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The Double-D cell for assembling hardware in upholstered furniture production

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Case studies of lean manufacturing in furniture and supplying industries
Applications for increased international competitiveness

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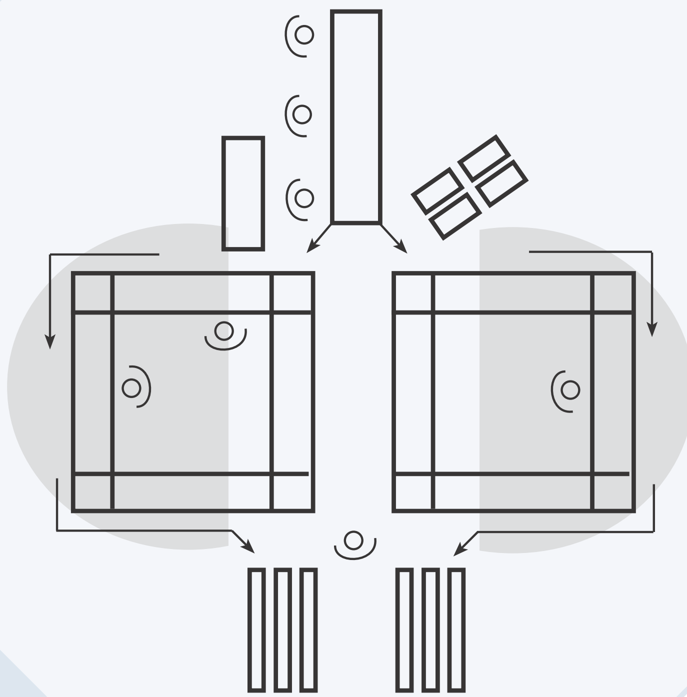

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#1 Case Study

Research Bulletin
Forest and Wildlife Research Center

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Case Study #1

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#1 Case Study

The *Double-D Cell* for Assembling Hardware in Upholstered Furniture Production

Introduction

This is the first case study in a series of studies that relate specifically to the development and application of lean manufacturing techniques of furniture and wood component supplying industries. Case study one is an example of how a subassembly process in an upholstered furniture facility was re-configured from a traditional flow line to a "Double-D" manufacturing cell.

This case study provides general information about lean manufacturing and how a lean manufacturing system can be implemented, followed by a detailed description of Franklin Corporation's adoption of a new type of manufacturing cell—the "Double-D". A discussion of the original state of the subassembly system and the result of the Double-D modifications are also given.

Other case studies in this series will be available as separate reports, including the use of value stream mapping in a case goods production facility, development of a manufacturing cell for final assembly in an upholstered chair production line, and process improvements that were implemented in a wood components manufacturing facility. (For availability see the publications 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 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. Lean manufacturing differs greatly from the older "batch" and "job shop" manufacturing system designs offering previously unattainable benefits.

Do the benefits of lean manufacturing outweigh the costs in *your* production facility? Although all facilities and production processes differ, the answer to this question is almost assuredly yes. The benefits of lean manufacturing are great, while in most cases the monetary costs are relatively low. However, conversion to a lean manufacturing system is not a simple task and requires a strong, continuing commitment from high-level management within the firm.

Even though this system offers a variety of benefits to manufacturers committed to its use, lean manufacturing has yet to be widely adopted in US furniture production facilities. The results of this case study and the others in this series demonstrate that lean manufacturing processes offer great potential for increasing productivity and product quality in this important 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.
- results in maximum flexibility in product types and styles produced.

These processes represent a significant means of achieving and sustaining "higher order" 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).

Lean 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 are "higher order" competitive advantages in that they are difficult to replicate quickly, particularly in countries that are geographically distant from major U.S. markets.

Given the attractiveness of the benefits of lean manufacturing, their low cost, and ease of conversion to this system, where might this type of system be used in the furniture industry, and how might its adoption be implemented? The answers to these questions can be found by exploring some changes within the Franklin Corporation.

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

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

Sekine, Kenichi. 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.

Before and After

About the Franklin Corporation

Franklin Corporation is an industry leader in the production of upholstered recliners, sofas and motion furniture. Established in 1970, Franklin Corporation strives to exceed the expectations of its customers through its commitment to innovation and value. Headquartered in Houston, Mississippi, the company was ranked 14th in the nation in total sales by the 2003 Upholstery Design and Management survey of U.S. upholstered furniture manufacturers (Chazin 2003). Franklin Corporation employs approximately 1,200 people and focuses on in-plant design, testing, manufacturing, and inspection.

