

INTEGRATION OF PROCESS PLANNING AND SCHEDULING FOR A MULTI PRODUCT MANUFACTURING SYSTEM

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Traditionally, process planning and shop floor scheduling are viewed as separate, discrete manufacturing activities. Conflicts between those activities happen all the time, because process planning is a technique-based, cost/quality-driven activity, and scheduling is a mathematical due date-driven activity. This paper describes an approach in which process planning and shop floor scheduling are integrated in order to achieve a unified manufacturing aim. The integration of process planning and scheduling makes way for the effective use of production resources and creation of realistic process plans that can be readily executed with less modifications in a computer integrated manufacturing system. In the paper we analyze the problems behind planning and scheduling in complex process environments and we propose to enhance the traditional schedulers by planning capabilities to solve these problems. We propose for using dynamic models to capture such mixed planning and scheduling environment.

1. INTRODUCTION

Manufacturing process plans are usually defined by the sequence of operations a job has to go through to transform raw materials to a finished product. Restricting process plans to be a sequence of operations often overconstraints the process plan beyond what processing technology would require. Relaxing the strict ordering in which operations are prescribed in conventional process plans can result in substantial reductions of lead time in manufacturing. Machine scheduling can take advantage of this fact by optimizing simultaneously the job schedule and the order of operations in each job. Although there is a strong relation between process planning and scheduling, conventionally the two functions have been studied independently (Lee, 2001).*

In most current APS (Advanced Planning and Scheduling) systems the planning and scheduling components are implemented separately in different modules. The planning module is responsible for preparing the plans, i.e. the sequences of the activities to satisfy the orders. The scheduling module schedules these activities, i.e. it assigns the activities to the resources and it determines the exact start and end times of the activities as well as other parameters of the activities. If the scheduler finds that it is not possible to schedule all the activities then it backtracks to the planner to find another plan. This decreases the overall performance of the system, if the planner produces too tight (hard to schedule) plans. On the other hand, if the planner produces too easy plans then the profit of the schedule is smaller than it could be because the resources are not utilized fully (Bartak, 1999). Because of above reasons we propose to combine both the planning and scheduling components into a single conceptual model. This model performs the scheduling task primarily but it has some planning capabilities as well.

2. NEED FOR THE INTEGRATION OF PROCESS PLANNING AND SCHEDULING

Process planning is a function within a manufacturing facility that selects the manufacturing processes and parameters to be used to convert a part from its initial form to a final form based on a predefined engineering drawing (Chang, 1990). It seems that a process plan contains the route, processes, process parameters, machines, and tools required for production. The process planning functions involve some important activities like selection of machining operations, sequencing of machining operations, selection of machine tools, determining setup requirements, and design of jigs and fixtures. The information generated by the process planning activities is used as the inputs of scheduling. Therefore, the process planning becomes an unavoidable constraint for scheduling. However, if this constraint may be relaxed then some extra improvements may be obtained. Figure 1 shows a traditional view of planning and scheduling in industry with separate modules.

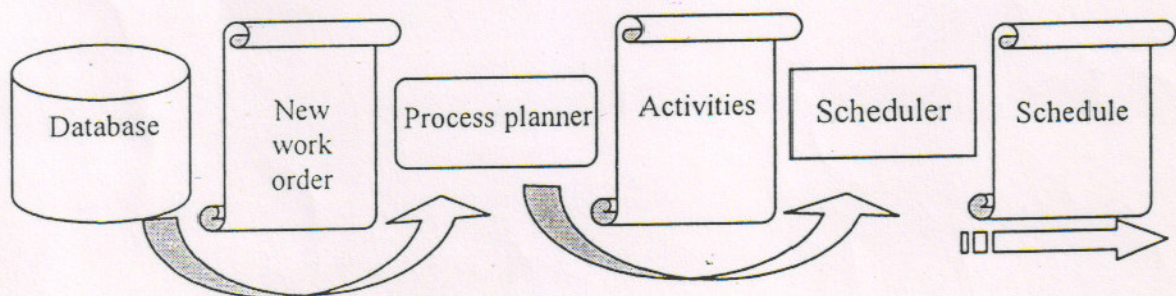


Figure 1 - A traditional view of planning and scheduling in industry with separate modules

The essential advantage of the integration is to eliminate the problems that arise as process planning and scheduling are performed separately in the manufacturing system. These problems are:

(i) Process planners assume an ideal factory with unlimited resources on the shop floor. They plan for the most recommended alternative process. Thus, various process planners select desirable machines repeatedly. As scheduling follows the process planning, actual process plans when carried out result into queues at various workstations and thus these optimal process plans become infeasible.

