Using Technology to Enable the Rapid Growth of Make-to-Order Manufacturing Businesses

Introduction

This white paper is about using technology to overcome the challenges in growing make-to-order businesses that make custom and semi-custom products to customer order. It is the distillation of over a decade of experience in using technology to assist companies whose sales have reached a plateau because of limitations in the management of their production operations.

We have clients who have doubled or even quadrupled their sales and profits within very few years after applying the methods described in this white paper.

In this white paper, we use the example of a manufacturer of wooden dining room chairs as this is easy to understand. This white paper is, however, a compilation of the experiences and lessons-learned by many BellHawk clients who make a wide range of products to customer order and who manage the delivery of complex projects.

This white paper is a companion to the white paper "Real-Time Work-in-Process Tracking Methods for Make-to-Order Industrial Organizations", which is available from www.BellHawk.com under the White Papers tab.

Our Example Problem

When Fred, the owner, started out, he worked alone, working on a single customer job at a time. Everyone loved the design and craftsmanship that went into each of his custom designed and built chairs so soon he had more work than he alone could handle.

So Fred hired some workers to help him make the chairs and founded a company called ChairCo. But he could not find craftsmen who could build whole chairs, so he hired people to make legs, and seats, and backs, and to assemble and stain the chairs. Soon he was so busy managing people that he hired a sales person and a designer and a production manager. And so the business grew.

Soon there were several people in the leg making, seat making, back making, assembly and finishing departments and each needed its own supervisor. Coordination became a major problem as each customer order required special parts and parts went missing or out-of-stock or were simply lost in the confusion of trying to manage orders for 400 sets of custom chairs all in different stages of completion at any one time.

Growth in sales slowed dramatically as order delivery times stretched out and the quality of the product slipped. But costs kept climbing as Fred hired more supervisors and expeditors and materials managers and quality control people to solve these problems.

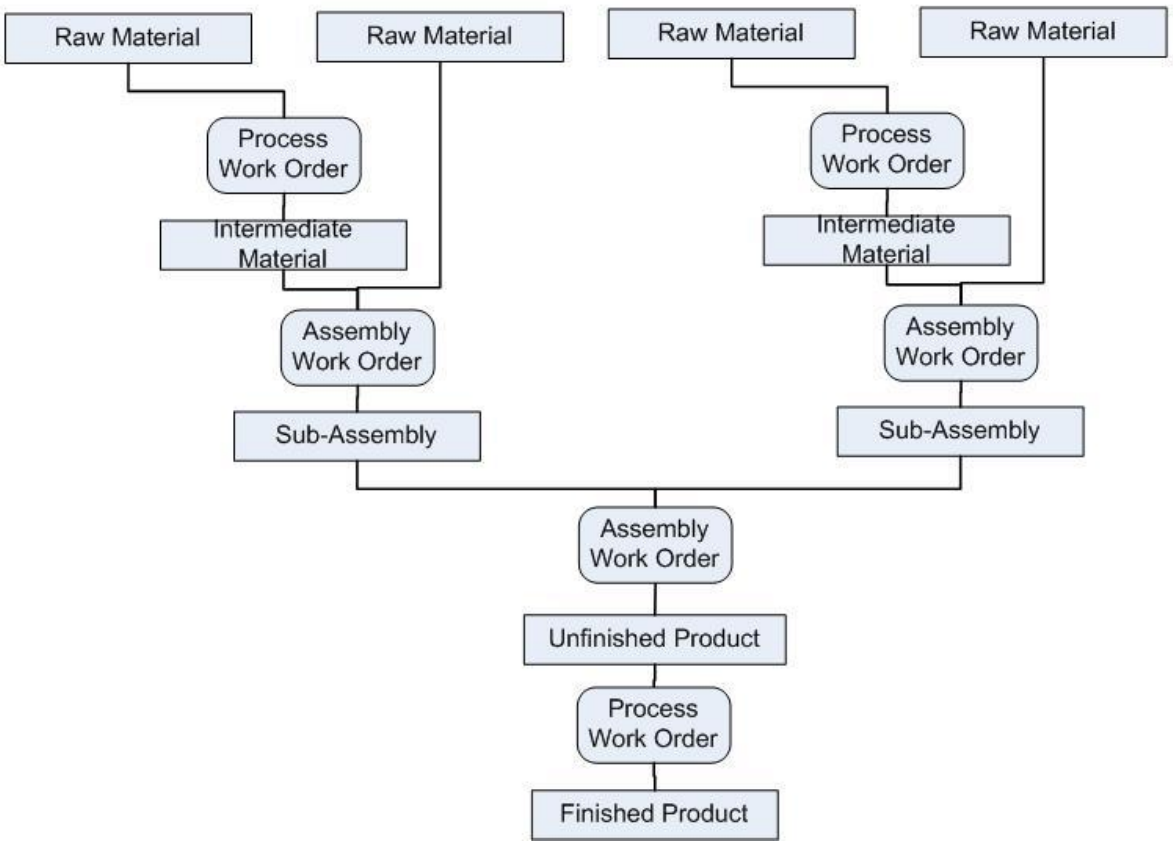
ChairCo had reached a plateau. No matter how hard they worked, sales were stuck at just under $10 Million. He knew that they could sell more. The customers still loved the fact that they could get custom (or at least semi-custom) chairs to meet their specific requirements at an affordable price. ChairCo was now starting to sell through several national furniture store chains. But they could not deliver any more custom products at a profit, the way they were going.