Franklin Corporation also has vertical depth in its manufacturing operations by producing several of its subassembly cue components. Some of the material preparations carried out by Franklin Corporation to achieve this vertical integration are the processing of frame components through a modern dimension mill and the sawing and finishing of wooden frame materials. Computer numerically controlled (CNC) processes are also used by the corporation to cut foam, fabric, leather and plywood components.

Other subassembly production aspects of Franklin Corporation's manufacturing operations include upholstery sewing and stamping metallic components. The result of this vertical depth of manufacturing is the assembly and packing of an enormous variety of recliner chairs and sofas, sleeper sofas, loveseats, stationary leather sofas and chairs, and other furniture products.

To keep its competitive edge, Franklin Corporation invests in technologies allowing for manufacturing processes that maximize quality without increasing costs or the end price presented to potential customers. When considering this goal alongside increasing foreign and domestic competition, Franklin Corporation management decided lean production systems were a necessary means of sustaining international competitive advantage.

Before: Franklin Corporation Circular Subassembly Flow Line

Before: Hardware Assembly Flow Line

Franklin Corporation identified a hardware assembly flow line as its first lean manufacturing system application. This flow line was a subassembly system for four sizes of recliner hardware. Hardware from this subassembly system subsequently became components for six final assembly lines.

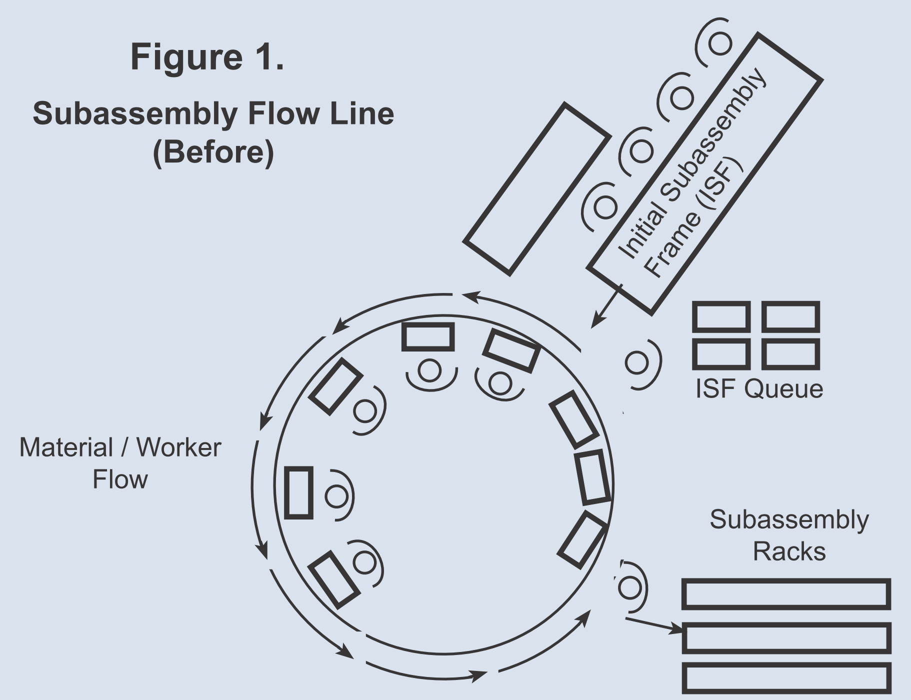
The subassembly flow line was a true flow line with one worker per workstation and consisted of two sections. The first section, the upper portion, was a straight table with four workstations for the initial assembly of the primary wood and hardware frame. This Initial Subassembly Frame (ISF) workstation supplied a large queue at the end of the assembly bench with the subassembly frame. Hardware frames remained at the end of this section of the line until passed to the lower, circular portion of the flow line, Figure 1.

At the circular portion of the flow line five workers, one per workstation, added components to the ISFs. This section consisted of roller tables onto which the ISFs were mounted after being passed to the flow line. The moveable assembly fixture table was then rolled from workstation to workstation around the interior of the flow line circle with the aid of a metal circular perimeter allowing workers at workstations around the circle to add components to the ISFs. While rolling of these frames on wheeled tables eliminated the need for workers to carry the frames from station to station, the rough concrete floor of the assembly area made the table fixtures difficult for the five lower (circular) flow line workers to push.

