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Effect of dynamic process interaction on the use of Advanced Planning Systems at the production marketing interface:

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Introduction

In the current environment of increased customer responsiveness, most companies are using Advanced Planning Systems (APS) to support their production planning processes, to achieve a certain flexibility of response.

The need for higher responsiveness at the production marketing interface, leads to the dynamic interaction of supporting associated processes such as order management, production planning and execution.

This paper explores how this dynamic process interaction affects the way in which the advanced planning systems are used for process and decision support. This usage is at variance with the designed usage of these advanced planning systems, and it is observed that suggested solutions are often different from the implemented solutions.

The proposed paper is a part of the study of the production planning process at a steel major in India and reports on some early results from the study. The entire production planning process was studied from the demand forecasting stage to the order dispatch stage. The various sub processes involved were also studied in-depth, both as designed and as executed in practice. It was an apriori observation that the solution as obtained from the APS system was not implemented on the shop floor. The solution was modified through systemic intervention.
through add-on processes, and was also modified manually by the managers, to cater to other plant requirements. The objective of the study was to find the reasons for the manual intervention and modification of the proposed solution by the managers.

The paper is structured as follows: First the methodology followed in this investigation is discussed. Then in section 3 the designed processes in the flat products section of the steel major are described. Four main processes related to planning at the production marketing interface are described in this section. In section 4, the process performance parameters are discussed along with the observed discrepancies in the designed processes. In section 5, the interaction in the working of the different processes is discussed, as discovered during the investigative interviews and direct observations.

2 **Methodology:**

The study was conducted in three phases.

In the first phase, the description of the designed working of the main processes – as established by the initial interviews and documents provided by the company – was obtained.

In the second phase, the actual process in use was studied using interviews, direct observation of the process execution, and being a silent observer at critical meetings. Also process performance measures were obtained and evaluated to obtain supporting evidence of the observed process performance.

In the third phase, the gaps between the designed and observed processes were identified. Then additional interviews were conducted to investigate the reasons gaps identified. Also the effect
on the use of the APS was studied with a focus on the apriori observation i.e. why the APS solutions were not being implemented on the shop floor.

Over 100 hours of interviews were recorded, over a period of four months by the researchers from almost all managers who were involved in Sales and Distribution (excluding the branch offices), Production Planning and Scheduling, Production, Dispatch and Order Management functions. The researchers were also allowed access to two major meetings which formed a core part of the planning process, and the proceedings were recorded as a part of the primary data. Besides the researchers were allowed access to planning data, material data and equipment performance data.

3. Designed processes:

The main processes at the production marketing interface were identified as:

i. Demand forecasting and planning process

ii. Order management process

iii. The actual production / conversion process

iv. Daily Process Management (Managing process variability)

1. The demand (and Order) forecasting process

![Diagram](image-url)
The demand forecasting process is geared on the premise that the total demand for the product is more than the available capacity of the Mill. The Customer Account Managers (CAMs) estimate the probable demand for the customers in their area and feed it as demand management input to the APS. This demand is aggregated and is then compared to the Annual Business Plan (ABP) for each region and sector. This demand is then discussed in a general meeting called the consensus meet. The CAMs discuss the customer demand and the trends in demand, and compare it to the Annual Business Plan. Based on this forecast and actual Mill capacity – Actual available to promise capacity is made available to each CAM. This capacity is then converted by the CAM to an order. If the order from the customer does not arrive, the CAM may forego the demand or fill out a Bill to forecast order for the customer (Fig 1). If the order is cancelled by the CAM, this is released at the national level, and then any other CAM may book this order. The final orders booked by the CAMs then comprise the order book for the scheduling of the mill. The dates for CRM (Cold Rolling Mill – described in detail in the next section) are about 4 weeks in advance, while for the HRM (Hot Rolling Mill) coil orders, a two week lag is often sufficient for booking the orders.
The demand data is fed to the SPP (Sales & Production Planning) module (see Fig 1) where the plant capacity and other constraints lead to a more realistic demand figure, which can be met with available capacity. The SCP (Supply Chain Module) module builds in the plant constraints and supply capacity constraints at the Planning Item (PI) level, and the output gives the ATP picture at PI level. [In the forecast for the flat products – the aggregated forecast level of planning is followed by a more detailed planning where each planning item (more detail) and it’s route sheet are used to calculate the plant capacity for each resource of the plant. The CRP (capacity requirements planning) module finally gives the actual available to promise (AATP) figure at the PI level with stock yard, and External Processing Agent (EPA) details if required. This data is fed into the Demand Forecasting 1 (DF1) module for order promising. (EPA is the agent who cuts the coil into sized sheets as required by the customer)

2. The Order management process

![Diagram of Order management process]

Fig 2. Process 2: Order Management
The order management process is designed with an objective to manage and prune the order book. Responsiveness to customer orders and changes in customer’s requirements is also an objective of the process.

