Flexible Manufacturing System evolving with IPPS processing system and Production Order

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Abstract

The advancement of computerized technology enables us to handle the file size as large as needed and retrieval may take a split of a second as well as the interaction of several files is quite possible. Therefore, the entire manufacturing system may change. Lately, Integrated Process Planning and Scheduling (IPPS) systems are published in abundant and probably successfully implemented for various level of the manufacturing scale. It seems that the previous system of Material Requirement Planning (MRP), capacity planning, production scheduling is going to disappear and the IPPS system replaces them. However, management insists to impose controlling factors such as delivery date and cost on IPPS systems to achieve successful execution. This paper proposes a flexible manufacturing system and describes the tasks of each unit. The production-order section is negotiating the realistic cost and delivery due-date and release jobs to IPPS and report customer inquiries on production order progress. IPSS is working as a processing system on the integration policy that a free resource searches a free operation. The proposed approach has been described with examples as well as the algorithm has been explained.

Keywords
IPPS, Flexible Manufacturing, CAPP, MRP, Production Scheduling.

1. INTRODUCTION

Manufacturing involves a series of activities to meet various objectives of governing management such as the execution and implementation of policies by Chief Executive Officers (CEOs), all Return On Investment (ROI) as well as efficient and optimal utilization of available resources of the company. In other words, the industry must make profit. Manufacturing is mainly concerned with the production of tangible goods and the activities are, as a rule, specified by the engineering profession as well as it is divided to many segments as per the specialized functions within the manufacturing. A usual manufacturing company follow the hierarchical structure which functions in a top-down manner having defined modules and their functionality with local objectives, in which the cost and profit is never the priority. Modules communication is permitted among the parent (top department) and child (bottom department). The planning and execution related to previously fixed decisions. So, it deprives the flexibility and efficiency from production [Jain et al 2013; Halevi 1980, 2012, 2014, 2017; Halevi & Wang, 2007; Halevi & Phanden 2019].

The hierarchical approach of manufacturing is the one-way sequence of linked events, where each link has a specific function and the earlier link being deemed as a constraint. For instance, a master production schedule accepts the Bill of Material (BOM) and routing sheet with delivery due dates and production quantity as fixed data. It never questions the authenticity of these data and its planning must obey with the provided data only. The process planner accepts the product design and its BOM with no query. De facto, they do not even consider the product, but rather, each part is regarded as a specific task. Only if the problems are come across in explaining the process for a specific part, they approach the product designer and advise or ask for a change in the design. The capacity planner readily accepts the routing as fixed data and utilizes the advanced algorithms to deliver an optimized capacity plan. So, the series of activities of manufacturing held independently with the local objectives (which are not directly connected to cost or profit). The probability of success of any link is independent of the other links with which it is functionality associated. The basic notions of the hierarchical way of manufacturing are:

- The use of "best" routine for the job.
- The "best" routine that is optimizing for maximum production will result in the shortest throughput.
- The delivery due date and cost are constant.
- The larger the quantity, the better the productivity.
- MRP considers all production orders, shatter the orders into its product tree as well as it combines the number (quantity) of single items, if possible.

Following are the arguments that lead to the conclusion that these notions are incorrect, in many cases.

Recent research in the field of Computer Aided Process Planning (CAPP) highlights the fact that routing (process planning) is a vague term. The exitance of "best" process plan is missing. Each task may possess more than one alternative process plans (routing) having divergence of processing cost as well as processing time. In practice, if the processing time of operation is shorter than the processing cost will be higher. Table 1 shows twenty-two alternative process plans for a sample component. From the table it can be calculated and concluded that the alternative 1 provide maximum production, alternative 22 provide minimum total cost, alternative 9 provide maximum profit, alternative 3 provide minimum investment, alternative 13 provide years for ROI and alternative 8 will provide the quantity for ROI. These results are very conclusive. However, they do not qualify for a scientific research standard. It might be a unique scenario, not the universal one. They only show a trend of increasing productivity with the increase in manufacturing flexibility. Also, is illustrate that there are numerous procedures to produce a product. In the conventional practice, one among the various possible alternative routing is chosen and utilized for as long as the product design in not changes irrespective of the modifications in the quantity of production order. The delivery date and cost are dictated by management (production order office) and in several cases, it is not practical. Thus, it results in scheduling difficulties and rush orders.