In addition to the four upper (straight) section workers and the five lower (circular) section workers, two employees with various tasks were present on the assembly flow line to assist primarily with handling materials and keeping the area supplied with components. Production time for each unit was approximately 30 seconds, which yielded a flow line production rate of 860 hardware assemblies per nine-hour shift.

Figure 1.

Subassembly Flow Line (Before)



After: Hardware Assembly with the Double-D Manufacturing Cell

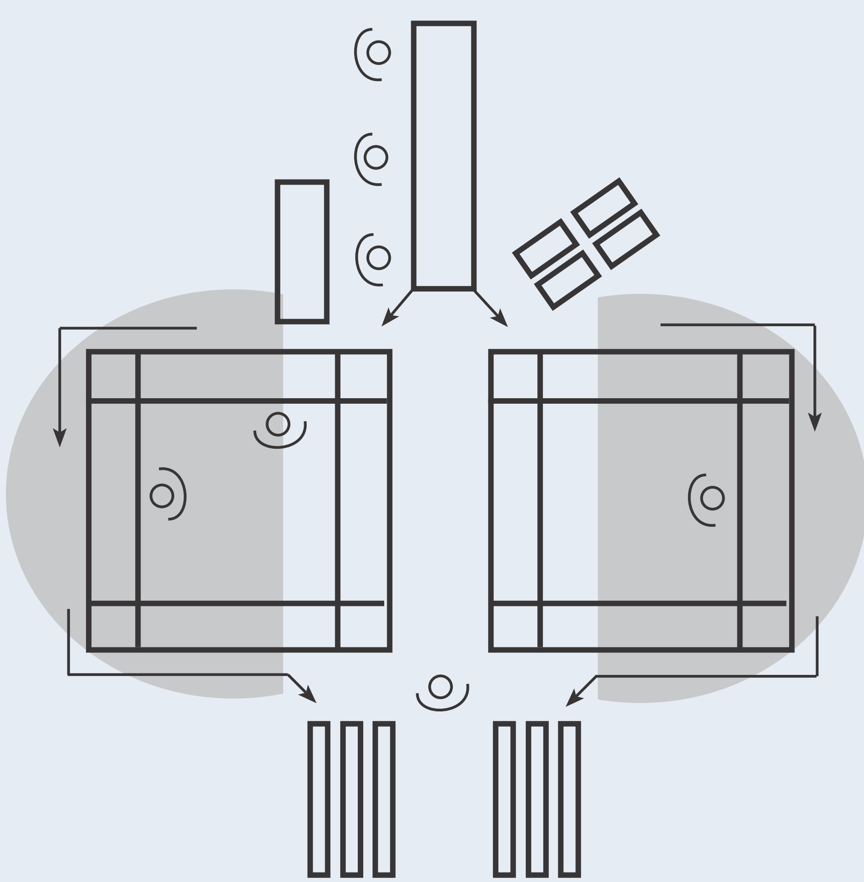
After reviewing the original flow line, a lean manufacturing solution was developed. In the redesigned subassembly process, the initial fixture assembly of the flow line remains the same; however, the lower, circular area has been completely reengineered. Rather than a circular shape, the lower portion, now a manufacturing cell, consists of two rectangular or D-shaped portions, Figure 2. This Double-D shaped assembly cell is used rather than one large circular or rectangular cell to minimize worker walking distance and the area needed to allow enough workspaces to meet the maximum daily requirement for hardware units. In addition to conserving movement and space, the Double-D configuration creates a shape with straight-line sections resulting in considerably less expensive roller conveyors than those needed for a circular space. An additional benefit of the Double-D design is added flexibility within the cell. For example, one D could be used for a specific size of hardware subassembly while the second D could accommodate a different sized (or several sizes of) hardware units.

The straight-configured upper flow line supplies both Ds with the basic hardware component upon which the subassembly is built. These hardware units will then be diverted into the lower D units. The D units are positioned back to back and the left side has a counterclockwise material flow while the right side material flows in a clockwise direction, Figure 2.

The texture of the floor is no longer an issue to hamper movement as the assembly fixtures no longer need to be mounted on roller tables and are

Figure 2.

Double-D Hardware Cell (After)



instead moved around the assembly cell on 30-inch wide gravity roller conveyors. This method of transport provides almost effortless movement of the assembly fixtures to the cell workstations.