Based on advice from some very expensive management consultants, Fred considered just making standard products. But then ChairCo would become just a me-too commodity furniture manufacturer competing with bigger organizations that made their furniture in countries with lower wages and less regulatory burdens.

Fred knew the future growth for his company lay in producing the custom and semi-custom products that his customers wanted, with quick-turnaround, high quality, and affordable prices. But he also knew that he could not achieve this at a profit by having the overhead of large numbers of people managing the delivery process.

Modeling the Process

In order to manage a make-to-order process, such as that at ChairCo, we first need to model the process. One way of modeling this process is using a Material Flow model, as shown below:



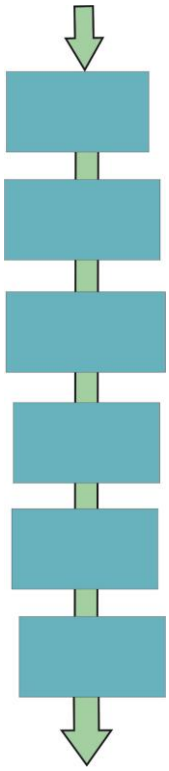
In this model, raw materials flow into the manufacturing process and are converted into intermediate parts; these intermediate parts are then sometimes assembled into sub-assemblies; sub-assemblies and parts are then assembled into products; these products are then finished, packed and shipped to customers.

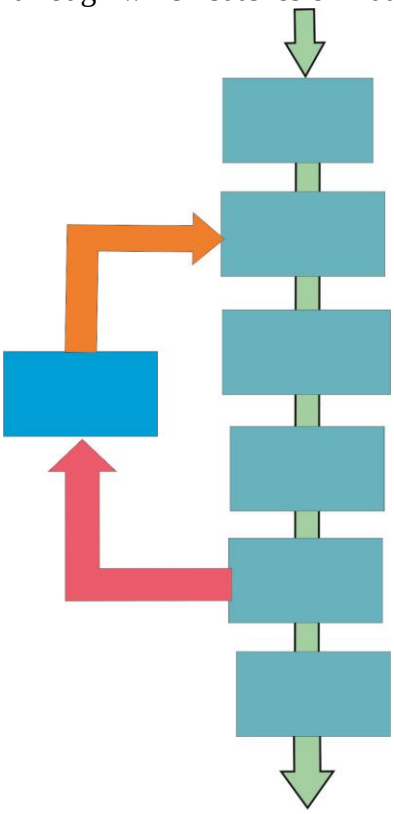
In between the conversion of materials is a work order, which may consist of one or more operations in one or more work centers.

At any one time there may be hundreds of different materials waiting for processing or being processed within hundreds of work orders. Because each customer order is different, this flow changes dynamically with different materials flowing through different operations depending on each specific customer order.

This material flow process looks like a river estuary with raw materials flowing in at the top and streaming into intermediate products which join to become finished product flowing out at the bottom.

Note that this is very different from the classical "ERP" manufacturing model in which the manufacturing process is simply modeled as a fixed route of steps or operations through which batches of material flow, as shown at right.





Each of the work orders within the material flow model may have one or more route steps, with work-in-process materials flowing between the route steps.

In a make-to-order operation though, work orders are much more likely to encompass operations, such as rework operations, which are not on the route, as shown at left and to consume materials at different steps along the work-order route rather than just having a BOM (bill of materials) for the whole work order.