Table 1. Alternative Process Plans with Cost and Time for a Sample Component

Alternative Number	Total Cost	Total Time	Max. Time
1	23.76	5.94	5.94
2	19.02	6.34	6.34
3	15.54	11.10	11.10
4	24.98	12.49	12.49
5	19.80	5.84	4.48
6	17.70	8.94	5.72
7	22.80	7.10	5.00
8	19.57	6.59	5.89
9	16.97	6.22	4.83
10	15.53	9.19	5.72
11	18.15	7.45	5.35
12	15.18	9.99	7.73
13	14.98	12.42	6.40
14	15.19	10.47	9.08
15	24.90	13.50	11.40
16	16.09	13.34	9.99
17	14.94	12.98	6.40
18	17.66	8.90	3.88

19	14.90	10.09	6.23
20	14.34	10.81	5.72
21	14.83	9.36	6.85
22	14.30	10.77	3.88

In literature, various methods have been proposed based on generating the best or alternative process plans and schedule using non-linear, closed-loop and two-phased distributed IPPS approaches [Phanden et al 2013]. Phanden et al (2011 and 2019) highlighted the pros and cons of the above mentioned IPPS methods. We considered that the discussion on the proposed IPPS approaches is beyond the scope of this paper since this is an exceptional idea of flexible manufacturing. Literature review reveals that a system for flexible manufacturing having IPPS as a processing system evolving with production order is a unique proposal to be considered. Also, it can be easily implemented in the manufacturing environment having an existing and functional IPPS system and production order department. Thus, the present work proposed flexible manufacturing in which the IPPS processing system has been used to manage the production orders as per the delivery date and cost.

This paper contains six sections in which the next section discuss the notations of the proposed approach and the third section describe the flexibility description of the proposed system. The fourth section possesses the concept and terminology. Fifth and sixth sections are presenting the algorithm and conclusion.

2. PROPOSED APPROACH

Due to the advancement in computerized technology, it becomes easier to handle the data files as large as needed and retrieval may take a split of a second as well as the interaction of several data and information files is possible and convenient. Manufacturing organization chart may change to introduce manufacturing flexibility thus job routine becomes variable. Therefore, bottlenecks can be lowered, and disruptions are solved automatically and hence the processing productivity increases significantly. The proposed approach is based on the following notions.

- The task of a process planner is to create a roadmap and not routing.
- Production planning treats each order independently as well as the item (product).
- The system creates a working product structure based on product levels.
- Production planning priority is given to critical orders.
- The system load for available capacity.
- The system eliminates or rectifies bottlenecks in production planning.
- Shop Floor Control (SFC) is maintained by a free resource search for free operations.
- Alteration is enabled in production plans at any point in the process.

Carrying out the planning actions as described above, results in:

- Minimum processing lead time
- Meeting delivery due dates
- Maximum resource utilization
- Minimum work in process (WIP)
- Minimum capital tie-down in production
- Elimination of bottlenecks in production

2.1 Resource Data and Operation Matrix

The process planner task is to create two matrixes of operations for each item (product) required by production orders. One matrix for operation time (for maximum production) and one for operation cost (for minimum cost). Table 2 display company resource data that affect routine decision-making. This can be termed as a process planner matrix. Table 3 presents a time roadmap and table 4 present a cost roadmap. Booth tables include all company resources and display the time or cost in minutes to perform a single operation is recorded. A resource that cannot perform an operation that time will be recorded as a high number (99). The "PR" priority column indicates the sequence of operation. "0" indicates that this operation may be performed anytime and any other number indicates that this operation can be performed only after operation number is performed. The "Rel" column indicates that this operation must be performed in conjunction with the indicated operation. Another column (which is not shown in these tables) indicates special code require to instruct scheduling and job release. These tables do not present routine but rather a several options, to be decided at a later step.

Table 2. Resource Data (Process Planer Matrix)

Resource No	Specifications	Power (KW)	Speed (RPM)	Handling Time (In Minute)	Relative Cost in USD
1	Milling Machining Center	35	1500	0.100	04
2	Large CNC Milling	35	1200	0.150	03
3	Manual Milling Resource	15	1500	0.660	1.4
4	Small Drill Press	01	1200	0.660	01
5	Old Milling Resource	15	2400	1.000	01
6	Small CNC Milling	10	3000	0.25	2

Table 3. Resource – Operation time matrix (Halevi, 1999).