The order management process is meant to manage the order book by pruning the late and cancelled orders and also orders which fail to get confirmed. The changing customer requirements are also built into the order book and planning process through order amendments. Small quantity leftover orders are also pruned through this process. Thus integrating customer demand with order book, also through confirming failed orders (orders which do not get a confirmed promise date) are some of the activities which constitute this process.

3. **Production Process**

![Production Process Diagram](image)

**Fig 3**: Production Process for flat products

Fig 3 shows the basic production process for flat products such as sheets, coils etc. The process starts with the production process for steel where the molten pig iron is taken from the Blast Furnace and then sent to the LD-converter (The LD converter is named after the Austrian place...
names Linz and Donawitz and is an improvement on the basic Bessemer converter) process where oxygen is blown through the molten metal to reduce it to steel, and then a secondary steel making process is executed in a vacuum degassifier. This molten steel is then cast into slabs in the slab caster. These slabs are then heated in a furnace in the Hot Strip Mill (HSM) and then rolled into Hot Rolled Coils of about 5 mm or higher thickness. Some Hot Rolled coils are sold, however a substantial portion is then sent for further processing into thinner Cold Rolled Coils. These rolls are may also be plated with Zinc (called Galvanizing in the lines labeled CGL1 and CGL2). Some coils are cleaned in the Electrolytic Cleaning Line (ECL) and then annealed in the Batch Annealing furnace (BAF) to obtain softer grade of steel. These coils are then passed through a Skin Pass Mill (SPM), to improve surface quality of the coiled sheet. Finally these coils are inspected for surface quality in a Recoiling Line (RCL) and Dispatched (D) to the customer.

4. A. Process Management
Process management involves the management of technical efficiency (keeping conversion costs low), and process variability at each stage of production.

![Diagram of Process Variability](image)

**Fig 4: Process 4: Managing Process Variability**
The managing process variability process is executed mainly by the production managers at the various sections of the plant. However the production planning process also gets affected by the process, and hence production planning managers also get involved in the process. The KPIs of the different functional areas at each stage affect the process for e.g. the management of volume fluctuation may be done by changing the throughput of the slab caster by changing the width of the slab caster. The figure is self explanatory, however a more detailed description is given in section 5 where interaction of these processes is discussed.

4.b  Daily Management (Daily Process Management)- The process of managing the production system including monitoring and control of various process parameters relating to the production process and planning process. These include

- management of the order book
- Inventory before and after each resource
- plant loading at each resource
- reporting requirements, managing customer interaction and urgent orders
- Without order material batches (WOO) generation and disposal
- Goodness of plans

Process 3 and 5 are supported by the APS (i2 system) through the use of the Factory Planner which creates the updated feasible schedule for all the major resources.
4. **Analyzing working of the processes and gap analysis:**

The planning process described above works as follows: The production planning starts (as discussed in section 3) in the demand management module of the APS (advanced planning system). This plan is generated as a list of planned orders at the forecast level and is then confirmed into orders booked by the Customer Account Managers (CAMs) based on customer orders. Thus a list of orders is generated in the order book. This order book as scheduled on the shop floor, forms the core of the plan at the planning item level. This top level plan is generated after optimizing the resources using the Constrained Optimization Algorithm (COA) [COA is a proprietary optimization software used by ‘i2’ the vendor for the optimization software or APS]

The ‘Factory Planner’ module (Fig 5) is used by the managers to manage this plan on a day to day basis. This works in conjunction with the ‘material allocator’ to adjust the plan with the actual figures of inventory available at each inventory point between the
resources. This also takes into account the unplanned events taking place on the shop floor which will affect the execution of the plan for each resource. This re-planning then prioritizes certain orders which can be executed and delays the orders which have some shortages.

