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Parallel pull flow: A new lean production design

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Case studies of lean manufacturing in furniture and supplying industries

Applications for increased international competitiveness

Parallel Pull Flow:

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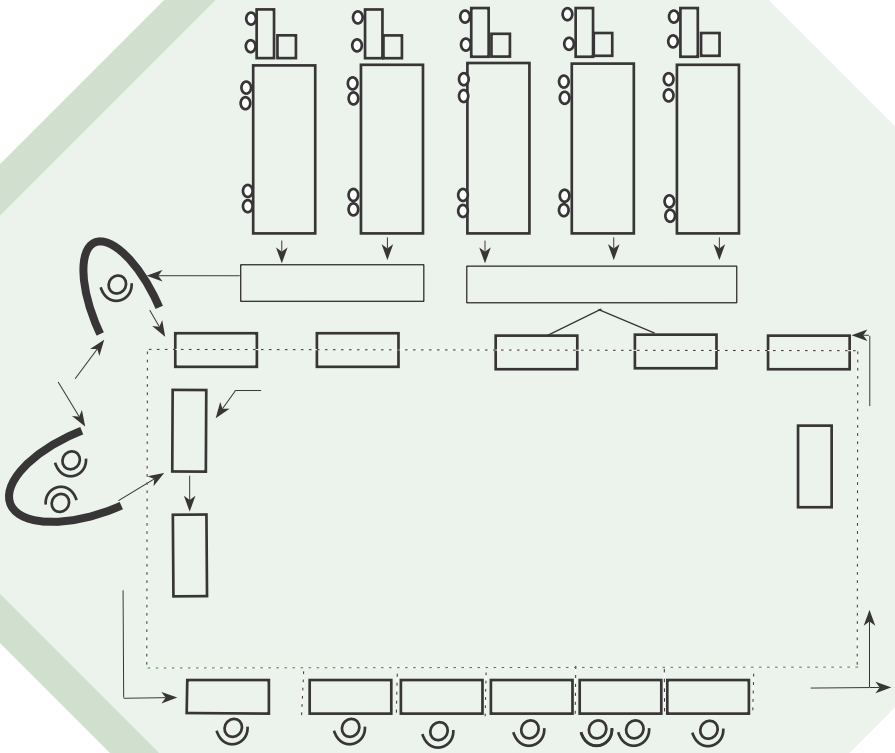

By

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#2 Case Study

Research Bulletin

Forest and Wildlife Research Center

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Parallel Pull Flow: A New Lean Production Design

Case Study #2

Case Studies of Lean Manufacturing in Furniture and Supplying Industries: Applications for Increased International Competitiveness

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Table of Contents

Introduction.....1

Overview of Lean Manufacturing.....2

Push vs. Pull 3

Flow Lines

- Parallel Pull Flow Concept.....4
- Potential Problems.....6

Parallel Flow at XYZ 7

Parallel Pull Flow at XYZ 8

Results.....9

Ergonomics.....10

Summary.....10

Glossary.....11

References.....12

#1 Case Study

Parallel Pull Flow:
A New Lean Production Design

Introduction

This case study is #2 in a series of studies that relate specifically to the development and application of lean manufacturing techniques for the furniture and wood component supplying industries. Case study #2 is an example of how productivity can be increased in a furniture manufacturing organization by using a new lean production design termed Parallel Pull Flow (PPF).

This case study provides information about lean manufacturing and how a lean manufacturing system can be implemented, followed by a detailed case study of a furniture manufacturing company's adoption of a new final assembly PPF lean production system.

Other case studies in this series will be available as separate reports. (For availability see the publication link at the Institute of Furniture Manufacturing and Management web site: www.ifmm.msstate.edu). Information helpful in understanding lean manufacturing systems can also be found in the resources listed in the next section of this report.