(ii) The throughput target of orders in a workshop often suffers from disruptions caused by bottleneck machines, non-availability of tools and personnel, or breakdown of machines and equipment. A readily generated schedule becomes invalid and has to be regenerated.

(iii) The time delay between planning phase and execution phase may cause trouble. Due to the dynamic nature of a production environment, it is very likely that when a design is ready to be manufactured, the constraints that were used in generating the plan have already changed greatly, thus rendering, that plan sub-optimal or totally invalid.

(iv) Often process planning and scheduling have conflicting objectives. Process planning emphasizes the technological requirements of a task, while scheduling involves the timing aspects of it. (Manish, 2003).

(v) Without the feedback from the shop it is difficult to measure the quality of a process plan.

Without the integration of process planning and scheduling, a true CIM system, which strives to integrate the various phases of manufacturing in a single comprehensive system will not effectively materialize (Torri 1983, Hou 1991). In this paper, the authors have made an attempt to address the integration issues of process planning and scheduling for a multi product manufacturing industry. We have considered heavy machine shop of BHEL, Ramchandrapuram for the steady and successfully developed scheduling module. The following sections present the details of the issues concerned to the present problem.

3. PROBLEM DEFINITION

The Production Planning and Control (PPC) department of the user industry has to prepare scheduling of jobs on the high cost / critical equipment available on the shop floor under various constraints. From the time a customer places order for a particular product the order is uniquely identified and all the parts regarding the product are also identified. The shop floors and machines are also uniquely identified. The user organization manufactures several types of products like steam turbines, gas turbines, compressors and generators etc. Each customer order is identified by a unique number called Work Order Number (WONO). Each Work Order (i.e Product) consists of several subassemblies and they were identified by a unique number known as Product Group Main Assembly (PGMA). Further each product group consists of individual parts identified by PARTNO and the operation sequence of each part is identified by operation No (OPNO). On an average each part undergo 25 to 125 operations *and a part may recirculate* (Pinado, 1995) *a machine more than once for an operation.*

At present the PPC department has been spending considerable amount of time to prepare scheduling of these jobs. They are employing some manual methods to solve these problems, which are consuming several man-hours and producing crude solutions leading to increased make span for delivering the product to the customer.

The size of the problem of scheduling is mathematically equivalent to N_p jobs to be scheduled on M_N machines, where

$$N_p = \sum_{i=1}^{n_1} \sum_{j=1}^{n_2} \sum_{k=1}^{n_3} WO_i \cdot P_{ij} \cdot N_{ijk}$$

$i = 1, 2, \dots, n_1$ (No. of work orders)

$j = 1, 2, \dots, n_2$ (No. of PGMA's)

$k = 1, 2, \dots, n_3$ (No. of Parts)

$WO_i = i^{\text{th}}$ Work Order

$P_{ij} = j^{\text{th}}$ PGMA in i^{th} Work Order

$N_{ijk} = k^{\text{th}}$ part in j^{th} PGMA of i^{th} Work Order

$$M_N = \sum_{i=1}^{m_1} \sum_{j=1}^{m_2} \sum_{k=1}^{m_3} WC_i \cdot WP_{ij} \cdot M_{ijk}$$

$i = 1, 2, \dots, m_1$ (No. of work centers).

$j = 1, 2, \dots, m_2$ (No. of work places)

$k = 1, 2, \dots, m_3$ (No. of machines)

$WC_i = i^{\text{th}}$ Work Center

$WP_{ij} = j^{\text{th}}$ Work Place in i^{th} Work Center

$M_{ijk} = k^{\text{th}}$ Machine in j^{th} Work Place of i^{th} Work Center

4. PROCESS PLANNING MODULE

Process planning is the process of determining the sequence of individual manufacturing operations needed to produce the part of product, determining the machining parameters, tools and fixtures. The separation of planning and scheduling is natural; the planner generates the activities and the scheduler allocates these activities to available resources. However, there are also disadvantages of such decomposition and these drawbacks become even more evident in some problem areas like complex-process environments.