Looking at the figures for various process measures as given in tables A1 and A2 in the Appendix, the number of orders booked through the Demand Forecasting module is 85-90% and so only about 10% orders are getting booked without a valid forecast for the order. Also the number of orders late by more than seven days is less than 10% which shows that orders are getting fulfilled and are not being delayed by more than a few days from the planned schedule. Dispatch compliance at 80% is also reasonable when benchmarked across the Industry. However the figure which is a cause for investigation is the plan adherence or compliance (table A2 in Appendix) of only about 35-40% at each resource. This shows that about 35% orders are being completed before the scheduled week and only about 40-45% orders are being completed in the week scheduled in the plan.

This calls for further investigation and a better understanding of plan execution at each resource. The reason for the forecast efficiency being at around 45% also needs investigation. The results of the investigation using interviews and direct observation are discussed in section 5.
5. **Description of interaction of above described processes.**

**Interaction of the above processes:**

While the design of each process individually is logically correct and robust, the interaction of these processes creates situations, when the multiple processes do not work in consonance with each other. This creates a situation where

1. There is local optimization of one process to the detriment of another linked process.
2. Certain logical errors creep into the system due to interaction of the processes.
3. Measures of performance for each process are different and are sometimes aligned so that they work at cross purposes with each other.

**5.1 Production Process interaction with Planning process:**

The interaction of production and planning process is largely through the monthly, weekly and daily production plans and schedules for various production resources. The performance metrics for production process are in terms of “Conversion costs” and “production volumes”. This is at variance with the ‘Production planning process’ which is measured in terms of “responsiveness to customer demand” and “Plan adherence”. While these mutually conflicting demands on process resources are common and have been a matter of debate for the last 4 decades, the matter becomes critical when process variability increases. When inventory buffer is not available to absorb this variation, either production capacity or the production plan takes the hit. For example: at the LD2 and Slab Caster (see fig 6a)
Production planning

DM  SPP  SCP  CRP  D F 1

Resource wise weekly order schedule and resource loading plan
Factory Planner with Material allocator for current feasible schedule

Production Process

B F  SC  HSM  CRM  Insp & dispatch

Fig 6a: Interaction of Prod planning and production

Customer demand

CAM

Failed Orders

Order Book

Order Management

Demand Forecasting

Planning – weekly plans/ downloaded to Factory Planner

Resource wise Planned Schedule

Factory Planner – Daily schedules based on material and

Fig 6b: Interaction of demand forecasting, order management and planning processes
VOLUME Variation

Weekly variation in Hot metal arrival is between 12,500 TPD to 16,500 TPD excluding variation due to major unnatural causes. [upto 32% on average – not taking extreme figures] On a week by week basis Hot Metal arrival is between 116350 Tons/week to 88,600 Tons / week [based on data for about 6.5 months in 2007.] leading to a variation of about 31.32% on total hot metal production. The variation on lesser number of furnaces assigned to LD2 is even higher.

This weekly variation is even more difficult to handle. Options for handling hot metal variation are

1. Dumping of hot metal (loss to Industry)
2. Storage upto 15 – 16 hours (Hot metal inventory not cleared if heavy flow continues)
3. Accommodate in throughput of LD2 and Slab Caster (capacity variation by increasing width of slab)

Given the criteria of MOPs for production, the option chosen is option 3, as breaching this KPI has lesser penalty as compared to hot metal dumping.

Grade Variation:

If pouring and cooling temperatures are not maintained, or due to any such variation in process parameters, the grade of the steel in the slab may change. In this case, the planned coils cannot be rolled. The actual chemistry of the slab may be tested online, and the material may either assigned to another order, or is kept aside as WOO slab, which is subsequently sold in market at a discount.
If the chemistry of the input metal varies such as

Case A: Hot metal with very low sulphur and low silicon or

Case B: very high Sulphur & low silicon

In case B the conversion cost to a good grade (low sulphur) of steel will be very high, as use of additives etc will be high. So if hot metal of chemistry as in case A comes, the effort of the shop is to make a better grade (low sulphur) of steel even if it is not scheduled in the plan for the week. This leads to plan non-adherence.

While plan adherence is a monitored parameter, and production shop is responsible for such adherence, the penalty for high conversion costs is much higher. Thus the pressure on the planner is to use the two week window to accommodate the changes in the plan. This maintains “Plan adherence” and also keeps ‘conversion costs’ low.

