How to Plan, Schedule and Sequence for Demand-based Manufacturing

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Abstract
This paper details the process of aligning production and purchasing plans with market demand. It is based on LEAN concepts that minimize all inventories: raw materials (RM), work-in-process (WIP) and finished goods (FG). It will demonstrate the calculation of rate-based material flow from receiving parts, through sub-assembly, and ultimately end item production. An algorithm will provide optimal part sequencing for use with mixed-model production (MMP).

Demand-based Flow Concepts
The development of rate-based production tied into market demand first requires that a company have definitive knowledge of their products' market demand, expressed as units or a percentage of volume mix. This is the starting point from which end item, subassembly and ultimately purchased part requirements are determined. Flow will be facilitated via high yields, short lead times and small lot sizes.

Further, the facility layout should accommodate linear routings or work cells that have minimized handling, movement and staging, all non-value added activities. This should include the receiving and shipping areas, as well as incorporating the external supply chain functions of purchasing/supplier scheduling and shipping/distribution.

Calculation of Flow Rates
The flow rate calculation simply uses algebraic formulas that require the following information: end item demand rate, bill of material (BOM) relationships (i.e. product structure), component quantity/per and yield rates for all manufactured items. Given this information, the rates are calculated via the following formulae.

FG finish (production) rate = FG sales rate
FG start rate = (FG finish rate/yield)
Subassembly finish rate = (FG start rate x qty./per)
Subassembly start rate = (Subassembly finish rate/yield)
Component purchase rate = (Subassembly start rate x qty./per)

Although this assumes a simple three-tiered BOM structure, the logic easily extends to product structures with many levels of subassemblies; always equate a subassembly finish rate to its parent start rate times the quantity per. The enlightened reader will note that these equations are the foundation of material requirements planning (MRP) logic. In fact, as MRP moves toward level loads and smaller time buckets, it approaches a flow environment.

Mixed-model Production (MMP) Sequencing
The discussion has thus far centered on the concept of relating internal material flows to the production of a specific end item. MMP assumes we have a repetitive line, or work cell, producing similar items with negligible changeover, each with their own respective market demand. A common challenge is how to sequence the end production of these various end items to match those demands. The following ratio and algorithm serve to optimize this process.

MMP Priority Sequencing Ratio = (number of parts sequenced/number of parts unsequenced), where the sum of parts sequenced + parts unsequenced = daily demand (or hourly demand, or whatever our demand basis is). This is basically a ratio of work sequenced v. work unsequenced on an *individual item* basis.

The algorithm is as follows:
Step 1. Calculate or update the MMP Ratio for each part number.
Step 2. (a). Select the item with the lowest ratio as the first or next part in the production sequence.
(b). If there are ties, select the part(s) with the higher number of parts unsequenced (greatest amount of work remaining).
(c). If there are still ties, make a random selection among those still under consideration.

Step 3. Repeat from Step 1 until all items are sequenced.

This assumes MMP allows us to switch from one part to the next with negligible setup time. This also assumes the item's production (or processing) time is irrelevant. For example, we could amend the ratio as follows: **MMP Ratio = (number of minutes sequenced/number of minutes unsequenced)**, where the number of minutes sequenced = (number of parts sequenced x minutes/part). This is still the ratio of work sequenced to work unsequenced, just expressed as minutes instead of pieces, and would yield the same result.

Note that repeating Step 1 only requires updating the ratio for those parts that underwent a "sequencing", that is, their respective quantity sequenced and quantity unsequenced have changed.

Let us try this with a simple example of three widgets. Daily production is 5,000 red, 3,000 green and 2,000 blue. We can reduce these numbers to 5, 3 and 2 respectively, to make for easier reading and calculations. Note that a computer program using the algorithm wouldn't care (i.e. a computer thinks 5,000/10,000 is the same as 1/2).

At the start, the number sequenced for each is zero (nothing has been sequenced yet), and the MMP ratios are:
Red MMP ratio = (0/5) = 0
Green MMP ratio = (0/3) = 0
Blue MMP ratio = (0/2) = 0

Our tiebreaker is to select **Red** (most work remaining unsequenced, 5). Now we update the Red MMP ratio = (1/4) = .25. We have sequenced 1 unit, and 4 units remain unsequenced.

We still have a tie between Green and Blue, each with zero, and select **Green** (most work remaining, 3 v. 2). Now update the Green MMP ratio = (1/2) = .5. We have one sequenced, two remain unsequenced.

Next we select **Blue**, which has the lowest ratio, zero. Update Blue's ratio = (1/1) = 1.
Next we select **Red**, which has the lowest ratio, .25. Update Red's ratio = (2/3) = .667.
Next we select **Green**, which has the lowest ratio, .5. Update Green's ratio = (2/1) = 2.
Next we select **Red**, which has the lowest ratio, .667. Update Red's ratio = (3/2) = 1.5.
Next we select **Blue**, which has the lowest ratio, 1. Update Blue's ratio = (2/0), undefined, Blue is done!
Next we select **Red**, which has the lowest ratio, 1.5. Update Red's ratio = (4/1) = 4.
Next we select **Green**, which has the lowest ratio, 2. Update Green's ratio = (3/0), Green's done!
The only item left is a **Red**. Update Red's ratio = (5/0), Red's done!

The sequence is thus **R-G-B-R-G-R-B-R-G-R**. You may actually have several equally optimal solutions. Alternative methods, being intuitive or trial-and-error, may or may not always yield the optimal result, especially when we do not have the "nice, neat" percentages in the above example. Further, an algorithm can be loaded into a software program to allow the computer do the math.

If the question is posed in terms of product mix percentages, you may just use the % as the part quantity (i.e. assumes 100 as the number of slots in the sequence). For the above example this would have meant 50, 30 and 20 for Red, Green and Blue respectively and would yield the same production sequence.

Summary
Demand-based manufacturing must incorporate the LEAN concepts of high yield, short lead time, streamlined layout and producing to market need. Simple mathematical relationships provide the optimal rates for the manufacture of internal assemblies as well as the supply rate of purchased parts. In the case of mixed-model production, the MMP Ratio and accompanying algorithm will optimize the sequence to satisfy market demand.

About the Author
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