

# ***Make-To-Order Kanban***

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## ***INTRODUCTION***

Most managers of non-repetitive shops look with envy on the ease of scheduling the repetitive shop with kanbans. The benefits of kanban pull systems in the repetitive shop have been significant and well-documented. Unfortunately, these same benefits have been elusive for the job shop, where departments are functionally organized, where work orders are required, or where many jobs are one-time production. Until now, that is.

SYNCHRONOUS MANAGEMENT has developed and implemented an approach we call MTO KANBAN, which "pulls" orders through the job shop based on both due date demand and the demonstrated ability of the shop to produce. The following describes the development of MTO KANBAN for a product and process Development Operation.

Development Operations (DO), an engineering prototype shop, employs about 300 direct labor personnel on each of two shifts, operating 183 functionally organized machining, fabricating and metal treating work centers. DO is a unionized shop with many labor categories and strict work assignment rules. For example, DO is prohibited from assigning a machine operator to work in another work center that may be temporarily bottlenecked.

The DO shop completes approximately 10,000 work orders per year (200 per week), usually in quantities of one each, with up to 350 operations on a routing. Forecasting is non-existent, and priorities are set via an infinite-reverse scheduling system. Priorities are then communicated via operation due dates and critical ratios, plus a management "priority code" override.

At the beginning of the engagement, about 2300 work orders (11.5 weeks' worth, and increasing) were in work-in-process (WIP), with another 1800 orders (9 weeks' worth) awaiting release. The 2300 orders in WIP represented over seven times the number of jobs which could be worked on at any point in time (2300 orders/300 operators). The average value-added or work/wait ratio (actual hands-on time vs. total lead time through the shop) was about 8%, and declining. On about 900 (40%) of the orders in the shop, the operation due dates and critical ratios were being overridden by the management priority code. In addition, shop management was spending up to three hours per day in expedite and shortage meetings.

The goals were to reduce the shop lead time to six weeks and to improve the work/wait ratio to 15%. The challenge was to provide a mechanism for reducing the multiple of orders to operators to a minimum, while still fully utilizing DO's critical resources. The results would be a reduction in shop lead times, and an increase in the work/wait ratio. With fewer orders in WIP, orders could be matched more closely to actual needs, improving the effectiveness of the existing shop load and priority scheduling systems.

The approach decided upon was a "pull" system which would throttle the release of work to the shop based on release date priorities *and* the actual completion of work. Since the non-repetitive nature of the shop precluded using a standard kanban approach based on the repetitive consumption of inventory, we focused instead on the consumption of critical capacity. All of the analysis on the project was done with MSEXcel and with DO's existing infinite reverse scheduling system.

## IDENTIFYING CRITICAL RESOURCES

The first step in developing the system was to identify the critical resources, or "control valves", to improved flow in the shop. These were identified through a simple capacity analysis. **CAPACITY ANALYSIS** shows the load to capacity ratios of key work centers over the scheduling horizon. Note the loads in weeks' worth of work due in the next four weeks and the next twelve weeks. These indicate both temporary and shifting bottlenecks.

AREA	MAN POWER	% OF TOTAL MANPOWER	TOTAL LOAD (WEEKS)	4-WEEK LOAD (WEEKS)	12-WEEK LOAD (WEEKS)
SHEET METAL	127	24.2	18.8	6.0	9.7
VTL	82	15.6	11.6	3.3	6.2
JIG BORE	55	10.5	15.5	7.9	13.8
TOOL&DIE	54	10.3	1.3	1.9	2.0
MILL	46	8.8	12.8	11.3	17.3
GRIND	26	5.0	5.0	6.3	13.8
EDM	18	3.4	1.6	3.1	5.6
PLASMA	18	3.4	7.1	21.1	32.1
WELD	18	3.4	4.0	3.3	12.8

**CAPACITY ANALYSIS**

The criteria used to identify critical resources were:

- Capacity bottlenecks: Although no permanent bottlenecks were found, temporary bottlenecks are common because of shifts in product mix. **CAPACITY ANALYSIS** indicates that Jig Bores, Milling, Grinding, and Plasma Spray are the current bottlenecks and that VTL, Grind, and Weld will become bottlenecks.
- Points of convergence, where many parts come together: Heat Treat, Outside Processing and Sheet Metal were identified in this group (see **CAPACITY ANALYSIS** and **MOVE PATTERNS**).
- Stand-alone areas, where parts are produced in their entirety in a single department. The only self-contained area was the Tool & Die Department.

## RANKING THE VALUE STREAMS

Once the critical areas were identified, all open work orders were categorized based on each area's level of constraint. These generic flow patterns were derived from a detailed analysis of the 4000 open order routings, and the work centers through which each order would flow. Since an order could flow through more than one critical area, a hierarchy was established among the constraints; an order would be classified based on the most critical area through which it flowed. **RESOURCE HIERARCHY** reflects the hierarchy established, based on a ranking of relative constraints and the direction of material flow.