Op	TP	PR	Rel	R1	R2	R3	R4	R5	R6
010	0.47	0	0	0.57	0.62	1.28	99	1.62	1.19
020	0.17	010	0	0.27	0.32	0.88	99	1.22	0.59
030	0.31	020	0	0.41	0.46	0.97	99	99	0.56
040	1.89	030	0	1.99	204	2.55	99	99	2.14
050	0.24	010	0	0.34	0.39	0.99	99	1.32	0.74
060	4.16	050	0	4.26	4.31	4.38	99	99	4.41
070	0.03	020	0	0.13	0.18	0.69	0.69	1.03	0.28
080	0.22	070	0	0.32	0.37	0.88	0.88	1.22	0.47
090	0.20	080	0	0.30	0.35	0.86	0.86	99	0.45
Total	7.69	--	--	8.59	9.04	13.92	--	--	10.82

Table 4. Resource – Operation cost matrix (Halevi, 1999).

Op	TP	PR	Rel	R1	R2	R3	R4	R5	R6	Min Cost
010	0.47	0	0	2.28	1.86	1.79	99	1.62	2.36	1.62 M5
020	0.17	010	0	1.08	0.96	1. 23	99	1.22	1.22	0.96 M2
030	0.31	020	0	1.64	1.38	1.36	99	99	1.12	1.12 M6
040	1.89	030	0	7.96	6.12	3.57	99	99	4.28	3.57 M3
050	0.24	010	0	1.36	1.17	1.39	99	1.32	1.48	1.17 M2
060	4.16	050	0	17.04	12.93	6.75	99	99	8.82	6.75 M3
070	0.03	020	0	0.52	0.54	0.97	0.69	1.03	0.56	0.52 M1
080	0.22	070	0	1.28	1.1	1.24	0.88	1.22	0.94	0.88 M4
090	0.20	080	0	1.20	1.05	1.20	0.86	99	0.90	0.86 M4
Total	7.69	--	--	34.36	27.12	19.50	--	--	21.64	17.45

2.2 Level Based Product Structure

The strategy is to allocate the stock to the critical order, where critical is defined as the order that its low-level item has to start at the earliest time. The earliest time might be in the past, or the future date. To meet this strategy the first step is to build the product structure on a time element scale, instead of on level base, as shown in figure 1. This figure shows three products A, B and C as well as the items that are in each product at each level. Level-0 is the product (or order) and the lowest level is in order C and it is level-3, which is also referred to as the "low level". The items 3 and 13 are referred to as low-level items. The connecting lines represent the relationship of the product, its sub-assemblies and the items that do not represent the time to process the item.

In order to determine which order is the critical order, the level-based product structure is converted into a time-based product structure. The name of the order is retrieved from the level-based product structure (level-0) and the matrix is called to generate a process-based for the order quantity for that item.

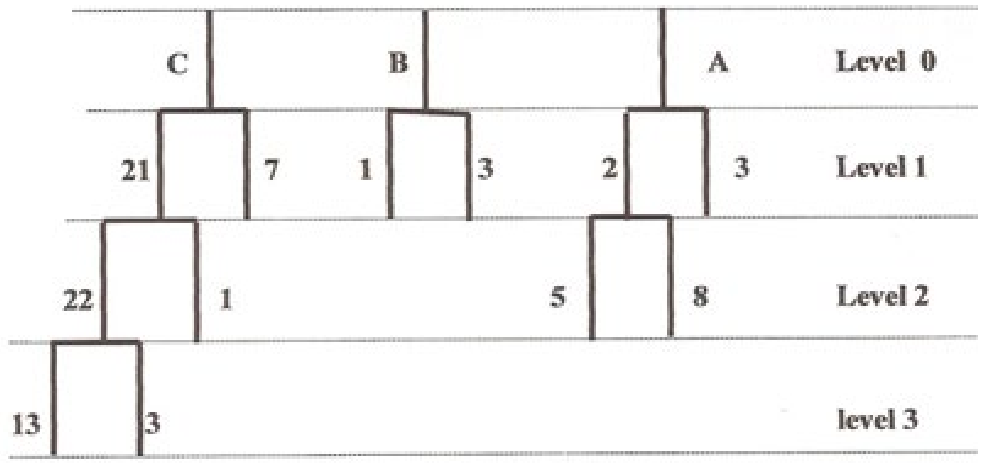

Figure 1. Level Based – Product Structure

2.3 Time Base Product Structure

The conversion of level-based to time-based product structure starts with order delivery date down to lower levels. Call the matrix to compute the assembly time of the product (level 0) multiply by the quantity the sum is converted to the delivery date units. This value is reduced from the delivery date. The result is the starting point in time of processing time of the level 1 items. Again, the time for processing each one of the items in level-1 of that order and its quantity is reduced from the previous level endpoint.