WHAT SUFFERS? – The penalty or cost is borne by the plan and the number of orders which are late, as the order for which no slab has been produced gets pushed back, in the factory planner, due to no material being available. Thus when material allocator is run, the factory planner finds no material and thus the order is scheduled for later, mean while the slabs which were mad, find an attached order and this is the order which gets scheduled in the factory planner in the day’s schedule. This leads to delay in certain orders. (about 10% late by >7 days and 25% to 40% late between 1-7 days)

Also the plans are not optimized at the shop level where the plans are modified by the use of technical constraints such as coffin schedules. These schedules have been generated because of
requirements of increasing roll life in the rolling process. Thus a plan is locally broken down into coffin schedules during the execution of the plans. This localization takes place at the local level and the coffin schedules are not built into the aggregate/order level plans. However this gives a reason for the managers to alter the schedule at the execution level.

5.2 Interaction between Production process and Daily management process for production planning:

Daily management is the management process for monitoring and controlling the Production and production planning process. This includes the monitoring and control of crucial process parameters such as order booking efficiency, order confirmation outside DF1 module, EDD/IF steel production, BAF filling factor, order lateness, inventory targets, number of order amendments etc. (see fig 6b)

The factory planner also supports the daily management process, by extracting the data on available stocks, outstanding orders (including priorities) list, and resource availability etc as shown in figure 5.

However the need to manage specific orders, or inventory of specific product, necessitates the study and estimation of the working of the factory planner. The production of different grades (as compared to PLAN) necessitates the search for orders at the slab caster level where a two week window is used to search for orders, matching the grade of slab actually produced.

Assignment of slab to production orders is done just at the slab caster after the slab is cut. The new order code number is then etched on to the slab.
The factory planner looks for the slab inventory matching to the scheduled orders on the day (at location between the slab caster and HSM). However not finding the scheduled order slab, the planner then looks for the next order which is feasible and has material available. This new order is then moved ahead of the queue of orders and is scheduled first. This new priority order is then scheduled ahead of earlier planned orders at all subsequent resources such as HSM and CRM (if a campaign is scheduled). Availability of slabs with right composition and size is a pre-requisite for any order to be scheduled at the HSM. The plan for the HSM (along with the requirements of the coffin schedule for rolling) is then converted into a draft schedule to which a list of slabs is then attached at the slab yard. This draft schedule determines the stacking of slabs in front of the preheating furnace conveyor. This conveyor is then loaded by the operator in the sequence of the queue or stack created while attaching the slab codes, and the slabs are rolled as they come out of the furnace.

The Slab caster is the “ORDER DECOUPLING POINT” in the plant, and hence the disturbance of the scheduled output at Slab Caster affects the output schedule of the whole plant. After a slab is cast the in process inventory and the schedule at the subsequent resources determine the throughput or processing lead time of the slab till it is rolled into a finished product. (In some cases EPA time is also included).

Factory Planner breaks up order position using inbuilt routings, then loads the resources with available orders. Then the loadings are leveled —using COA and first leveling the CR loading, then the slab caster and any other critical resource, finally the HR schedule is loaded. This loading pattern is not intuitive — and does not lend itself to offline planning. So second guessing
the system is often done. This second guessing is done so that the parameters of the process as specified in ‘Daily Management’ and which are a part of the KPIs of the managers of the planning process can actually be controlled to a certain extent. This is necessary as the managers are accountable for the events on the shop floor and so the plan as specified in the APS output has to be changed, to help them run the mill more smoothly and also to help them meet their targets.

The problems in the APS solution such as “lack of a heat building logic” for the slab caster which was introduced only in September 2007, has reinforced the perception amongst the managers that they can manage the mill more smoothly by using heuristics and broad plans rather than blindly following the APS system. The effort required in tuning the APS system, needs a dedicated team which can work out the solution by trial and error. This requires time and operations managers do not have such time to spare. Thus the task of recursively correcting the solution through fine tuning the built in rules is a very slow process and is taking a lot of time.(due to lack of a dedicated team and such resources)

The kind of problems faced currently by managers are:

1. Inventory cannot be handled and lowered as desired due to uncertainties in the planning process and order requirements.