First, backtracking from the scheduler to the planner is required if the clash in the plan is found during scheduling or if the plan does not utilize the resources fully. Such backtracking is not desirable because it complicates the communication between the modules (the scheduler should inform the planner about the reason of backtracking) and it decreases the overall efficiency of the system. To restrict the number of backtracks we need a more informed planner which means the planner that uses similar information about the resources like the scheduler.

The user industry considered produces various types of turbines; the processing sequences of major parts of these turbines are mostly same. The user industry maintains the history of process planning of all the work orders that were processed on the shop floor. Hence, whenever a new work order enters into the system, the process plan of it is developed by retrieving the information from an equivalent work order from the database. The industry may have more than one work place (machine) in a work center (group of machines) possessing the similar processing capabilities. In general, work centers are identified by a number as WCNO and work places are identified as WPNO. If a particular work place required for the new work order is busy in processing the existing work orders within the time horizon considered, then possible alternatives (i.e., a work place with similar

capabilities) must be identified before generating the process plan for the new work order. This reduces the number of clashes to be resolved while scheduling. Thus, it minimizes the backtracking between the planner and the scheduler at the later stage. A typical structure of the process plan maintained in the database is as shown in the table 1 below.

Table 1: Typical Structure of the process plan

WONO	PGMA	PART NO	OPNO	WPNO	WCNO	PCS	OP TIME	SETUP TIME	TOT TIME
10198025	30101	1001	2	9863	1032	1	---	---	480
10198025	30101	1001	3	9412	3116	1	---	---	480
10198025	30101	1001	4	4828	3116	1	2100	60	2160
10198025	30101	1001	5	9991	3116	1	1050	---	1050
10198025	30101	1001	6	4828	3116	1	1600	60	1660
10198025	30101	1001	7	9991	3116	1	800	---	800
10198025	30101	1001	8	9421	3116	1	200	---	200

It is proposed to develop software, which can address the integration of process planning and scheduling to represent a realistic manufacturing environment. The input can be accessed directly from the oracle database and the process plan for the new work order can be generated by the concept of *equivalent work order*. The various integrated modules shown in Figure 2 shall take care of the overall management of the software.