The processing time of such a process is given for every single item. The total processing time is computed by multiplying the quantity by the processing time of a single product. Convert the computed total length of time to the time scale (let say days) and subtract it from the delivery date of the order. Draw a line starting from the order delivery date backwards, at the computed length. The endpoint of this line indicates the date at which the assembly (processing of the order) must start to meet the delivery date. Record this line on the time-based product structure. Next, treat one by one all items of level-1 of the same order, regarding the start processing date of level-0 as the delivery date of each item of level-1. Call the matrix to generate the economic process, compute the total time and convert it to the scale time and draw the connecting line by this length. Repeat this process to all levels of the order and till all orders on the file.

2.4 Example

Figure 1 shows three orders for product A, B, and C. The computation may start with any order. For example, it starts with order A than the assembly of order A is treated first, and the matrix issue the time to assemble. This time is indicated by the length of the line, from the delivery date of order A backward in time.

Next, on the product A structure is sub-assembly 2. The quantity is computed by the order quantity multiplied by the number of subassembly-2 in one product A. The system turns to the matrix and retrieves the time to assembly sub-assembly 2. The assembly ends at the beginning of assembly-A and starts at the due date minus the assembly of subassembly-2.

Next, the sub-assembly 2 is composed of items 5 and 8. Their due date is the beginning of sub-assembly 2. The quantity of item 5 is computed, by multiplying the quantity of item 2 by the number of items 5 in assembly 2. The system turns to the matrix and retrieves the time to produce item 5. The processing due date is at the beginning of sub-assembly 2 and ends at this date minus the processing time of item 5. A similar process is made for the item. The due date for item 3 is the beginning date of order A. Again, the matrix supplies the processing duration. It is important to note that the quantities of each item will consider scrap factor. Figure 2 shows the time base product structure of three orders having different delivery due date.

The level-based product structure is regarded as a master structure, and refers to all products of company, while the time base product structure is a working structure and refers only to the open orders of the company. The working product structure represents the activities that should be taken to supply customer orders.

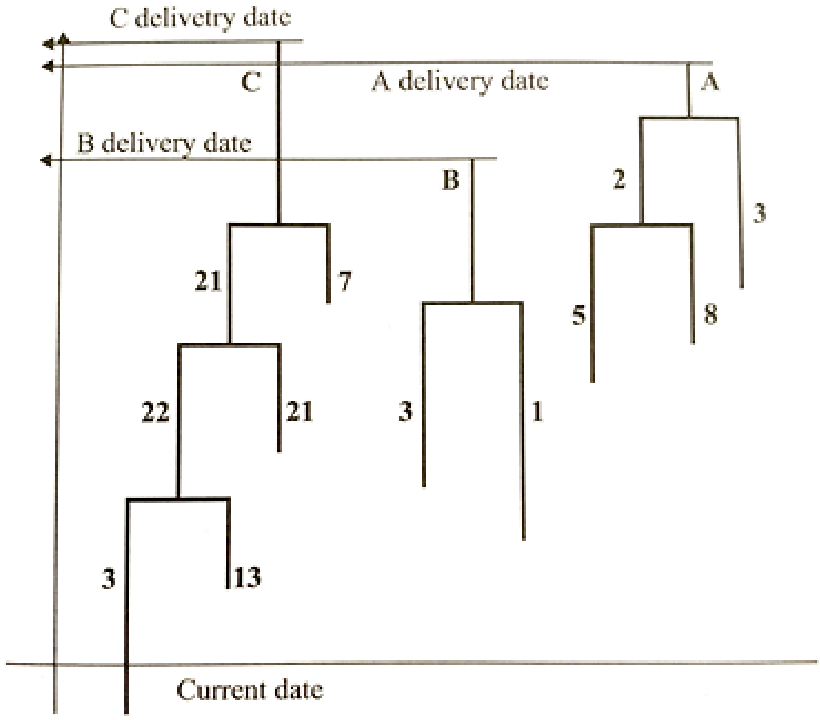

Figure 2. Time-Based Product Tree

3. SYSTEM DESCRIPTION

To practice the above concepts, the proposed system is built on two sections (departments):

1. Production Order Section: This department is considered to ensure the flexible manufacturing with three functions viz., (a) Release job to IPPS, (b) Negotiation with the customer to agree on delivery date and cost, and (c) Report customer inquiries regarding its order progress.