Since the number of critical resources is minimal in even such a complex, functional shop such as DO, all 4,000 open work orders could be grouped into only seven categories: Tool & Die, Milling, Jig Bore, Grinding, Plasma Spray, Sheet Metal, and Miscellaneous. Note that not all of the critical areas in **RESOURCE HIERARCHY** define order categories. Some areas, such as Heat Treat, Outside Processing, and Inspection could at times become short-term downstream bottlenecks, and were defined to help control flow on the shop floor.

So, any order that passes through Tool & Die is classified as Rank 1. Any order that passes through Milling is classified as Rank 2, unless it also passes through Tool & Die, and so on down the list.

RANK	CATEGORY
1	Tool & Die
2	Milling
3	Grinding
4	Jig Bore
5	Plasma Spray
6	Sheet Metal
7	Heat Treat
8	Outside Processing
9	Excess Capacity Areas
10	In-Process Inspection
11	Final Inspection

**RESOURCE HIERARCHY**

These order categories were the key to providing a definition of "value streams" sufficient to support a mechanism for pulling work into the shop - based on the *consumption of critical resource capacity*. That is, work in a category would be released into WIP based on the completion of work in that category.

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## REDUCING WORK IN PROCESS

After all open orders were categorized, a required throughput level for each category was set. The current open production orders in each category were grouped into weekly buckets by promised completion date, and the resulting order profiles were smoothed out over the scheduling horizon to provide the average number of orders per week which had to be completed from each category (see **OPEN ORDERS DUE BY WEEK**).

CATEGORY	WEEK DUE												TOTAL	5-WK AVG	
	PAST DUE	1	2	2	4	5	6	7	8	9	10	11			12
TOOL & DIE	41	7	9	6	3		3	2	2					73	13
MILLING	133	16	20	11	6		6		22	1	1			216	37
GRINDING	140	11	14	5	8									178	36
JIG BORE	115	22	11	7	3		6	6		3	1			174	32
PLASMA	71	7	3	2	2		3	1	1					90	17
SHEET METAL	186	77	36	36	18		10	1	6	1	1		6	378	71
MISC.	113	23	15	7	7		1	1		1	1			169	33
<b>TOTAL</b>	<b>799</b>	<b>163</b>	<b>108</b>	<b>74</b>	<b>47</b>		<b>29</b>	<b>11</b>	<b>31</b>	<b>6</b>	<b>4</b>		<b>6</b>	<b>1278</b>	<b>238</b>

OPEN ORDERS DUE BY WEEK

Based on these required throughput levels, management set initial *target WIP levels* of 3 to 8 weeks of orders for each category, calculated as follows. Tool & Die orders, for example, average about 123 man-hours of hands-on time per order. A work/wait ratio of 15% would mean that a Tool & Die order would spend about 820 total hours in the shop (123/.15), or about 10 weeks (820/80 working hours per week). At a throughput level of 10 orders per week (**OPEN ORDERS DUE BY WEEK**), the *theoretical* target WIP level for Tool & Die orders was about 100 orders. Similar calculations were also made for the other categories. Of course, the minimum practicable WIP level for all categories would be about 300 orders total, or one for each operator on a shift.

Work in process was then decreased to the target levels, category by category, through a combination of activities:

- Canceling orders which were no longer required. A little research revealed that a number of orders had been in the shop for months, or even years, and were no longer required.
- Temporarily increasing capacity in bottlenecked work areas. This was particularly effective in downstream temporary bottlenecks, such as Heat Treat or Final Inspection.
- Physically removing lower priority orders from the shop floor. This "de-releasing" of low-priority orders was particularly important for demonstrating management's commitment to the approach, while improving visibility of actual requirements.
- Restricting order release to fewer orders than were completed. Once the initial cleanup of WIP was accomplished, this enabled management to continue to approach the target levels gradually, without additional disruption to the floor.

It should be noted that the initial target WIP levels for each category were determined *theoretically*. The actual minimum levels were determined *empirically* by reducing the WIP in each category until idle time was forced in the critical area. Then WIP was then raised just to the level which was required to keep the critical resources fully utilized.

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## CONTROLLING ORDER FLOW

The final step in the development of the MTO KANBAN system was to provide mechanisms for controlling the release of orders to WIP and the flow of orders through the shop. The key flow control mechanism, and the heart of the MTO KANBAN system, is the **OPEN ORDERS PROFILE**. This report, which is generated weekly, shows the number of orders in each category which are currently unreleased and the number backlogged at each critical area, as well as the total WIP for each category relative to its target.