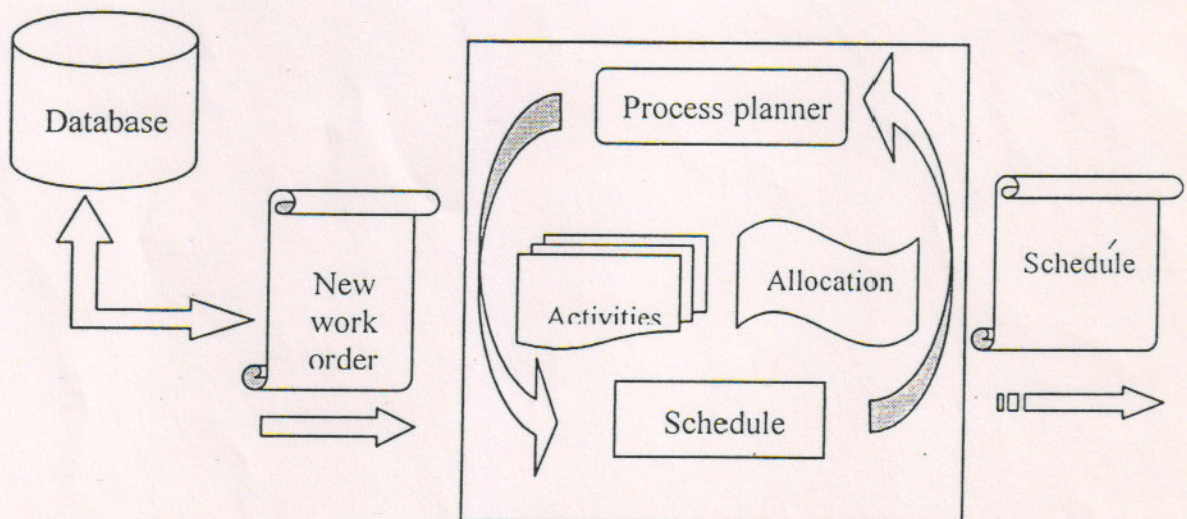


Figure 2 - A general framework for mixing process planning and scheduling

5. SCHEDULING MODULE

As the scheduling problem is of larger size and the number of constraints involved are large, the schedule generation program follows a Heuristic procedure. Though some of the clashes were resolved while generating the process plan, still the clashes may exist while scheduling different work orders. This may be due to unavailability

of the idle machines within the time horizon. The Heuristic procedure uses priority rule whenever there is a contention for the same machine by different parts of the same product or a different product. The authors have developed a multi-project scheduling system for the user industry earlier, which mainly concentrates the scheduling aspect of various jobs on hand and on order. The scheduling program takes care of the following constraints while generating activity schedule for a given number of work orders:

1. The sequence of operations for manufacturing a product is fixed.
2. The part or job may visit the same machine several times.
3. The priority of a work order is not fixed.
4. The efficiencies of the work places may vary with time and there is possibility of breakdown.
5. Break down of a work place.
6. Change in Material Availability Dates.

The scheduling algorithm used consists of the following sequence of steps:

Step 1: The details of New Work order, Priority and Start date are to be entered in input format.

Step 2: Select an equivalent Work order from Master database or add the entire data of New Work order to the Current database.

Step 3: The Work orders, which are in contention for the same Work place, are identified.

Step 4: The clash between the Work orders waiting to be processed on the same Work place is resolved initially based on the priorities of Work orders.

Step 5: The schedules generated are further improved by applying heuristics like SPT, LPT to the existing schedules generated based on dynamic priorities, i.e. if parts with same priority are contending for the same Work place then they are loaded on to the Work places based on SPT/LPT.

Step 6: The results of these schedules are presented in various formats like Project schedules, Component schedules, Work center schedules, Work place schedules, Delivery dates of Work orders and Work center change information etc.

Step 7: Any modifications in the database like change in Material availability dates, change in Priorities of Work orders, change in Work place efficiency, Break down of Work places etc are considered and rescheduling is done.

The results of these schedules are presented in various formats like work order details, workcentre and work place schedules etc as shown in figure 3, figure 4 and figure 5.

WORK ORDER DETAILS

WONO	CUSTOMER	PRIORITY	ORDER DATE	DELIVERY DATE	MAKESPAN
10198028	SAGAR SUGAR 20.4MW	1	28-Feb-99	15-Jul-99	138
10192081	MARATHA 15MW	2	31-Mar-99	06-Sep-99	160
10198029	GANAPATHI 15.6MW	3	30-Apr-99	10-Sep-99	134
10167053	TALCHER 4/1	4	30-Sep-99	01-Mar-00	154
10164013	VARAM 6MW	5	31-Oct-99	12-May-00	195
10173007	RAMA 23MW	6	31-Oct-99	04-Apr-00	157
10167054	TALCHER 4/2	7	01-Nov-99	02-Apr-00	154
10167052	TALCHER 3/2	8	30-Nov-99	03-May-00	156

EXIT

Figure 3 - Work Order schedules based on Priority

WORK CENTER LOADING

SELECT THE WORK CENTER **1032**

SELECT DATE INTERVAL
01-Jan-99 **30-Nov-01**

WONO	PGMA	PARTNO	WCNO	SDATE	EDATE
10198028	30101	1001	1032	01-Mar-99	01-Mar-99
10198028	30104	4001	1032	01-Mar-99	01-Mar-99
10198028	30105	5001	1032	01-Mar-99	01-Mar-99
10198028	30109	9001	1032	01-Mar-99	02-Mar-99
10198028	30125	25001	1032	01-Mar-99	01-Mar-99
10198028	30146	46001	1032	01-Mar-99	01-Mar-99
10198028	30201	1001	1032	01-Mar-99	02-Mar-99
10198028	30301	1001	1032	01-Mar-99	02-Mar-99
10198028	30503	3001	1032	01-Mar-99	02-Mar-99
10198028	30539	39035	1032	01-Mar-99	01-Mar-99
10198028	30541	41071	1032	01-Mar-99	02-Mar-99

