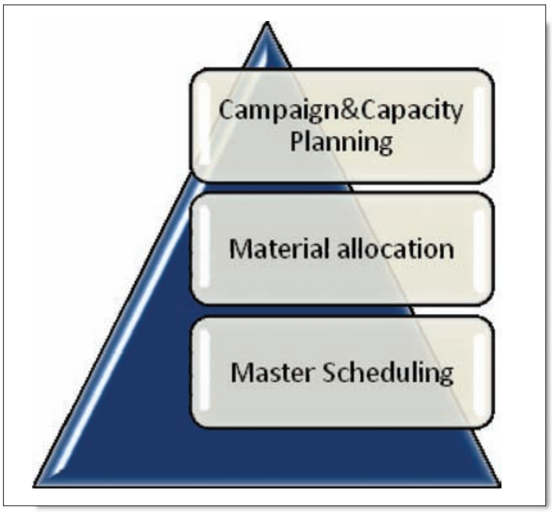

Fig.3 Planning and scheduling layers

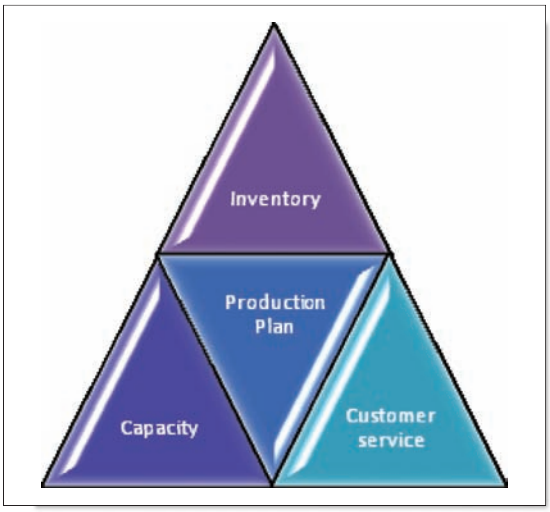

Fig.4 Conflicting targets

This means the planner and schedulers have alternative possibilities to process final orders, however, these alternative production routes often share the same inventory and complicate the optimisation.

The solution described in this paper will consider both the planning and the detailed scheduling process. The following steps will be distinguished:

Material flow co-ordination At this level we focus on the different material flows that have to be controlled in a service center. This material flow co-ordination has to match the demand against the available production capacity for a time horizon of up to a few weeks of production. The capacity plan resulting from this level will assign product families (aggregation of similar production sharing the production route and productivity) to time buckets. The campaign plan will also be a result of this level.

Material allocation Service centers have to control the inventory levels of semi and final products. At each intermediate inventory, material units can be assigned, unassigned and re-assigned to production orders. The assignment optimisation is very important in order to control the inventory levels of the service center. In the case of slitting and cutting lines, the material allocation has to deal with one material unit to be assigned to multiple production orders in order to minimise the resulting scrap.

Master scheduling and detailed scheduling Each material unit processed on a processing line has to scheduled, respecting scheduling rules and selecting the most urgent and to be completed production orders. Scheduling decisions have to be propagated to the next processing lines. *Figure 3* illustrates the planning and scheduling layers.

MATERIAL FLOW CO-ORDINATION

For material flow co-ordination we use the Material Flow Co-ordinator (MFC) of the SteelPlanner suite. It is a management and optimisation tool that integrates medium term capacity planning with short term production order scheduling. Characterised by an information flow and communication between these planning levels, MFC balances customer requirements, material flows, inventory planning (safety stocks) and scheduling quality in order to find an optimised global solution. *Figure 4* illustrates some of the conflicting targets.

MFC can work in either a pull mode, push mode or in a combined pull/push mode around the bottleneck source. Ideally with the increasing trend towards lean manufacturing (where high throughput rates and customer satisfaction are met with minimal stocks) a complete pull system would minimise stock. However, a complete pull system usually fails in the steel industry because of the complexity of scheduling individual lines where a product mix or campaign is required. The MFC deals with this by a combination of line centric optimisation and negotiations between the detailed scheduling modules to minimise or optimise the inventory before the downstream line.