CATEGORY	UNREL	TOOL & DIE	MILL	GRIND	JIG BORE	PLAS	SHEET METAL	HEAT TREAT	OUTSIDE PROC	MISC	INPROC INSP	FINAL INSP	TOTAL WIP	TARGET WIP
TOOL & DIE	14	35	2	5	2	0	2	0	4	21	0	17	88	100
MILLING	171		63	1	19	0	17	3	50	65	18	5	241	240
GRINDING	23			14	4	2	5	0	13	15	13	11	77	80
JIG BORE	192				29	1	29	3	26	42	29	8	167	170
PLASMA	416					77	21	3	40	11	24	1	177	80
SHEET METAL	377						193	7	27	74	50	14	365	225
MISC.	150							4	50	89	16	8	167	200
TOTAL	1343	35	65	20	54	80	267	20	210	317	150	64	1282	1095
MANPOWER		27	23	13	30	9	75	6		115	10	8	316	

OPEN ORDERS PROFILE

The MTO KANBAN system is administered via a weekly one-hour "strategy meeting" involving personnel from Material Planning, Area Expediting, Shop Supervision, and Shop Scheduling. Using the Open Orders Profile, shop resources are allocated, overtime is scheduled, and orders are off-loaded based on the relative load/capacity relationships among order categories and key work areas. If a temporary bottleneck is developing, it can be quickly identified and resolved. Thus, orders are kept flowing by the timely resolution of such problems as engineering holdups, material shortages, lack of capacity, and lack of operator flexibility. Of course, the number of orders authorized for release each week is merely the difference between the Total WIP and Target WIP in each category on the Open Orders Profile.

Note that what makes a work area a temporary bottleneck is not just that it is overloaded; the key issue is whether or not it is holding up the completion of orders, and thus impeding the release of orders to critical resources. Management was committed to a policy of not releasing work in an order category just to keep people busy - that is, unless an order is completed from that category. Completion of work through only the critical work centers does not trigger release, since an order may be delayed at a temporary bottleneck further downstream. If, for any reason, orders must be released in violation of the target WIP levels, the shop "de-releases" and physically removes from WIP a corresponding number of the lowest priority orders in that category.

Supporting the **OPEN ORDER PROFILE** is a listing of *unreleased orders*, by category, in scheduled release date sequence (see **UNRELEASED ORDERS**). As WIP levels drop below target, new orders are released in the sequence listed. If more orders are scheduled for release than are authorized, they are offloaded, or lower priority orders are "de-released". If fewer orders are scheduled for release than are authorized, personnel at critical resources are redeployed to other areas. Orders are not released prior to their scheduled release dates unless shop load reports indicate overload in future periods.

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WORK ORDER	PART NUMBER	DESCRIPTION	CATEGORY	RELEASE DATE
20030	59430	DUCT	GRIND	10/22
28760	58680	DIFFUSER	GRIND	10/23
21090	58798	LINER	JIG BORE	10/1
21070	51843	LINER	JIG BORE	10/8
21080	54358	LINER	JIG BORE	10/12
25550	59911	CASE	JIG BORE	10/17
21440	59076	CASE	JIG BORE	10/18
22050	52837	CASE	JIG BORE	10/18
27110	59294	DIFFUSER	MILL	10/15
27120	53584	DIFFUSER	MILL	10/15
27330	52564	DIFFUSER	MILL	10/16
29990	58852	DIFFUSER	MILL	10/18
20580	53911	CLOSURE	SHEET METAL	10/7
21320	56452	SEGMENT	SHEET METAL	10/9
21160	55475	SEGMENT	SHEET METAL	10/13

UNRELEASED ORDERS

Lists are also generated each week showing, by order category, the *released orders* currently in backlog at each of the major work areas (see **OPEN TOOL & DIE ORDERS BY LOCATION**). These lists are used, along with the scheduling dispatch lists, to make off-loading, overtime, and "derelease" decisions.

WORK ORDER	PART NUMBER	DESCRIPTION	CURRENT LOCATION	DUE DATE	TOTAL BY LOC
21160	56122	SEGMENT	MILLING	10/13/89	
25550	57114	CASE	MILLING	10/17/89	2
21070	53620	LINER	GRIND	10/8/89	
21320	50575	SEGMENT	GRIND	10/9/89	
21080	57259	LINER	GRIND	10/12/89	
27330	55206	DIFFUSER	GRIND	10/16/89	
26500	56967	CASE	GRIND	12/23/89	5
27110	53315	DIFFUSER	JIG BORE	10/15/89	
22050	53914	CASE	JIG BORE	10/18/89	2
20580	58262	CLOSURE	SHEET METAL	10/7/89	
27120	56684	DIFFUSER	SHEET METAL	10/15/89	2