The Double-D cell operates in a typical assembly cell manner. Workers begin the assembly process by taking an empty fixture and adding a cam and base component; sometimes material handlers will complete this step. After attaching the cam and base component, the worker will systematically build the complete hardware assembly by moving the fixture sequentially to each of the five workstations, adding new components at each station. After final subassembly at station five, the fixture is rolled to the exit area and a material handler removes the completed hardware unit to a rack. Having completed the cycle, the empty fixture is then pushed toward the cell load area and taken by a cell worker or material handler who then loads a cam and base thereby initiating a new assembly cycle.

Excessive hardware assembly inventory queues ahead of the subassembly workstations have been a past and current problem. A kanban inventory and production control system will be implemented to solve this queueing problem. This kanban subsystem will drive the inventory queue to the lowest workable level. This subsystem design will reduce work-in-process inventory which will in turn reduce carrying costs, adding to profitability. The kanban system will also drive continuous improvement efforts, therefore increasing quality while improving productivity.

After: Franklin Corporation Double-D Hardware Assembly Cell

Case Study #1

Cellular Assembly Benefits

- Productivity increase
- Less labor required
- Improved quality
- No line balancing
- Improved ergonomics
- Continuous process improvement

Results and Benefits

Production Benefits

The new Double-D assembly cell produces 950 units per shift with only seven workers compared to the 11 workers used in the old flow line. Therefore, the cell produces the required number of hardware units with three less workers and one less material handler. This reduction in needed employees provides a productivity savings equal to two workers' wages and benefits. The approximate productivity increase in output is 36 percent.

In addition to the productivity increase and reduced staffing the Double-D design allows the assembly cell supervisor the capability of accurately adjusting the cell's output by simply adjusting the number of workers in the cell. This flexible system can easily throttle output up or down to meet the needs of the manufacturer simply by adding or removing workers. This flexibility is shown in the table below.

The output columns of the table display the range of production from 226 hardware units per shift for one worker to 2,469 units per shift with the fully-manned ten worker Double-D cell. However, as each D in the cell achieves the maximum of five workers, flexibility will be jeopardized. When all workstations in a D are full, the assembly cell becomes a flow line and requires line balancing to retain flexibility. However, as long as one or more workstations within the cell are vacant, line balancing within the cell is not needed.

Although the new system is flexible and can produce a wide range of units per shift, the previous circular flow line produced the required 860 subassemblies daily.

Double-D Assembly Cell Estimated Output

Five Stations each D Element

Personnel One D Element	Est. Output One D (Pcs/Shift)	Cycle Time (Secs)	Personnel Two D (Pcs/Shift)	Est. Output Two D (Pcs/Shift)	Effective Cycle Time (Secs)
1	226	114.0	2	453	57.0
2	478	54.0	4	956	27.0
3	733	35.3	6	1,462	17.7
4	981	26.3	8	1,962	13.2
5	1,234	20.9	10	2,469	10.5

Employee Benefits and Ergonomics

A key quality of lean manufacturing is its focus on employees as key resources in production due to their flexibility and creativity. This viewpoint leads to many benefits for employees in addition to production and cost benefits offered by the Double-D subassembly cell and lean manufacturing in general. Employees in this system have the benefit of increased, easy 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.

The Double-D design also has provided ergonomic benefits. The replacement of roll tables on the rough concrete floor with gravity roller conveyors increases free movement and reduces the possibility of work-related muscular skeletal disorders (WMSD) in the arms, back and shoulders. In the Double-D subassembly cell, workers will be stationed in a work area (cell) floored with rubber mats. These mats improve worker safety with a high-traction, no-slip surface comfortable for standing as well as for walking. The shock absorbing qualities of these mats will also help to reduce worker fatigue as they walk around the cell.

In addition to ergonomic benefits afforded to workers by the design of the Double-D 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.

Ergonomic Changes with the Double-D Design

- Fatigue matts
- Adjustable height roller conveyor
  - set at proper reach and height
  - effortless movements of assembly fixtures
- Counter balanced air tools
- Assembly components set for easy access
  - proper reach
  - easy to load

Case Study #1

Summary

Manufacturing systems must be carefully planned to maximize profits while minimizing risks. Lean manufacturing systems are flexible while designed to produce superior quality products, on-time, at the lowest possible cost, and on a continuous basis. To remain competitive in the increasingly competitive upholstered furniture market, the Franklin Corporation elected to adopt a Lean Manufacturing approach.