As explained earlier, the capacity planning of service centers is highly constrained by the campaign organisation of the coating lines. The production of galvanising and painting lines have to be split into exclusive campaigns determined by process setup

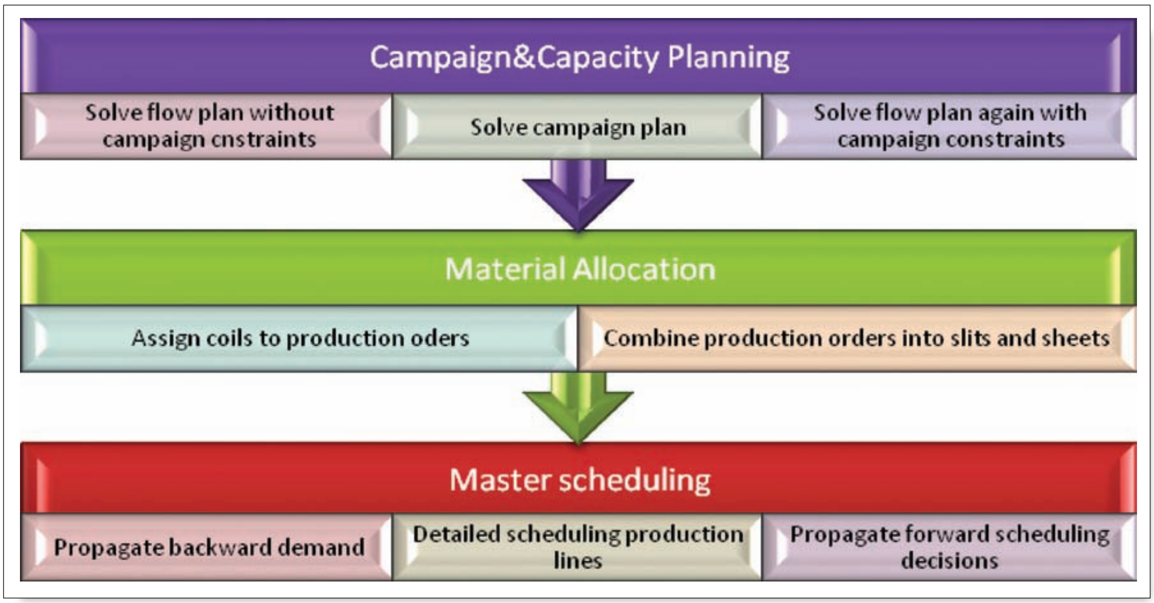

Fig.5 Planning and scheduling strategy

parameters and coating material added to the strip. One cannot change these parameters during a campaign, which can last from one to several days of production - and this has an important influence of the service center's material flow of the downstream inventory levels and processing lines. The capacity planning of MFC considers and determines these long lasting campaigns of the coating line. The resulting capacity and campaign plans are then downloaded as constraints for the master scheduling of the whole plant and the detailed scheduling of each production lines (see *Fig. 5)*.

MATERIAL ALLOCATION

The environment in a steel service center is characterised by high levels of intermediate and final products and low storage capacity, hence assignment becomes quite complex and the opportunity of assigning `old`, yet suitable, material is quite critical. Different coupling and uncoupling points exist in a service center.

The initial processing lines are coil based. Cold mills, galvanising and painting lines process one coil after the other. The assignment optimisation of coils to production orders are one-to-one where one coil is fully assigned to one production order. The assignment logic is rule-based and refers to coil grade, coil dimensions and surface quality. Some coils, of course, can be allocated to a variety of production orders. To minimise inventory levels, respect due dates of production orders, and complete as much production orders as possible, optimisation is required.

For one-to-one material allocation, we use ProductMatch, which is an optimisation tool that works in two phases:

- First, all feasible matching between material units and production orders are generated. Matching rules define which combinations are possible and which are not. The matching generation also evaluates the `quality` of a matching. Different matching criteria such as quality, grade, dimensions, origin and pricing are evaluated and result in an overall matching `score`.
- Second, these matches and their score will be used in the second phase where the best matchings are selected and an overall optimal material allocation is performed.

The optimisation algorithm of ProductMatch results in:

- Better use of available stock
- Higher assignment quality, considering dozens of parameters
- Reduction of non-applied stock
- Reducing work in progress (pipeline) stock
- Additional application by reviewing near miss assignments
- Improved order finishing
- Improved order homogeneity
- Better due date performance
- Faster assignment process
- Greater number of finished orders
- Higher percentage of finished priority and backlog orders