2. IPPS Section: This integration policy is that a free resource searches a free operation, i.e., there is no routing for how to process any item. The objective is to keep the resources fully occupied. To overcome disruptions, in case that the planned schedule cannot be implemented then the system will schedule another job. There is no capacity planning in advanced. IPPS will accept orders from the Production Order Section and report back on progress.

3.1 Production Order Section

(a) Release job to IPPS

Figure 3 presents all orders of a company with a time base product tree. The jobs are release job to IPPS based on the concept discussed in section 2.2 (refer figure 3). The length of the line represents the processing time of each order. The time is computed by using the minimum-cost-process plan (or estimation) multiply by the order quantity. The left vertical line represents a clock and the bottom line represent the current time.

Jobs will be released to IPPS in batches and the batch size should supply work for a couple of days (assume 5 days) each plant may decide his preference. The size of a batch is computed by the number of available processing-working-resources, (assume 6 resources) multiply by the number of standard working hours a day (assume 7 hours). In this example 7*6*5 = 210 hours. It is worth to mention here that the proposed system is flexible (i.e. it will adapt itself automatically to the company size).

The task of the order department is to prepare a product mix of orders to supply work orders for 210 hours. To do this, the time-based product tree as shown in figure 3 is used. The lines may be coded in three colors. Black indicates that the order is waiting to be processed, red indicates that the order was transferred to IPPS (in the process) and green indicates that the processing of this order is finished.

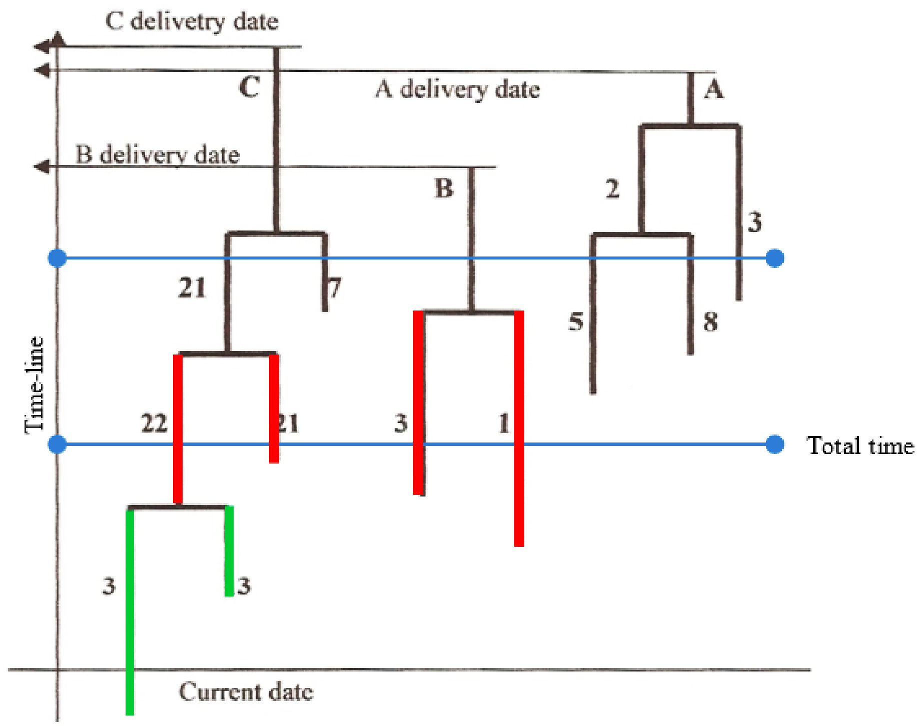

Figure 3. Time-Based Product Tree (example with timeline).

The suggested method to select the product mix is by drawing blue lines 210 hours apart and selecting all orders that this blue line crosses. Example: In figure 3, the order is 21, 7, B, 5, 8, 3. Summing up the processing time of these order processing time is shown in figure 3 as "total time".

Around 300 hours before the blue line the order office should check to make sure that all accessories to fabrication are available and to act accordingly. Before releasing the product mix, need to check in inventory that how many items are available for each order. Such quantity should be deducted from the original in stock order quantity. The processing time should be adjusted accordingly. The ordering office should consider if the time saved is large enough to include another order to the product mix.

The proposed method has a large slack allowing the programmer freedom to use his common sense in deviating from the strict system method. It is recommended to release orders and not partial orders thus complicating the recording system. On receipt acknowledge note from IPPS those orders line color are changed from black to red. On receipt receiving from IPPS note that processing order is finished, the line color of this order is changed from red to green.