Overview of Lean Manufacturing

Lean manufacturing, also termed lean production (LP) systems, involve manufacturing and assembly cells, "pull system" methodologies, and other techniques to create the most effective and productive manufacturing system possible for any given product. LP differs greatly from the older batch and queue and job shop manufacturing system designs and offers previously unattainable benefits. A detailed description of the differences between LP and batch and job shop manufacturing can be found in the first paper of this series (FWRC Research Bulletin FP300).

The benefits of LP are great, while in most cases the monetary costs are relatively low. Conversion to a LP system is not a simple task, however; conversion requires a strong, continuing commitment from high-level management within the firm.

Even though LP offers a variety of benefits to manufacturers committed to its use, it has yet to be widely adopted in US furniture production facilities. As is shown, the results of this case study and the others in this series demonstrate that LP processes offer great potential for increasing productivity and product quality in this important industry.

LP processes represent a significant means of achieving and sustaining competitive advantages in a manufacturing environment facing strong pressures from global competitors. Competitive pressures in the furniture industry today are particularly rigorous from countries with relatively low wages and, in some cases, relatively low requirements for worker safety, environmental protection, and other regulatory issues that directly impact production costs (Bullard and West, 2002).

LP techniques help manufacturers produce high-quality products, on time, with great flexibility, and with a high rate of productivity. Clearly, these methods help producers capitalize on "home court" advantages, and these advantages are higher order competitive advantages in that they are difficult to replicate quickly.

Given the attractiveness of the benefits of LP, its low cost, and the ease of conversion to this system, furniture manufacturing firms should consider its adoption. Exploring documented change and benefits at XYZ furniture corporation will provide those firms considering such a change important information on implementation in the furniture manufacturing industry.

Compared to previous manufacturing systems, lean manufacturing generally:

- requires less labor and floor space;
- requires fewer design hours for product development;
- requires less stock on hand;
- results in fewer defects;
- increases quality;
- enables faster delivery;
- results in improved ergonomics; and
- results in maximum flexibility in product types and styles produced.

Push vs. Pull

When utilizing lean systems, each step in the manufacturing sequence is triggered by a requirement for more material at the next downstream stage. In this respect, LP cells utilize a "pull" system for production where production only takes place in response to a requirement for more material at the next step (Hunter 1991). In contrast, traditional manufacturing systems, such as the functional job shop, are "push" production control systems in which operations are triggered by material and labor availability rather than by customer demand.

The "pull" system is functionally different when compared to the "push" system. The push system typically builds to a predetermined schedule which may have little direct concern when materials, processes, and labor are available. When these critical three factors are present, product is manufactured. This system has little regard for what the manufacturing system actually needs at any given time. This type of activity often results in components that are produced but not needed (Monden 1983).

On the other hand, the pull system is driven by system needs at any particular time. This approach does not allow unneeded product to be manufactured, thus accurately controlling inventory levels. Also, in the pull system, products and components are manufactured just-in-time; that is, as system needs arise, the pull system has already signaled for and met the requirement. The pull system periodically sends signals upstream in the manufacturing facility when products or components are needed for downstream production. The requirement signal is automatically sent by the simple act of withdrawing either components or finished product.

Some further resources outside of this series regarding lean manufacturing processes:

Black, JT., and S.L. Hunter. 2003. Lean Manufacturing Systems and Cell Design. Society of Manufacturing Engineers, Dearborn, MI, 336p.

MacInnes, R.L. 2002. The Lean Enterprise Memory Jogger. GOAL/QPC, Salem, NH, 166p.

Ohno, T. 1978. Toyota Production System. Productivity Press. Cambridge, MA, 143p.

Schonberger, R.J. 1982. Japanese Manufacturing Techniques. The Free Press, New York, NY, 260p.

Sekine, K. 1992. One-piece Flow. Productivity Press. Cambridge, MA, 286p.

Womack, J.P., D.T. Jones, and D. Roos. 1991. The Machine That Changed the World. First Harper Perennial Publishers, New York, NY, 336p.