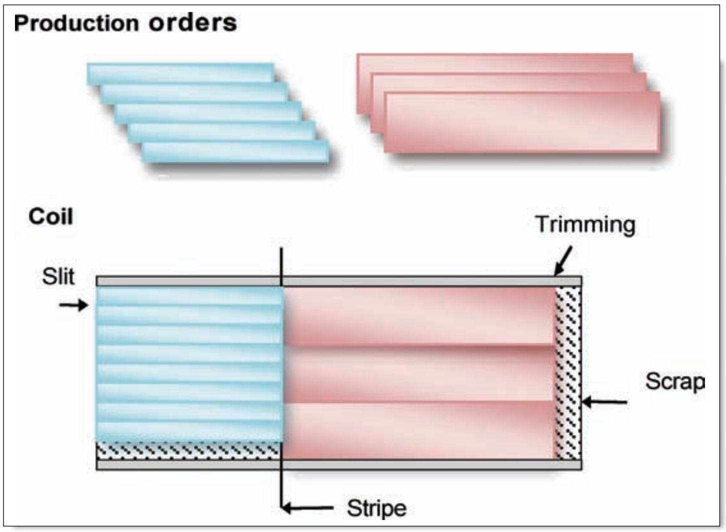

Fig.6 Cutting and slitting plan with SASCO

During the slitting and cutting processes, the one-to-one assignment of material unit to production order is broken. Coils are separated into slits, sub-coils or sheets, and the different pieces can be allocated to different production orders. This material allocation problem is combined with a cutting plan generation and scrap minimsation. For this material allocation we use the SACSO (steel assignment cutting and slitting optimisation) module of SteelPlanner. SACSO handles stock assignment to production orders for different processes sharing a common stock *(see Fig. 6)*.

This assignment process optimises feasible cutting patterns in order to minimise the steel loss and is made possible by the following mechanisms:

- Automatic generation of feasible matches for each coil and each production order based on the assignment criteria defined by the user (coil to order matches). This matching procedure assigns scores to the different matches based on the user preferences. This allows the service centre, for instance, to orient the coil assignation to the most preferred process.
- Automatic generation of matches between production orders and order-to-order matches. In the same manner as coil-to-order matches, order-to-order matches have scores reflecting the preference in mixing orders on the same coil. For instance, if orders are compatible but far apart in due dates, it might be preferable not to assign them to the same coil. This weighing of the matches also solves the common stock problem by forbidding the assignment of different process orders (slit orders with cut orders for example) on the same coil.
- Optimisation of the assignments and the cutting patterns by selecting the best feasible matches out of this population and by minimising the resulting scrap. Besides the matched preferences, scrap minimisation allows the competition among the different processes regarding the parallel stock to be solved as the coil will be assigned to the process raising the less scrap.
- Handling of flow constraints to balance the stock between the different lines and processes.

Compatible orders can be combined on the same compatible coil. In some cases (certain lines) we have to edge trim. The trimming depends on the order to coil assignation.

A set of requirements has to be fulfilled:

- Production orders must be compatible with the assigned coil and must be compatible between each other if they are combined on the same coil
- The total weight assigned to each production order must fulfill a range weight
- The dimensions of the slits (weights and width) must be fulfilled by the cutting pattern

A set of optimisation criteria has to be fulfilled:

- Scrap must be minimised (length and width)
- Change of slits among strips of the same coil must be minimised as this change induces a time-consuming set-up time. It is preferred to maintain the same knife configuration on the whole length of the coil.
- Order priorities should be considered. If the coil yard does not contain enough coils to satisfy all the production orders, urgent orders should be served first.
- There is a preference to finish orders. An assignment that finishes one order is better than one that assigns coils to two orders without satisfying the total weight requirement of either of those orders

The main benefits expected from SACSO are:

Scrap optimisation By optimally combining production orders and minimising the steel loss (width and length)

Better use of the available and shared stock By minimising the matching penalties and searching for a globally optimal solution this will lead to less unassigned material and a higher quality assignment.

Better due date performance Production orders with high priority (rush, remake, urgent due date) will be completed first.

Faster generation of results By automating the whole assignment process, the operator will obtain results faster

