VORTEX™

A Historical Perspective of Demand-Pull Production

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Contents

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EXECUTIVE SUMMARY

The Japanese automobile company, Toyota, introduced products produced with the Toyota Production System (TPS) in 1958 and slowly set fire to the US auto industry. Over the next 40-years, the TPS was a key component in enabling Toyota to overtake GM as the #1 selling car brand in the US, even though the US automakers did their best to emulate it.

In the 1970's, as chronicled in the classic book by MIT authors James P. Womack, Daniel T. Jones, and Daniel Roos, **The Machine that Changed the World**, Toyota was producing cars with 50% less labor, 40% less factory space, 66% fewer defects, and an astounding 99% less inventory. This book brought the term Lean Manufacturing into the industry lexicon. One of the primary elements of TPS that allowed Toyota to be so efficient is demand-pull production dispatching, or the Kanban system in their idiom. This system was designed for repetitive, and linear, manufacturing and not well suited to other production models.

In the 1990's, Dr. Rajan Suri recognized the weakness of the Kanban system in addressing demand-pull for non-repetitive manufacturers and developed a system called POLCA (Paired-cell Overlapping Loops of Cards with Authorization). This system has gained traction in the high-variety and customized products industry and those efforts continue to today.

Fast-forward another 30-years and more than 50% of US and EU manufacturers have high-variety, non-repetitive, and complex workflow production models. Most of these companies have been unable to implement a demand-pull production dispatching system due the complexity of their manufacturing environments. This report further details the need for a better solution and why the Digital Transformation is changing the landscape and making the previously impossible, possible.

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Demand-Pull for Repetitive Manufacturing

The importance of continuous flow manufacturing was the foundation of the revolution in manufacturing brought forth by Toyota's industrial engineering giants Taiichi Ohno and Shigeo Shingo. They viewed any time that a production piece was not being worked on as non-value-added waste and devised a production dispatching system designed to minimize all wasted time.

MRP vendors' response to this problem is to further complicate the system by using finite capacity scheduling whereby the productive capacity of all operations must be constantly updated so that the system can take into account downstream capacity when making upstream dispatching decisions. However, this is found to be extremely labor-intensive on the planning operations and systems are rarely well-maintained.

The TPS Kanban system avoids this complexity and utilizes a simple method whereby the downstream operations authorize production in the upstream operations by the use of an authorization (Kanban) card. When the downstream operation needs more material, it sends a card to the upstream operation authorizing it to produce more parts. No authorization card, no production, and thus minimizing queues to the level dictated by the number of cards on the shop floor. Simple, and brilliant!

> *"All we are doing is looking at the time line, from the moment the customer gives us an order to the point when we collect the cash. And we are reducing the time line by reducing the non-value adding wastes." … Taiichi Ohno, Toyota Motor Company*

One of the primary causes of wasted time in the traditional MRP approach to dispatching work is that the work is "pushed" through the factory based only on a production schedule and the productive capacity of the work center in which it resides. The production volume is not synchronized to the productive capacity of downstream work centers, so material tends to be pushed into queues. Then the material in the queues must be dispatched based on ever-changing priorities, which tend to make some work wait even longer as other work leap-frogs it.

Then by reducing batch sizes and setup times, Toyota was able to squeeze an enormous

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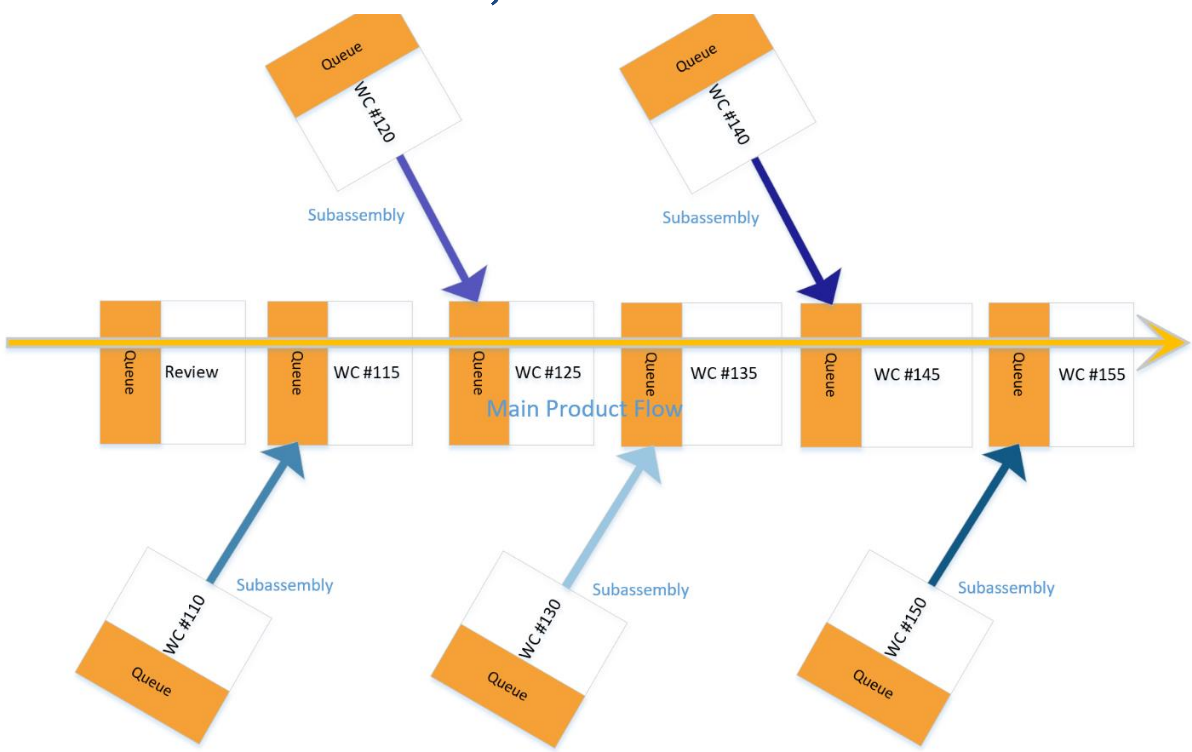
amount of waste (parts that were not being work on) out of their production operations. This accelerates the production process and reduces the cycle-time through the factory, which in turn improves quality. When a downstream operation finds a quality problem, it immediately slows down the entire factory because the cards stop flowing until the quality problem is resolved. Thus, fewer parts are produced with the same quality problem.