Flow Lines

Parallel Pull Flow Concept

The overall lean production PPF shop concept (see **Figure 3**), consists of a return-loop system, of rectangular or oval configuration. The products to be assembled on this system are confined to assemblies that all have components contained in the mobile assembly vehicle such as a wheeled cart or something similar. Wheeled transport apparatus are necessary because LP methodology is based on workers walking with the moving transport while they perform the assembly task.

It is envisioned that one side of the parallel pull loop is utilized for kitting and staging carts while the other side is for assembly (see **Figure 3**). Ideally, in the PPF concept, truckloads of components would be delivered directly from the vendor to bays along one wall where the kitting area is located. An empty assembly cart starts the kitting process via a computer-generated pick list for a given assembly. Components taken from the adjacent trailers and in-house stores, according to the next assembly pick list, would be placed on the assembly cart. The trailers would provide components at point of use and components would be consumed without inspection since the vendors supplying components would be pre-certified. Therefore, there is no need for quality or quantity inspection at the receiving point.

Some components used on the PPF final assembly line may be produced in manufacturing cells or subassembly PPF lines. These upstream areas may be co-located close to the PPF line or connected by a Kanban inventory and production control subsystem. Lean production systems often have remote manufacturing cells connected by the Kanban production and inventory control subsystem. These in-house-produced components are placed on the assembly cart along with vendor-supplied parts. Once the assembly cart is kitted, it is then rolled into the final assembly start position; thus, beginning the assembly process.

The PPF system developed for XYZ corporation is comprised of a return loop of rectangular or oval configuration as shown in **Figure 3**. Components are placed on the assembly cart in accordance with the pick list and it is rolled into the final assembly staging area to begin the assembly process.

The assembly cart carries a complete set of components necessary to complete an assembly. The complete component set allows workers the flexibility for work distribution during the assembly process in accordance with LP principles. These principles rely on the availability of each worker to the entire component set; the PPF line staffed by workers capable of carrying out all flow-line tasks; and all tools available to each worker at each station. With these ingredients, work on assemblies continues without interruption despite inevitable time delays at work stations.

Table 1: Benefits of Lean Production

Cellular Assembly Benefits
Productivity increase
Less labor required
Improved quality
No line balancing
Improved ergonomics for workers
Continuous process improvement

In practice, the PPF line functions as a result of downstream workers pulling semi-completed assemblies from upstream workers. The downstream worker then takes partially completed assemblies from the next adjacent upstream worker and so on. The worker at the last work station, Station 5 in **Figure 3**, controls the output rate because their work piece received from upstream Station 4 is semi-finished and they must complete it. Although the line may initially be balanced, such that each worker has approximately the same amount of time to accomplish their work, time-related delays inevitably occur. As for any LP system the PPF system readily resolves any problems resulting from such delays.