The biggest issue, however, is that just tracking the status of each work orders, independent of its context for the overall customer job or project, is like looking at one leg of an elephant through a magnifying glass and trying to determine the status of the elephant.

For each customer order there may be hundreds of intermediate parts being worked on in multiple work centers based on dozens of work orders active at any one time. Multiply this by a few hundred customer orders and ensuring that each customer order gets shipped on time becomes a very complex problem.

Using Technology to Track Materials and Work Orders

A system such as BellHawk uses barcode technology to track:

- Raw materials being received from suppliers.

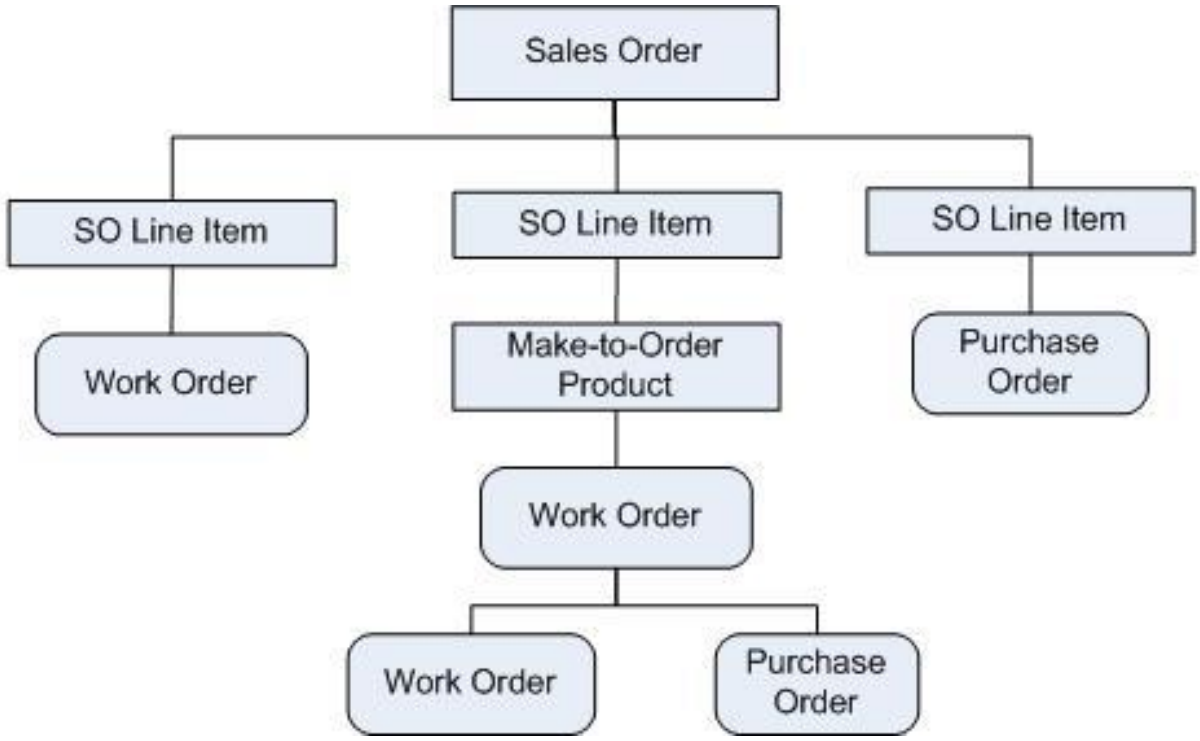
- When an employee starts work and ends work on an operation as part of a work order, this includes recording the elapsed time as well as the labor time consumed.
- Raw, intermediate or work-in-process materials consumed in that operation.
- Work-in-process, intermediate and finished goods produced by an operation.
- Picking, packing and shipping of finished products to customers.

Raw materials are typically tracked as they are put-away in barcoded racks in which they are stacked. Intermediate and work-in-process materials typically tracked in barcoded totes. Assemblies and sub-assemblies tracked with individual barcodes.

This gives users of a system like BellHawk visibility of the real-time status of all the inventory and work-in-process materials, as well as the status of each of the work orders, such as who is working on which operation. But with hundreds of customer orders each involving the manufacture of hundreds of parts, sub-assemblies and assemblies, it becomes very difficult to track the status of each customer order.