The reengineering of the Franklin Corporation subassembly flow line into a manufacturing cell signaled the beginning of a factory-wide conversion to lean production. There are several reasons that Franklin Corporation may have chosen lean production. It uses less human effort, less manufacturing space, less tooling, and less engineering time to develop new products while increasing the quality of products.

The fundamentals of Lean Production

- Newest manufacturing system design
- Functionally and operationally different from other manufacturing systems
- Utilizes manufacturing and assembly cells
- Focused on pull system methodology
- Leads to 100% good quality
- Results in on-time delivery every time
- Emphasizes a respect for people, both customers and employees
- Maximizes use of non-depreciable resources - people and raw materials

Why choose Lean Production?

- Uses less human effort
- Uses less manufacturing space
- Uses less tooling
- Uses less engineering time to develop new products
- Increases quality of products

To adopt lean production, Franklin Corporation needed to incorporate a manufacturing cell into their production process. The design of the lean manufacturing system implemented in this case study is a unique Double-D cell supplied by a traditional straight-line flow. The Double-D design allows the output rate to be adjusted by adding or removing workers. Implementing this flow line change has led Franklin Corporation to benefit from a real productivity gain of 36 percent. In addition to increases in productivity are potential health benefits.

The purpose of designing a manufacturing system is to create a physical entity that minimizes the expenditure of non-depreciable resources (materials and labor) while meeting the functional requirements expected of the system. It is clear from the benefits accompanying Franklin Corporation's change to lean manufacturing and the results achieved that the new manufacturing system implemented fully accomplishes this purpose. A move toward lean manufacturing is not a short-term fix to the problem of competitiveness, it is rather a long-term change. Lean manufacturing implementation requires a systems-level change for the factory—a change that will impact every segment of the company, from accounting to shipping. This publication and the others in this series demonstrate examples of lean manufacturing implementation in furniture production. Further information on this work and other activities is available at the web site of the Institute of Furniture Manufacturing and Management at Mississippi State University.

Institute of Furniture Manufacturing and Management

The Institute of Furniture Manufacturing and Management was organized at Mississippi State University in 2001. Since the mid-1980s the Furniture Research Unit of the Department of Forest Products, Forest and Wildlife Research Center, has included a cadre of highly trained scientists working on furniture manufacturing and management issues. Today, the Institute is helping to focus resources and capabilities of the entire University to effectively partner with industry and others to address current and future needs of the furniture industry. ***The primary goal of the Institute is to increase the international competitiveness of Mississippi's furniture industry and thus help secure the future of the industry in the state and region.***

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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.

Double-D configuration – a double rectangle or round cell on the production floor using lean manufacturing concepts. This shape minimizes the distance that workers have to walk in an area while allowing enough workspaces to meet production requirements. Double-D configuration can also reduce costs of mechanisms for moving products through production, like conveyor, by simplifying the production floor path while also allowing for flexibility within production cells.

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.

References

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

Black, JT. 1999. Black's blueprint for lean manufacturing. Unpublished manuscript, Industrial and Systems Engineering Department, Auburn University, AL.

Bullard, S.H., and C.D. West. 2002. Furniture manufacturing and marketing: Eight strategic issues for the 21st century. Forest and Wildlife Research Center, Bulletin FP 227, Mississippi State, MS. 24p.

Chazin, M. 2003. The top 50 largest upholstery manufacturers. Upholstery Design and Management 16(5):16-29.

Hunter, S.L. 1992. The design and implementation of a manned remanufacturing cell: A case study. Proceedings of APICS Aerospace & Defense Symposium. p.177.

Mital, Anil. 1995. The role of ergo in designing for manufacturability and humans in general in advanced manufacturing technology: Preparing the American workforce for global competition beyond the year 2000. International Journal of Industrial Ergonomics 15(2):129-135.

Monden, Y. 1983. Toyota production system. Industrial Engineering and Management Press, IIE, Norcross, GA.

Schonberger, R.J. 1982. Japanese manufacturing techniques: Nine hidden lessons in simplicity. The Free Press, New York.

Schonberger, R.J. 1986. World class manufacturing: The lessons of simplicity applied. The Free Press, New York.

Womack, J.P., D.T. Jones, and D. Roos. 1991. The machine that changed the world: The story of lean production. First Harper Perennial Publishers, NY.