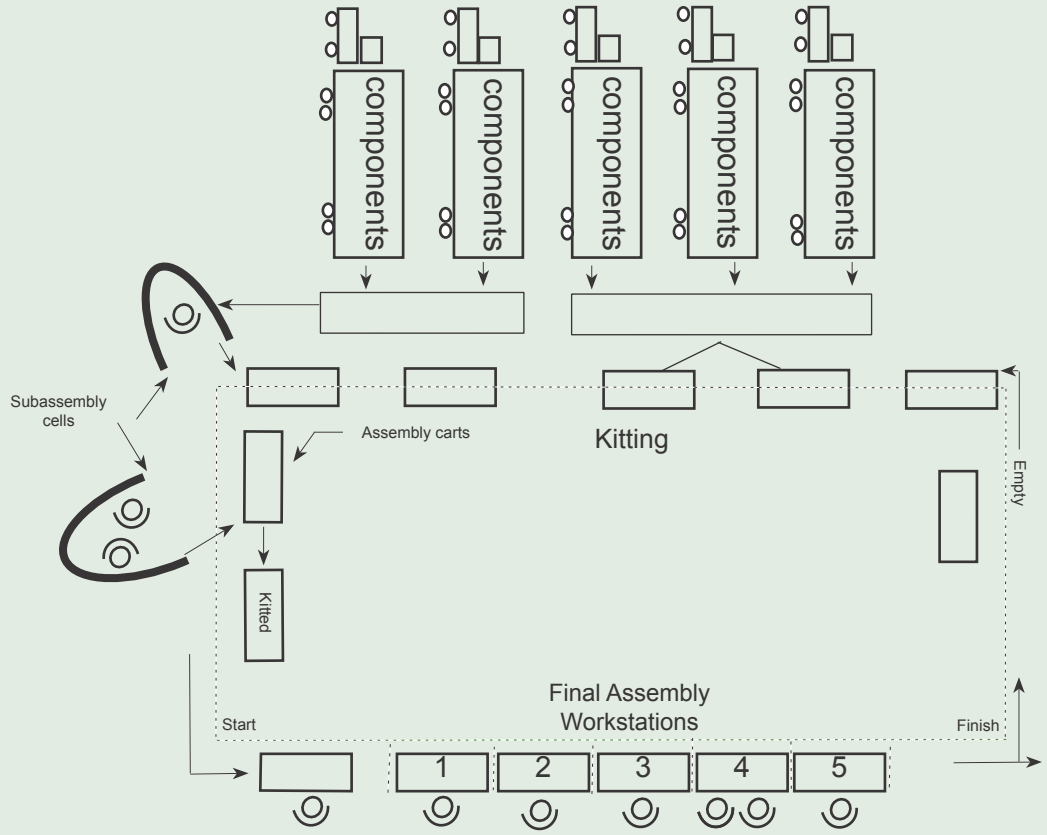

Figure 3. Conceptual Lean Production Parallel Pull Flow line

Flow Lines

Potential Problems

The following two examples explain the most frequently encountered time-delay problems for PPF systems. These examples illustrate the power of LP pull systems to self correct time-delay problems occurring on the line.

Referring to **Figure 3**, assume that the final worker at Station 5 has suffered an unavoidable delay and cannot complete their assigned task in the allotted time period required for a balanced line.

In the PPF example, the continued work performed by upstream workers on their work piece will be more than is normally expected due to the delay at Station 5. Therefore, each worker, with the exception of the delayed Station 5 worker, passes assemblies downstream with more than the normal amount of work performed. After the worker at Station 5 catches up with the work on the delayed assembly they receive a unit from the upstream worker at Station 4 with more assembly progress than normal. Therefore, the Station 5 worker has less work to perform on this unit and thereby can catch up on this new work piece. This flexibility built into the PPF system by LP principles allows for the smooth resolution of minor delays without lost productivity.

In a second problem example we assume a PPF worker, other than the last worker at Station 5, is delayed. Let us assume that this worker is at Station 3. In this situation the adjacent downstream worker at Station 4 would be delayed if they waited for the Station 3 work to be completed. However, by the LP PPF methodology the worker at Station 4 pulls the work piece even though it is not completed to the normal extent. With the full complement of components and tools the Station 4 worker can complete the work unfinished by the worker at Station 3 without hindrance. Likewise, each worker upstream of worker 4 inducts a new upstream work piece. The worker at Station 1, when their work piece is pulled downstream, introduces a new kitted assembly cart into the line. Meanwhile, the particular assembly causing the problem is rectified by the downstream worker(s), or the problem is constantly pulled until it reaches the last downstream worker, at which point the line self-corrects according to the scenario described for the first problem type example.

In a traditional push-controlled flow line the Station 5 delay would have caused a line stoppage as each upstream worker completed their work and was forced to stop or to build semi-completed units. However, by the PPF line methodology, the blocked upstream workers are able to utilize the complete array of tools and components on their carts and they continue to work on their units without inducting new upstream assemblies. No disturbance in the line occurs due to the delay of a pull signal at the expected time.