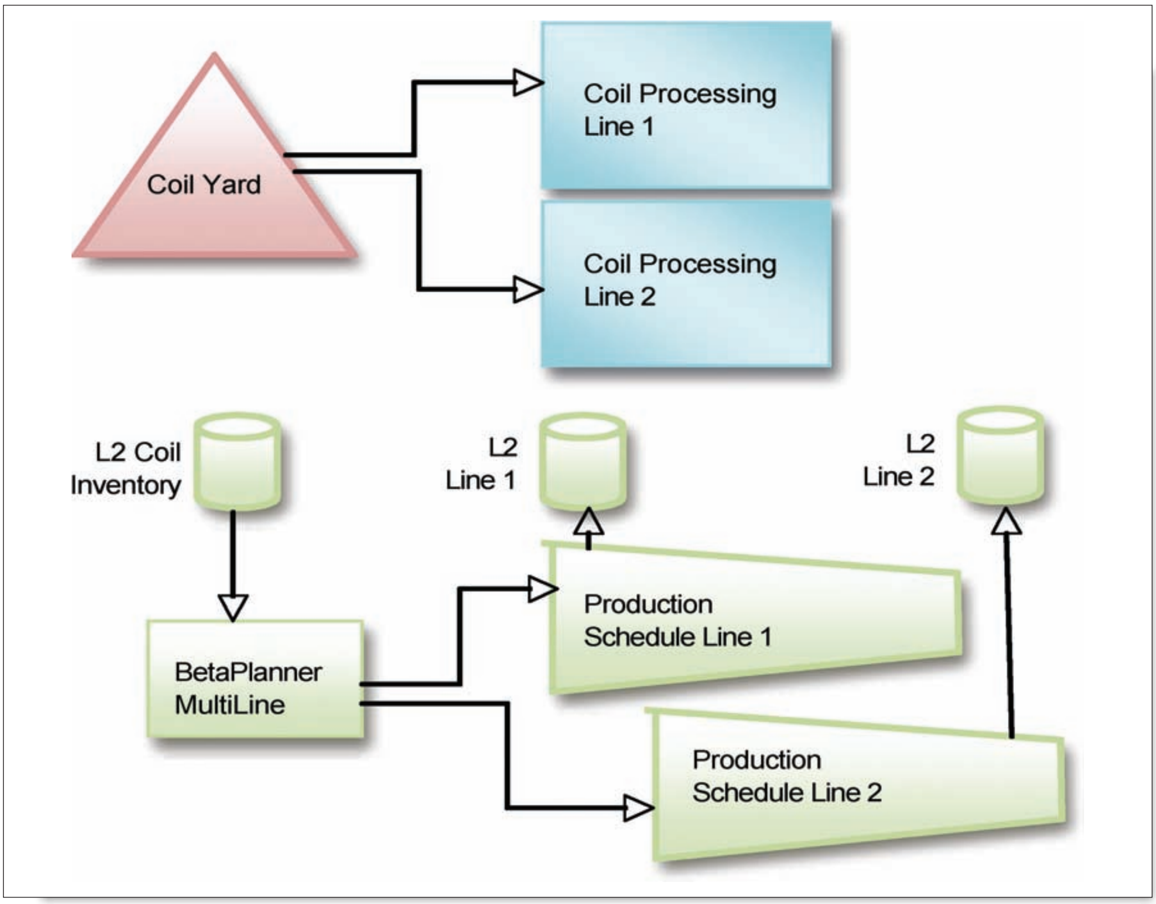

Fig.7 Detailed scheduling with BetaPlannerMulti

DETAILED PRODUCTION SCHEDULING

Steel centers involve a high degree of parallelism in their production environment with, for instance, the main production processes (cutting, slitting, tubes milling, etc) accomplished by parallel production lines (presenting specific technical characteristics). This parallelism also extends to the stock of intermediate products where many groups of parallel production lines share the same common stock.

This special configuration (parallel lines requires the use of a parallel scheduling and assignment tool to take advantage of this flexibility (production lines can process common/specific material and stock cannot be categorised by process beforehand). BetaPlannerMulti is a parallel scheduling tool perfectly adapted to this kind of configuration *(see Fig. 7)*. In addition to the classical scheduling constraints per individual line, Beta Multi Line can handle:

- Specific technical restrictions per line (type of dimensions, type of material to be processed on the line, capacity of the line). This constraint induces a first filtering on the flow to be processed on each of the lines
- Priorities between the parallel lines: which material to process preferably on which production line.
- Flow balance constraints (to balance the different processes and possibly the individual lines)

The use of a BetaPlannerMulti allows global optimising of the load on the different lines in order to achieve a better due date performance. Solving each line sequentially presents the drawback of being sub-optimal by making very good schedules on the first examined lines and deteriorating steadily the solution for the last lines to be solved.

CONCLUSIONS

The main challenges that have to be tackled in a steel service center are capacity and campaign planning, inventory management, and alternative processing line optimisation. The solutions proposed in the SteelPlanner suite allow these problems to be dealt with by taking into account the specificity of this dynamic environment. For instance ProductMatch and SACSO handle the assignment and the cutting plan optimisation of a common stockyard. MFC offers a global supply chain solution including campaign and flow balancing over alternative production lines and Beta MultiLine deals with the scheduling optimisation of parallel production lines.

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