DETAILS CLEAR REPORT EXIT

MULTI PROJECT SCHEDULER 04-Dec-01 6:08 PM

Figure 4 - Details of Work Centre Schedule

Multi Project Scheduler - [WORK PLACE PLANS]

File Edit View Tools Window Results Reports History Graphs Help

WORK PLACE LOADING DETAILS

01-Jan-99 30-Nov-01 SELECT WCNO AND WPNO 1032 9863

WONO	PGMA	PARTNO	WCNO	WPNO	SDATE	EDATE
10198028	30101	1001	1032	9863	01-Mar-99	01-Mar-99
10198028	30104	4001	1032	9863	01-Mar-99	01-Mar-99
10198028	30105	5001	1032	9863	01-Mar-99	01-Mar-99
10198028	30109	9001	1032	9863	01-Mar-99	02-Mar-99
10198028	30125	25001	1032	9863	01-Mar-99	01-Mar-99
10198028	30146	46001	1032	9863	01-Mar-99	01-Mar-99
10198028	30201	1001	1032	9863	01-Mar-99	02-Mar-99
10198028	30301	1001	1032	9863	01-Mar-99	02-Mar-99
10198028	30503	3001	1032	9863	01-Mar-99	02-Mar-99
10198028	30539	39035	1032	9863	01-Mar-99	01-Mar-99
10198028	30541	41071	1032	9863	01-Mar-99	02-Mar-99
10198028	30556	56001	1032	9863	01-Mar-99	02-Mar-99
10198028	30556	56002	1032	9863	01-Mar-99	01-Mar-99

DETAILS CLEAR REPORT END

MULTI PROJECT SCHEDULER 04-Dec-01 6:10 PM

Figure 5 - Details of Work Place Schedule

6. CONCLUSIONS

In the conventional approach where the scheduling function is isolated from process planning, the selection of process is an important decision making problem owing to the presence of multiple alternative plans. In this paper a new approach for the integration of process planning and scheduling was proposed by making use of the scheduling performance measures and the flexibility of in-house developed process planning module. In the proposed system, process planning and scheduling maintain their own identity but at the same time interact dynamically with each other for obtaining better results. By applying the proposed methodology in the industry, the resources can be better utilized, the bottleneck problems of the shop floor can be reduced and consequently the throughput of the parts significantly increases.

7. REFERENCES

1. Lee.H and Kim S.S, "Integration of Process Planning and Scheduling Using Simulation Based Genetic Algorithms", *Int J Adv Manuf Technol* (2001) 18:586-590, 2001.
2. Torri. J, N.Ohtuski, M.Suzuki, "Development of on-line, real time, scheduling methods for a computer aided manufacturing systems, *Ann.CIRP* 32 (1), 1983.
3. Manish .K, Sunil Rajotia, "Integration of scheduling with computer aided process planning", *Journal of Materials Processing Technology* 6643 (2003) 1-4.
4. Pinado, "Scheduling theory, algorithms&systems", Prentice hall publications, 1995.
5. McKay, K.N., "Production Planning and Scheduling: A model for manufacturing Decisions Requiring Judgement", PhD thesis, University of Waterloo, Canada.
6. Liao T.W, E.R. Coates, F.Aghazadeh, L.Mann, N.Guha, "Modification of CAPP systems for CAPP/Scheduling integration", *Comp.Ind.Eng.* 25 (1-4) 203-206,1993.
7. Hou T.H, H.P Wang, "Integration of a CAPP system and an FMS", *Comput.Ind.Eng.* 20(2), 231-242, 1991.
8. Chang T.C, "Expert process planning for manufacturing", Prentice Hall, Englewood, NJ,1990.
9. Soldberg, J.J., 1989, "Production planning and scheduling in CIM", In G.X.Ritter *Information Processing*, pp.919-925 (1989).