Parallel Flow at XYZ

The PPF concept described will now be illustrated by an example of installation of a PPF line at an upholstered furniture manufacturing company. The XYZ Corporation has been in business since the early part of the twentieth century and produces final assembly of many styles of niche products. XYZ was employing traditional job shop manufacturing systems. However, it also fit the PPF criteria listed in **Table 2**, and a parallel pull methodology was applied to one of the manufacturing operations. XYZ manufacturing processes include cutting and sewing upholstery material and cutting and finishing wooden frame materials. They also utilize computer numeric control (CNC) routers to cut numerous parts and shapes from plywood and other components. Subassembly and assembly operations include assembling mechanical chair components through subassembly to final assembly and packing.

XYZ's management decided that in order for the company not only to survive intense foreign and domestic competition, but also to thrive, they would have to adopt a new way of manufacturing. They decided to utilize LP philosophies and methodologies. Typically, LP is implemented in upstream processes, systematically forming a linked cell manufacturing system as manufacturing areas are converted to LP cells. Final assembly lines may be converted to cellular manufacturing and assembly cells, and XYZ had begun designing and implementing various cells, although they have not converted any of their final assembly lines. While considering converting a final assembly to cellular assembly, they decided a cell was not the best approach. After considering alternatives, XYZ decided to employ the PPF methodology described here.

Table 2

Parallel Pull Requirements

1	Workers must be proficient at each of the line's workstations.
2	A portable assembly worksite to carry all fixtures and a complete kit of assembly components is required.
3	All necessary tools must be available to each worker.
4	A complete kit of parts must be available at each assembly worksite.
5	Assembly procedures must be exactly followed.

Parallel Pull Flow at XYZ

The following describes the conversion of a final assembly line to a PPF line. The implemented XYZ PPF assembly line consists of five workstations with seven workers. In addition, the line is supplied with subassemblies from a five-workstation subassembly cell tended by three workers. These ten workers comprise team one. Future plans call for setting up a second PPF line adjacent to the first system manned by team two. The total number of workers on the two parallel pull assembly lines and two supplying manufacturing cells will be 20 at that time.

The design of the first PPF line, is basically rectangular (see **Figure 4**) with the material flowing counter clockwise. Mobile assembly carts are used as moving assembly platforms for the final assembly. Once the assembly carts have had the finished assembly placed on the powered conveyor to packing, they travel to the assembly start point at the manufacturing cell. During this return leg, the assembly carts are kitted.

The first two work stations in the PPF line are upholstery operations. The last three workstations, three through five, are manned by one worker each who completes final assembly operations. Workers push the assembly carts from workstation one through workstation five via a guide rail mounted on the concrete floor.

The assembly process begins with carts arriving at the subassembly cell staging area kitted and ready to receive a subassembly. Upon arrival a subassembly is placed on the assembly cart. The assembly cart then queues, waiting to be pulled into the PPF final assembly line. When the workers at Workstation 2 pull the assembly cart from Workstation 1 workers have the assembly cart they are working on pulled from them, and they in turn pull Workstation 1's assembly cart. This sequence of assembly operations continues for all five workstations. This pull sequence flowing up the line illustrates the automatic LP pull methodology built into the cell functions.