(b) Negotiation with the customer to agree on delivery due date and cost

Production Order office should draw the time-based product tree for the customer request. The time-based tree may be drawn by estimated values of processing time and cost. The order officer will regard (use) this estimation (or real numbers) to compute X="*total time*" of the negotiated order, let us call it Y= "*estimated total time*". Using figure 3, the time-based product tree compares these two values along the blue lines. Start from the early time and proceed up in time. Any junction that has *Z=(X+Y) *25%>T* means this delivery date is not accepted. The value of T in the previous example (in the above subsection) was 250 hours. Which is for a company with 6 processing-working-resources, it may be adjusted according to any number of resources.

The T value might be the beginning of a negotiation process. The connection between time and cost is flexible. Use of maximum production process plan instead of minimum cost process plan will reduce the processing time while increasing the processing cost. Working overtime increases production and cost and pay bonus also increase production and cost.
Decisions that affect processing should be delivered to release the job to IPPS processing system to include them in the "Rel" column – refer table 3 and 4 (i.e. to use maximum production instead of minimum cost).

(c) Report customer inquiries regarding its order progress

Customer inquiries regarding an order status will be handle by this production order section (department) using order status, as per the time-based product tree (given in figure 3). Additional information may be obtained from table 5 of shop floor.

3.2 IPPS

A batch of production orders is compiled at the release order section and transferred to the IPPS processing section. The batch size should supply work for a period of periods. Here, the SFC offers a technique that establishes flexibility and dynamics to streamlines the decision-making process in production planning. The SFC method, which is a module of the production management system, proposes that in order to introduce manufacturing flexibility, the routings should be regarded as a variable.

The proposed SFC method does not plan the routine for each released job in advance. Consequently, bottlenecks cannot be formed, and disturbances are resolved, automatically. All the possible alternatives are prepared in the table. The method uses a matrix, as shown in Table 5, the enables to materials the SFC concepts. The data for this matrix is supplied by the release section. Process plan of each item is a copy of the table as shown in tables 2 and 3.

The column in table 5 labelled as "PR" priority, "Op" operation, "X" means that this operation is done. "00" means that 40 is a free operation and operation 50 will become free when "Op. " 40 become "X". The matrix for item #3 is transferred to Table 5 where the processing time is multiplied by the order quantity. The "BES" column represents the best machine for each operation. "Cel" – (not shown) include special codes that instruct SFC to consider in selecting the task.

Table 5 – Shop Floor Status (when R4 is idle) [Halevi & Phanden 2019].

Op	PR	R1	R2	R3	**R4 IDLE**	R5	R6	BEST	Δ
	I	T	E	M		#3			
10	X	12.5	9.51	5.15	**99**	4.02	6.54	5	
20	X	5.04	3.93	2.55	**99**	99	2.82	3	
30	X	6.28	4.86	2.98	**2.53**	2.47	3.44	5	
40	***00***	***6.38***	***6.12***	***7.05***	***5.78***	***5.93***	***6.83***	***4***	***1.27***
50	40	8.24	6.33	3.67	**2.96**	2.62	4.42	5	
60	50	5.15	99	4.02	**4.86**	2.98	2.53	6	
	I	T	E	M		#5			
10	X	3.12	3.17	4.02	**3.27**	99	99	1	
20	***00***	***13.9***	***10.3***	***10.8***	***9.95***	***12.5***	***99***	***4***	***3.95***
30	20	4.86	2.98	2.53	**4.86**	2.98	2.53	3	
40	20	6.04	4.68	2.90	**99**	99	3.32	3	
50	40	5.76	4.47	2.8	**99**	99	3.18	3	
	I	T	E	M		#7			
10	X	3.12	3.17	4.02	**3.27**	99	99	1	
20	X	6.15	4.2	8.05	**9.3**	99	99	2	

30	***00***	***8.34***	***8.92***	***7.58***	***7.23***	***8.76***	***8.12***	***4***	***1,69***
40	30	2.06	2.11	2.96	**2.21**	99	99	1	
	I	T	E	M		#9			
10	X	4.6	3.60	2.39	**99**	2.05	2.60	5	
20	X	5.96	4.59	2.87	**99**	99	3.28	3	
30	***00***	***11.5***	***12.8***	***11.9***	***11.4***	***13.1***	***99***	***4***	***1.7***
40	30	99	99	99	**99**	1.45	1.72	5	

4. SHOP FLOOR CONTROL (SFC) - CONCEPT & TERMINOLOGY

SPC work on a policy that a free resource quest the free operation. A free resource is defined as a resource which is available to load at any point of time. An operation which is available to perform or processed at any point of time termed as a free operation. The scheduling performed in a cyclic way of scanning all resources for free resources. So, the free resource scans all free operations and lists the available free operations. The best operation for the free resource can be selected by considering the minimum processing cost and/or minimum processing time performance measure(s). The searching procedure enlists the candidates for scheduling based on if/then rule given below.