OPEN TOOL & DIE ORDERS BY LOCATION

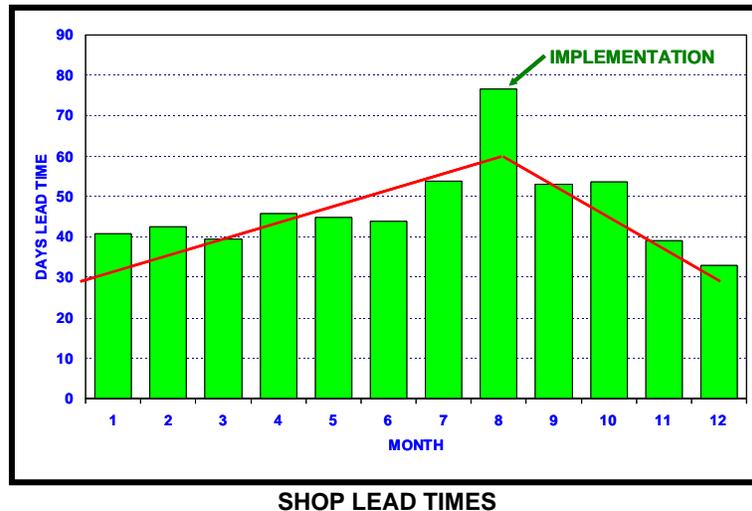
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## CONCLUSIONS

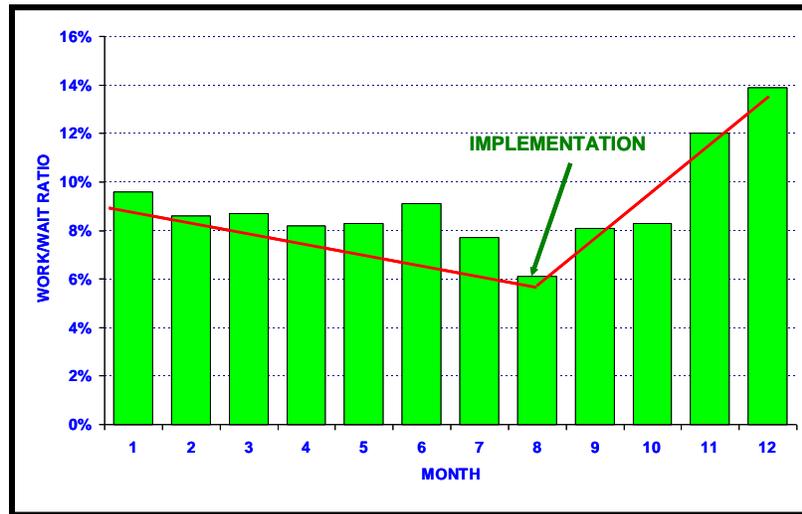
The MTO KANBAN system supplements, rather than replaces, the existing shop scheduling system. As the number of orders on the floor is reduced, new orders can be released much closer to actual requirements. Since orders are released only if they are needed, and only if they can be worked to completion, the priorities set by the scheduling system for individual work centers are now seldom overridden. In addition, existing shop load reports are now better able to provide visibility for controlling backlogs at individual work centers.



Because the approach was vigorously supported by upper level management through changes in policy, and because the users were involved in its design and implementation, the result has been a significant improvement in control over work in process. Within five months, shop lead times were down from 11.5 weeks to about 5 weeks, a 55% reduction (see **SHOP LEAD TIMES**). That is, the number of open orders in the shop was down to about 1000, and critical resources were still being fully utilized. At the same time, the overall work/wait ratio in the shop increased to over 15% (see **WORK TO WAIT RATIOS**), and the number of orders overridden with special priority codes dropped from 40% of all open orders to less than 2% (and some weeks zero). Finally, because shop labor was going into throughput rather than inventory, the shop was completing over 200 orders per week, with about 10% more labor content per order. Plant management considered the MTO KANBAN system an unqualified success.

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WORK TO WAIT RATIOS

Of course, the MTO KANBAN approach has also been successfully implemented in a number of shops which are far less complicated than Development Operations, and with similar results. MTO KANBAN is being used for the control of low-volume "specials" in conjunction with repetitive kanbans for high-volume work. It is also applied to finish-to-order products, where the demand for common component parts is repetitive enough for the conventional kanban approach. It is now clear that every manufacturing business, whether repetitive or make-to-order, or anywhere in-between, can now benefit from the control of work flow through the application of pull signals methodologies.

## EPILOGUE

DO recognized that a 5 week lead time and 15% work/wait ratio were only the beginning. The next step was to improve operator flexibility. This would allow them to reassign operators to open up temporary bottlenecks. During the next round of labor negotiations, they were able to reduce the number of labor categories and to improve operator work assignment flexibility. The result was another 25% reduction in lead time and improvement in the work/wait ratio.