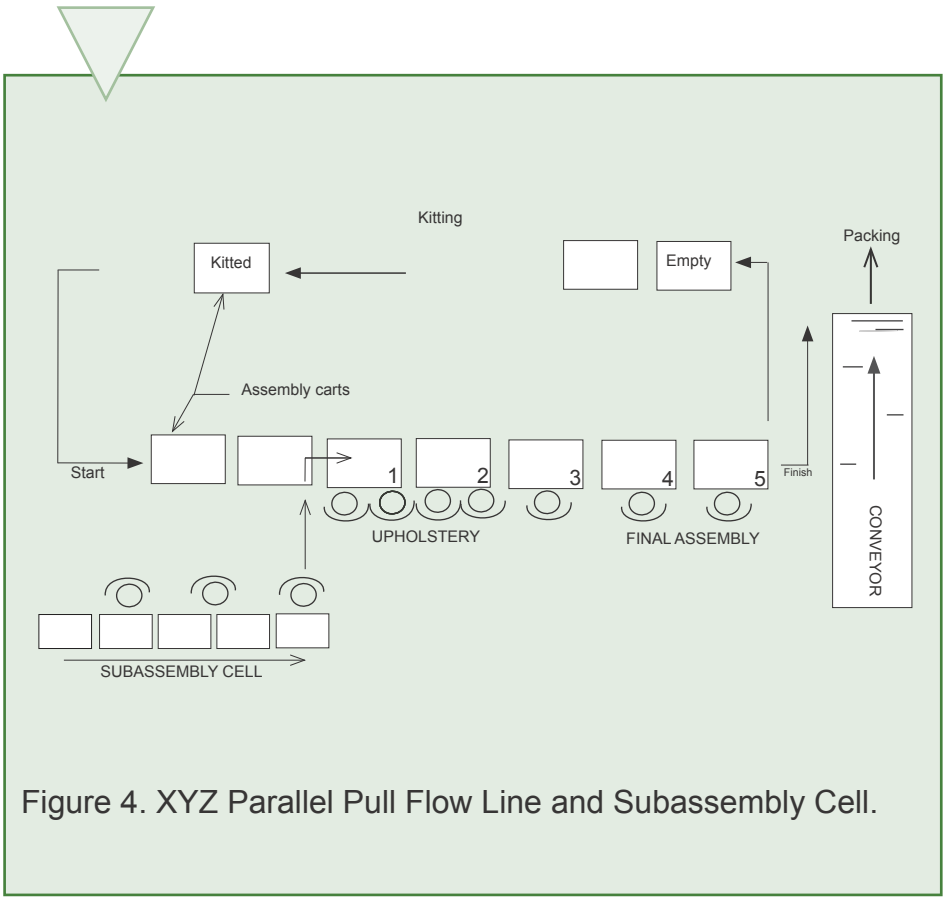

Figure 4. XYZ Parallel Pull Flow Line and Subassembly Cell.

Results

Before the conversion to the PPF system, the traditional flow line final assembly at XYZ produced 50 final assembly units per nine-hour day utilizing 23 workers (see **Table 3**). Note that XYZ has adopted the nine-hour day standard work week. The nine-hour day allows 510 minutes of available work time, after mandatory breaks, and a production rate of 10.2 minutes per finished unit or approximately 5.9 units per hour. The area was manned with 23 workers; therefore, the total final assembly labor required was 234.6 labor minutes per unit. The pre-conversion ratio of output to workers was 2.17 units per worker per nine-hour day.

After the conversion to the PPF system, the number of workers was reduced to 20 (see **Table 3**). The number of units produced by the new system dramatically increased from 50 per day to 75, a 50 percent increase in productivity. The number of workers was reduced from 23 to 20. An additional 125 units per week were produced with three less workers. Overall productivity increased from 2.17 units per worker to 3.75 units per worker, an increase of 72 percent. The new PPF line also resulted in a 33 percent decrease in time per unit.

Other benefits of the PPF line included floor space savings. Reduction in floor space is a typical benefit realized with the reengineering efforts of LP. The XYZ facility was no exception with an estimated 20 percent less space required for the new PPF assembly line.

Table 3
Conventional vs. Parallel Pull LP Comparison Chart

Item	Conventional Final Assembly	Parallel Pull Final Assembly	Percent Improvement
Number units per nine hour shift	50	75	50% increase
Total units per week	250	375	50% increase
Number workers	23	20	13% decrease
Units per worker	2.17	3.75	72% increase
Time per unit (minutes)	10.2	6.8	33% decrease

Ergonomics

Like all LP systems, the PPF system focuses on employees as a key resource in production due to their flexibility and creativity. This viewpoint leads to a variety of benefits for system workers including increased communication, increased movement on the job floor, and increased job responsibility. This system design also provides employees more control over the speed of the production process, and encourages employees to ensure that each product leaving the production line is of the best possible quality.