Tracking the Status of Make-to-Order Customer Orders

To do this we need to tie our work orders and materials to sales order lines:



A customer order may consist of multiple line items for:

1. Work to be performed on a work order, such as engineering or design services
2. Stock items to be shipped with the order

3. Make-to-Order Products

The make-to-order products will require the issuance of a work order to make, assemble, or otherwise produce the custom item. This may require the issuance of subsidiary work orders to make sub-assemblies or intermediate items or to purchase special raw materials or pre-built sub-assemblies or intermediate parts from suppliers.

If we link all the work orders and purchase orders to the customer sales order line that they are required for, then we can produce a report showing the status of these orders. If we add to that report, the status of all the intermediate, work-in-process and finished products related to that sales order, then we can get a report that shows the real-time status of all the of a customer order.

This then enables us to see the status of each order individually separate from the all the customer orders flowing simultaneously through our production operation.

It is certainly more efficient to be able to look at a computer screen and tell a customer the status of their order rather than sending an expediter to the shop floor to find out the status of all of the parts of their order. But this is not enough to efficiently manage our make-to-order operation.

Materials Management Tools

If we have think back to our example of ChairCo, Fred's production manager can certainly manually create work orders for each of the parts that ChairCo needs to make. But the creation of all these work orders can take a large amount of time. It also brings with it the decision as to what parts to make and how many, as well as whether to make or buy intermediate materials.

As ChairCo has grown, it not only buys raw materials, it also sometimes purchases intermediate materials or subs out the work of making these intermediate materials. Also it has standardized on certain intermediate parts so that these can be used to make multiple different models of chair. But the finished products are still highly custom and are available in a wide variety of sizes, finishes, and with many different options.

Large manufacturing companies, such as Toyota, and their suppliers rely on Materials Requirements Planning (MRP) software. MRP takes the projected demand for all the finished products over the next few months and computes all the purchase orders and work orders to be issued and when, and how much labor and materials will be required, so as to most efficiently produce the planned shipment schedule of finished products.

This does not work for companies like ChairCo which survive and thrive in today's global market because they are able to offer semicustom products with a wide variety of options with very quick turnaround. Their sales order horizon is days not weeks or months. In the case of one client we worked with, they were able to turn around custom orders in less than 48 hours and, in most cases, were able to ship within 24 hours.

So how do we achieve the equivalent of MRP in a quick-turn make-to-order operation? In BellHawk we use two software modules:

1. **Real-Time Available Inventory Prediction (AIP)**. For each raw, intermediate or finished product this tracks :
    a. Physical inventory in stock

b. Plus materials on order from suppliers or due to be made on a work order

c. Minus materials due to be consumed on a work order or shipped to a customer.

2. **Demand Based Materials Requirements Planning (DRP)**. In this, the system starts with each sales order line for a selected customer order and, if there is not enough available inventory, then the system presents the operations manager with a make/buy choice for the additional inventory needed. If the part is to be made then the BOM for the work order is used to present the manager with a list of parts for which there is not enough available inventory. For each part the manager can choose to make or buy all parts that can be manufactured within the plant. This process is repeated until all the needed work orders and purchase orders have been created.

Note that in this process:

- Work orders and purchase orders can be linked to specific customer orders so users are able to see the status of all the work orders and purchase orders and materials related to each customer order.

- We are essentially doing the same action as a fully automated MRP system but we are replacing the fixed rules of an MRP system with decisions made by an operations manager in the middle of a loop.

- We are doing this on a customer order by customer order basis and not attempting to automatically aggregate work orders based on some future sales projection, which is probably wrong anyway. Instead we let the operations manager create new work orders or purchase orders or to add the quantities to be made or ordered to existing orders.

We have found that those make-to-order users of BellHawk who do simpler make-to-order processes, such as converting, mixing, or treating materials typically only use AIP and make their own decisions about what work orders and purchase orders to create. But for those clients, such as our hypothetical ChairCo, with complex assembly requirements, find that using DRP to create the required purchase and work orders can be a great time saver.

Work Center Scheduling

In our AIP and DRPmaterials planning processes, we are not doing any resource limited scheduling of people or machines. To do resource limited scheduling (sometimes called MRP II) typically requires a team of people maintaining an artificial intelligence knowledge base about the availability of people and machines and their capabilities. For a company such as Toyota this requires more people maintaining the knowledge base than work at a company such as ChairCo.

Also, resource limited scheduling requires the ability to have forward-looking visibility of customer demand and the availability of people and labor. In a company such as ChairCo the demand for chairs or even some models of chairs can be recorded over a several month period and used to predict aggregate demand. This can then be used to predict how many employees with which skills may be needed and what machines should be purchased.