- If the list contains only one entry, then that operation is loaded on that resource.
- If the list contains more than one entry, then the system allocates the operation with the biggest time gap of processing on another resource.
- If the list is empty, this means that there is no free operation available for processing on that resource. Hence, the resource becomes idle and waiting for an appropriate operation.

It is well known that idleness is not desired in the manufacturing system. It is an utter wastage of resources in term of their values if the operations are waiting and free to process. Rather than an increase in the overall processing time or makespan of the manufacturing system, it is better to reduce the idleness by processing the free operation. Thus, the proposed SFC searches free operation to decrease undesirable idleness of resources. On the other hand, it has been noticed that the idle machines tool may not be considered as the best resource to perform the free operation although it is economical to do so.

A suitable method to compute and compare the time consumed by a free resource can be based on the economics of using "best" and alternative operation. In this method, one can calculate the time difference of "best" and alternative operation to compare it with the time consumed by the free (available) resource. Thus, one can reach on a decision of assignment of free resource to the free operation or to keep the resource idle.

Let us take the quantity of items is 100 units and the best processing time is 5 minutes. Assume that the 6 minutes of processing time is consumed by the alternative available resource and 150 minutes is the waiting time for it. So, concerning the above-mentioned method, the economic aspect can be considered as:

- The operation can be performed using "best" resource and it consumes 500 minutes.
- The operation can be performed using an alternative resource and it will consume 600 minutes and 150 minutes are waiting time.

Thus, the actual processing time consumption will be 450 minutes (600 – 450 minutes). So, the alternative resource which is working incompetent (considered as an alternative only) will spare 50 minutes. It is important to understand that in case the next operation is more economical with respect to the performance of the taken resource than it can be assigned to that resource. The meaning of better (economical) resource is that the resource is best for an operation or its processing cost/time minus a transfer penalty is equal or less than the best time of that operation. The transfer penalty is the cost or time consumed to send a job from one resource to another. It will consider the inspection time, storage time, setup time and material handling time. If there is a machine breakdown there will be no special treatment is required. It will be considered as a busy resource. Also, there will be no execution of scanning/search cycle on it. If the items are rejected in between, the product structure is referred to find it, and it will hold the assembly. In this case, all items needed for that assembly are not required and it will be removed from the list of released jobs for that duration of time.

5. ALGORITHM

The activities on SFC will begin with the catalogue of jobs that to be processed during the applicable duration of time. This list is compiled at the realize job section and transferred to SFC. It is having (a) job name and number, (b) quantity of jobs, (c) sequence of operations for jobs (i.e. priority information) and (d) order of BOM.

The jobs listed in the catalogue are available for processing. Although, before starting of actual processing some supplementary jobs are considered. All the free jobs (production order) are retrieved from the database having 2-dimensional process plan roadmap. Subsequently, the 3-dimensional process plan roadmap is constructed, as presented in table 2 to 4. The algorithm works with resource status file (RSF), History File (HF) and Scheduling Module (SM). The RSF is planned to keep the updated status of available resources all the way through the production scheduling period. It stores the data on resource number, quantity of units, loaded items and operation, a link to BOM, resource counter as well as the sequence of entries in the history file. The resource counter confirms the pending time to start the process of the selected item. This counter established through the multiplication of processing time with the quantity of jobs as shown in table 1. This counter is updated in an iterative manner through the scan (search) cycle by the elapsed time from the last scanning cycle.

HF is planned to store the past information for SFC and management people so that the actual performance of the shop floor can be compared and tracked accordingly. This file contains the sequence and resource number, product, item, and operation details as well as the start time and finished time in order to arrive at an actual cost of item and resource load.

SM work as per the sequence cycle loop which performs the analysis of all resources listed in the RSF as it loads the free resources as well as it updates the resource counter. The loop is executed as soon as the operation finished. At this moment, the resource becomes idle and the decision has to be made on the next assignment.