This system was revolutionary and embraced world-wide by the automotive industry and other industries with similar production models, namely ***repetitive manufacturing***, for which the Kanban system was designed. In the repetitive manufacturing model, as shown in *Figure 1*, a single product is produced, e.g. the Toyota Landcruiser, with a single serial work flow that is fed by tributary work centers and/or suppliers. Each of the work centers in the main product flow has Kanban loops to its upstream suppliers and the inventory in each loop is controlled by Kanban cards. The Kanban cards indicate exactly which part number, and the quantity thereof, that it authorizes the upstream work center to produce. In this way production is pulled through the factory and each work center's output is synchronized to the demand of its downstream work center by the Kanban demand-pull system.

Life is Lean for the repetitive manufacturer!

Figure 1- Single Product, Single Workflow – Repetitive Model



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The Rise of Non-Repetitive and Re-entrant Manufacturing

Over the past 50-years, much of the repetitive manufacturing operations have migrated to low-cost labor regions, such as China, Southeast Asia, Mexico, and South America. At the same time, North American and European (NA/EU) manufacturers have diversified their production operations and converted plants to produce many different products within the same facility. Many manufacturing plants produce products that are engineered-to-order, truly unique, one-of-a-kind, products designed and produced for a specific application or installation. We see this often in the Defense and Aerospace industries, but also in the heavy industries that support chemical and petrochemical production. We have broken these production models into three categories:

1. High-Mix, Single Workflow;
2. High-Mix, Multi-workflow; and
3. Re-entrant Workflow.

We call these, collectively, complex-workflow production environments and describe them in further detail here.

High-Mix, Single Workflow

This model, *Figure 2*, is characterized by production of many different products, typically in varying volumes, through a single, or similar, workflow. Because the mix of products can vary in part types and volumes, the Kanban method would require sets of cards for each product and each work center. Instead of one Kanban card set for each work center, we will need many card-sets for each work center. And the quantity of parts that each card authorizes must be synchronized to the production schedule for each part, conceivably having to be re-synchronized on a frequent basis as demand changes.

The efficiency of the Kanban system is considerably diminished in this factory environment as the overhead costs associated with production control increase dramatically with the variety of products being produced. Where in the repetitive example we have k number of Kanban card-sets, now we must have n x k, where n is the number of products being produced. Most factories find it more efficient to live with the high inventories dictated by MRP scheduling in this more complex scenario.

Figure 2 – High-Mix, Single Workflow Model

Products A, B, and E may be produced on a regular basis, whereas products C & D may be one-offs or engineered to order. But all use the same Workflow, or sequence of operations and Work Centers.

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High-Mix, Multi-Workflow

In the High-mix, Multi-workflow category, as described in *Figure 3* below, many different products are produced that do not follow the same path through production. Each work center may now have multiple upstream work centers depending on the parts being produced at any moment in time. Now using the Kanban method becomes even more complex since, instead of having only one upstream work center, each work center may have many.

In this scenario, not only has the number of Kanban card-sets multiplied, but also the distribution of those card-sets has multiplied. With production volumes varying between the various workflows and products, the management of Kanban cards becomes extremely complex.

Further, some of the products, and their associated workflows may be engineered-to-order, in other words a Kanban card-set would be used once and never again. So the overhead associated with the production planning process has no benefit of volume scale, becoming prohibitively expensive.

In the 1990’s Dr. Rajan Suri developed a system called POLCA that is an effective demand-pull solution for this production model. This system does not pull production by part-type and quantity, but rather by capacity units and this is one solution for the high-mix, multi-workflow production environment. But this system still relies on an MRP-based shop floor control system to perform dispatching and does not lend itself well to an algorithm-based software solution.

Clearly, another solution would be desirable.