2. Certain orders cannot be delivered on due dates (promised dates) as Factory Planner randomly pushes them back.

3. Urgent orders cannot be handpicked and scheduled as the “PROCESS SEMANTICS” do not lend themselves to direct interpretation across the different shops, and schedules of
slab caster cannot be linked directly to orders (as a natural understanding – only a few handpicked managers have some idea of the linkages) as a knowledge of semantics is required across the shops- Steel chemistry at Slab Caster to Rolling grades at HRM and Commercial grades at CRM. Order may contain IS grades as the specifications. The APS system has such logic built – but unless this rationalization is done, easy visual inspection and management through linking of orders and schedules cannot be properly done. “A rationalization of order grades and grades across the shops is required, as the movement of order across the various shops becomes less visible. The internal knowledge required by the managers for a conversion of grades to other nomenclature is not easy and does not happen naturally. It takes very long for this information to be properly internalized by the managers (and mistakes in logic are common) and this increases the learning time for managers before they become productive.

4. Low inventories are required to lower throughput time for most orders. Though through put time for HR and CRM (specially CGL 1 and 2) has been lowered, further rationalization is possible. This parameter is not being tracked and this leads to a problem with the CAMs. Their problem is that if the customer has a new order – they can never promise him an actual delivery date with a reasonable Delivery Lead time. For higher flexibility of the plant, this delivery lead time should be very low.

5. Little’s law states that in process Inventory increases the order fulfillment lead time. Large inventories at slab caster and HR coil etc lead to a high order fulfillment time – if this is lowered, through lowering of in-process inventories – then the problem of the
CAM regarding order fulfillment lead time can be reduced. Other parameters such as percentage of late orders and plan and dispatch compliance will also improve.

**Conclusion**

Preliminary results indicate that there is a reasonable interaction amongst four major processes which comprise the overall production planning process. However the paper focuses on the interaction of the three major processes – the demand forecasting and planning process, the actual production process, and the daily management process.

The research highlights how the production manager faces conflicting requirements where dumping molten steel is a trade off for keeping to plan compliance in the current setup. The process variation in the production process, as well as the priorities (based on his KPIs) of the planning manager and the production manager, affect the actual schedule of the slab caster. Further the priorities of the managers of the downstream facilities such as HSM and CRM and the need to meet local requirements such as coffin schedules etc (section 5.1) also affect the planning and scheduling decisions at the point of interaction of the planning process and the production process.

The problem setting is more complex than modeled into the optimization algorithms and constraints of the APS as evidenced by lack of heat building logic and incorporation of coffin schedules at the local shop level. Also the requirements of organizational responsiveness to customer orders and changing requirements lead to the order management process which also affects the schedules as suggested by the APS software.
# APPENDIX 1

Table A1: Process Measures

<table>
<thead>
<tr>
<th>Measure</th>
<th>Operational Range (as of September 2007)</th>
</tr>
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<tbody>
<tr>
<td>Forecast Accuracy</td>
<td>35 to 45 % as defined. Accuracy is less at item level, but improves at aggregate level i.e. at PI level or at FI level.</td>
</tr>
<tr>
<td>Late Orders &gt; 7 days</td>
<td>Improved from 50% - 60% of total orders to less than 10% of total orders</td>
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<tr>
<td>Late Orders (between 1 day to 7 days)</td>
<td>Remains in range of 35% to 45 %. Except during a period from 10/6/2006 to 15/12/2006 when it dropped to a range of 15% of total orders.</td>
</tr>
<tr>
<td>Dispatch compliance</td>
<td>Has risen from a level of 35-40% of orders to 75-80% of orders.</td>
</tr>
<tr>
<td>Conversion costs and Product costs</td>
<td>Remain within levels decided in ABP.</td>
</tr>
<tr>
<td>Ex-Mill Order netting efficiency</td>
<td>Improved to about 70%</td>
</tr>
<tr>
<td>Order Booking Efficiency</td>
<td>Improved to about 80%. Percentage of orders booked through DF1 is between 80- 90% but these orders are getting amended.</td>
</tr>
</tbody>
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Table A2: Actual Plan Compliance (production plan compliance at each of the major resources- the slab caster, the Hot Strip Mill and the Cold Rolling Mill):

<table>
<thead>
<tr>
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<th>Week 37 Plan*</th>
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<tbody>
<tr>
<td>Week 38</td>
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<td>SC</td>
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<td>HSM</td>
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Table shows WEEK 37 plan for each resource actually being adhered to at the resource in week W-2 to week W+1