In addition to cost and production benefits, PPF also offers a variety of health benefits to employees through improved ergonomics. Among these are rubber mats to provide a safe walking surface for the subassembly and final assembly lines. The mats have shock absorbance capabilities that reduce worker fatigue (Mital 1995). Work-related muscular skeletal disorders (WMSD) in the arms, back and shoulders are also reduced due to an increase in free movement.

In addition to ergonomic benefits afforded to workers by the design of the PPF subassembly cell, the increase in worker mobility provides long-term health benefits. These include increased bone strength, reduced cholesterol and blood vessel plaque, healthier hearts, and reduced or eliminated risk of venous pooling which may result in deep-vein thrombosis (Mital 1995). The increased movement associated with more tasks to carry out per production cycle also dramatically reduces the risk of repetitive motion injury by giving micro-injuries time to heal. These micro-injuries are most common in work environments utilizing repetitive movements in assembly line type systems and can lead to carpal tunnel disorders and other WMSDs.

Summary

Lean manufacturing implementation requires a system level change for the factory—a change that impacts every segment of the company, from accounting to shipping. XYZ has adopted LP manufacturing and is presently systematically reengineering the factory into manufacturing and assembly cells and final assembly PPF.

This case study relates the transition of a furniture factory from the old job shop system to modern manufacturing and assembly cells. Specifically, this case study reported on the reengineering of a flow shop into a PPF line. The results of manufacturing metrics clearly illustrate that the new PPF line out performs the old system in every productivity category. Also, worker safety and health are improved by incorporating ergonomic features.

Glossary

Batch and queue operations – a manufacturing process used by the functional job shop manufacturing systems that manufactures and moves large numbers of identical units at once. Each lot of units, called a batch, moves through a queue of operations during the process of production.

Cellular manufacturing system – a manufacturing system using a one-piece flow through a variety of workstations in a cellular way to achieve a final product. Each cell specializes in manufacturing a family of parts completely in one aspect of the production process. Machines used in cells are not "supermachines" instead, they accomplish only one task in parallel. Workers check product quality, machine function, and performance with each step of production.

Cycle time – the time it takes to complete the tasks required for a work process to be completed successfully.

Economy of scope – a characteristic of lean production where a factory is capable of productivity and making a profit on a wide variety of products selling at low prices.

Kanban – a physical production-control system that uses cards or other visual signals to trigger the flow of materials from one part of the production process to the next.

Lean manufacturing – a manufacturing process that productively adds value to materials by capturing proprietary production processes in manufacturing cells supplied by sole-source vendors. Lean manufacturing addresses material, administration, and labor costs—including the costs of storing and handling materials within the factory.

Lean production – the newest manufacturing system consisting of manufacturing and assembly cell and other vital subsystems dedicated to elimination of waste. Products created using a lean production system are produced on an as-needed basis using one-piece-flow methodology.

Manufacturing cell – an area, usually "U" shaped, on the production floor responsible for manufacturing parts, subassemblies, and the end product. These cells are flexibly designed to decrease cycle time and normally consist of different machining processes arranged to produce a family of parts.

Manufacturing system – a system focused on converting raw materials into usable goods at a profit.

Multifunctional worker – a worker responsible for more than one aspect of the manufacturing process. Workers often carry out all of the processes required in a production cell in a lean manufacturing system.

One-piece flow – the movement of products through the cell one unit at a time rather than in batches of multiple units.

Pull system – a production system in which nothing is produced until it is needed by either the internal or external customer. Goods are manufactured only when they are requested by a downstream process or a customer order.

Push system – a production system in which goods are produced then stored as inventory until needed.

Stock-on-hand inventory – when labor, new materials, and process capacity is available regardless of system needs. Material within a cell is called stock-on-hand. Material between cells is referred to as work-in-process.

Takt time – the total available work time per day or shift divided by customer-demand requirements per day or shift. Takt time sets the pace of a production system to match the rate of customer demand.

Work-in-process inventory – material, usually in small batches, between cells is called work-in-process. Material within cells is referred to as stock-on-hand.

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