Sequence cycle time is the elapsed time between the present time and the previous sequence cycle loop. The running clock is used to calculate the sequence cycle time. It starts with the scheduling process and moves forward corresponding to the working time.

SFC initiates based on the concept that whenever a resource is free, it searches for a free operation to process. A free operation is identified by scanning the column of "PR" of 3D roadmap process plan roadmap. Any operation with PR equal to zero is a free operation. A free resource is identified by the resource counter is equal to zero. The sequence cycle loop scans all resources and checks the field resource counter.

- If, the resource counter = 0; (i.e. the resource was idle in the last scanning cycle), go to the next case.
- If, the resource counter ≠ 0, the sequence cycle time is deducted from the resource counter. If the result becomes 0 (i.e. the process of the current operation is over). Then, the priority field "PR" of this operation is marked by X. Also, the priorities of all operations with this operation number are changed to 00.

Automatically, the next operation on that item becomes free and gets priority in processing if it is economical to do so. It represents that this resource is the "BEST" for this operation or that its processing cost or processing time minus transfer penalty is equal or less than "BEST" time of that operation. The operation is assigned to that resource and its RSF is updated accordingly. Hence, the resource counter is set to the new working time.

Let us take an example as shown in table 5. It represents the shop floor status at a certain time. Operation 20 of item #7 was just finished, and it was processed on R2, and operation 30 became free. The best resource for this operation is R4 with 7.23 minutes per item. A check is made if it is economical to process this operation on R2 in order to save transfer time. The time to process on R2 is 8.92. The increase in time is (8.92-7.23) i.e. 1.79. If, the penalty to transfer is 25 minutes for 40 units than the time is increased by 71.6 minutes (i.e. 40*1.79). So, the time is saved by 25 minutes only. Thus, it cannot be economical.

Let us take another case in which the operation 20 of item #9 was just finished, it was processed on R3, and thus operation 30 became free. The best resource for this operation is R4 with 11.4 minutes per item. A check is made if it is economical to process this operation on R3 in order to save transfer time. The time to process on the resource R3 is 11.9 minutes. The increase in time is (11.9-11.4) 0.4 minutes. If the penalty to transfer is 25 minutes for 40 units then the time is increased by 16 minutes (i.e. 40*0.4). So, the time is saved by 25 minutes, then it is economical and R3 will process with operation 30.

In case, it is not economical to process the following operation on the preceding resource or the resource was idle from the preceding sequential cycle, then the system searches the matrices of all parts in this specific resource column, and lists all free operations with the best spot on them. This list includes all free operations that the specific resource can do the best.

If the list contains only one entry, then this entry (operation) is allocated to the resource and its RSFs are updated and its resource counter is set to the new operating time. On the other side, If the list comprises more than one entry, then the system assigns the operation with the biggest time gap of achieving it on an alternative resource. This value is revealed by searching the operation row in the applicable roadmap and calculating the processing time difference among the best resource and the processing time on several resources. Each free operation will be labelled by this difference value. The free operation with the top tag value will be the one that will be given on this sequence cycle on the idle resource.

Table 5 demonstrates this algorithm. R4 is the idle resource and there are four free operations for which this resource is the best one. The system searches these operations through the whole resources and calculates the variation among minimum time (BEST) and the time on each resource. The maximum difference value is on the column marked by delta "Δ". In this case, the difference among the BEST resource and the resource processing time of item 5 operation 2 is the biggest (13.9 - 9.95 = 3.95). So, this operation will be assigned to the R4 resource. Its RSF is updated, and its counter is set to the new operating time.

If the list is empty a "look ahead" feature is used to determine the "waiting time" for the best operation to become "free". This hunt is done by examining the idle resource column for a quest of free operation. When such operation is encountered, (it is not the best for that resource) the BEST field of this raw indicates which resource is the best for that operation. The entry in the field resource counter of the resource status file indicates the waiting time of that resource.

6. CONCLUSION

With the advancements in the computational capability, the manufacturing data could be handled more carefully, and which ultimately yield a better decision-making process. Therefore, the IPPS can be achieved and consideration of delivery due date and cost is possible. Based on this assumption, this paper proposed a flexible manufacturing system and describes the tasks of each section. The production-order section is negotiating the realistic cost and delivery due date and release jobs to IPPS and report customer inquiries on production order progress. IPSS is working as a processing system on the integration policy that a free resource searches a free operation. The proposed approach has been described with examples as well as the algorithm has been explained. However, the practical implementation of the proposed system is still pending.

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Biographies

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