But, on a day-to-day basis the demand for specific models of chair may vary widely and with it the skills and equipment required. This is why, in a make-to-order operation, it is important to

cross-train people and to use machinery that is flexible and easy to setup and changeover rather than select specialized equipment with high throughput but limited flexibility.

In a make-to-order operation, we recognize that the critical element in success is making sure that everyone in each work center is working on the most important work order at any one time. This can be achieved by presenting the employees in each work center with the available work orders to be worked on in their work center, in importance order, and allowing them to select which one to work on when they have finished working on their prior work order. In BellHawk this is done through its Work Center Scheduling (WCS) module.

In WCS, we do not force the employee to select a specific work order, as the machine required for the work order operation may be down or the required materials may not be available and we do not want the employees waiting around for the machine to be fixed or the materials to be available. Rather we want the employees to select the highest importance job that they can work on and then go do that operation of that work order.

By default, the importance is set by the wanted date of the overall customer order but may, with operations manager intervention, be set based on the wanted date of the work order or the specific operation within the work order. Also the operations manager can manually adjust the importance based on his or her knowledge of the importance of the order (such as that the customer is a major customer of ChairCo or the customer's President plays golf with Fred). In BellHawk this importance can be automatically adjusted by a rules and algorithm based artificial intelligence process that runs in the background to take into account more complex scheduling factors.

When a work order is released it appears in the scheduling queue for the work center corresponding to the first operation in the work order route. When the operation is being worked on, the work order disappears from the scheduling queue. When the operation is complete, the employee is asked to select the next work center and operation for the work order. By default this will be the next step on the route but may be an "out-of-route" rework operation. The work order then appears in the scheduling queue for the next work center and so forth until the work order is completed and finished or intermediate products produced.

In this way, work orders get queued up at work centers and processed in a reasonably optimal order in such a way that higher priority is given to work orders as they get closer to the delivery date for their customer order. This has a tendency to make sure that all the components of a customer order are completed at about the same time and as close to the wanted date as possible.

But it does not guarantee that each order will be shipped on time. This can only be "guaranteed" by making sure that the production facility has adequate people and machine resources with appropriately flexible capabilities. Even then there is a trade-off between the probability of shipping each order on time and the excess (idle) resources available on average in each work center; but that is the subject for another white paper.

When the best laid plans go wrong

We have seen how, even for relatively small make-to-order operations, we can use technology to track the purchase orders and work orders as well as the related raw, intermediate and finished materials for each sales order.

While being able to generate a report showing the status of each sales order, in all its detail, is useful, these can be complex reports, especially for complicated make-to-order jobs or projects. Multiply this by dozens or even hundreds of customer orders being worked on at the same time and it is very difficult and time consuming to spot when something is going wrong.

Such problems can include:

- Materials needed for an operation on a work order has not arrived in time.
- Floor stock or KanBan inventory has not been replenished on time.
- Materials on order from a supplier have not arrived on time.
- Work orders are being held up in the input queue for a work center for too long.
- Work order operations are taking longer than planned in terms of labor or machine time.
- Work order operations have been started but not completed within a reasonable time.
- Custom finished products have not been completed by the wanted date.
- Products have been completed but not shipped on time.

In BellHawk we can have intelligent agents periodically examine the tracking database for problems such as these and Email alerts to designated people that their intervention is required. These alerts can be sent to mobile devices as well as to manager's desktop computers.

This can help avoid the problem of an operation manager not spotting a problem in time to take corrective action due to the overwhelming amount of information that can be available about the operations in a complex make-to-order operation.

Commentary

Many make-to-order businesses find a market niche and then grow rapidly until they plateau because they do not have the systems in place to enable them to manage a complex make-to-order manufacturing operation. With the use of systems such as BellHawk it is possible to break through this barrier and once again achieve rapid growth.

Author

The author of this white paper is Dr. Peter Green who is the Technical Director for Milramco. He earned a BSEE and a Ph.D. in Computer Science from Leeds University in England. He was a Senior Member of the Research Staff at MIT and a full Professor at WPI. He is also a member of APICS and gives professional development talks about using technology for real-time operations tracking and management.

Dr Green has been implementing operations tracking and monitoring solutions for over two decades. Dr. Green is a domain expert in automated data collection as well as in materials tracking and traceability. His has been responsible for implementing nearly 100 systems for clients including manufacturers, food and pharmaceutical processors, medical and biotechnology laboratories, as well as systems for the US Navy and Air Force and the Centers for Disease Control.