FIGURE 3 - HIGH MIX, MULTI-WORKFLOW MODEL

	WORK CENTERS					
WORKFLOW	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
#1	REVIEW	WC #115	WC #125	WC #135	WC #145	WC #155
#2	REVIEW	WC #115	WC #125	WC #130	WC #140	WC #155
#3	REVIEW	WC #115	WC #150	WC #130	WC #140	WC #155
#4	REVIEW	WC #115	WC #150	WC #130	WC #145	WC #155

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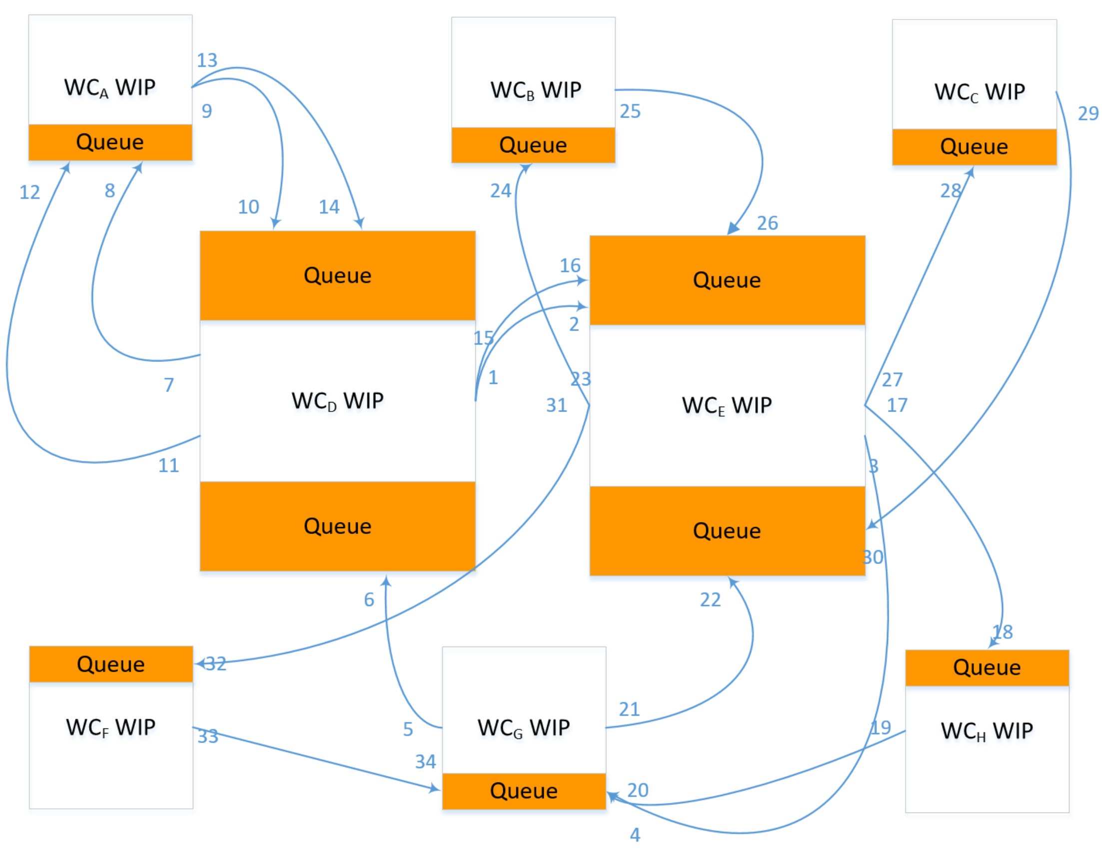
Re-entrant Production Workflows

Finally, we have the re-entrant workflow model of Figure 4 whereby the production material will flow through some of its work centers multiple times. We see this type of workflow commonly in the semiconductor fabrication industry as well as the custom machining industry. Here the Kanban system is utterly hopeless to control the flow of material. Likewise, POLCA, with its manual nature and MRP-based dispatching reliance, is not a cost-effective method in this case.

The part-number/quantity paradigm dictated by the TPS Kanban method and the capacity unit based POLCA method were not designed for this type of production environment and, as a result, companies in industries that employ this production model have no access to the improved operational results that are enabled by a demand-pull system. Efforts have been made over the years to develop a demand-pull system that would work in these environments, but none of them have been particularly successful. In particular, the added complexity of the capital-intensity of these industries have always moved the dispatching focus to favor equipment utilization over queue minimization.

Figure 4 - Re-entrant Workflow Model



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Conclusion

Although the TPS Kanban technology unleashed dramatic operational improvements in the repetitive production environments for which it was designed, there are various examples of non-repetitive, or complex-workflow environments for which it is ineffective. Producers with these complex assembly and fabrication production processes have had no access to the improvements available through the Kanban technology.

Recent research and development conducted by Equation1, however, has produced an innovative, and patented, approach to the production dispatching problems presented by re-entrant production workflows as well as the multi-workflow and high-mix examples discuss previously. In fact, Equation1 has developed a method that is completely workflow agnostic and will discuss the details of this method in future white papers.

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