INTEGRATING ISO PRINCIPLES, LEAN MANUFACTURING PRACTICES, AND SIX SIGMA PROGRAMS

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By submitting this paper, I affirm that this work is my own except for where the words or ideas of others are specifically acknowledged. I also affirm that this work, as it stands, did not exist before the beginning of the course for which it is submitted.

Target Audience: A wide variety of management teams within the manufacturing and service sectors. The teams are often characterized as possessing members whose skill sets range from experienced to novice with these three management tools.

Purpose of this Paper: This paper is designed to place before a wide management audience the complementary nature of three management tools often used throughout the world.

Executive Summary: There is a plethora of management tools for the executive of the 21st century. This paper focuses on the integration of three complementary management tools of ISO, Lean Manufacturing and Six Sigma (ILS). Simply stated, ISO is the documentation of a process, Lean Manufacturing is the physical distribution of a process and Six Sigma is the statistical quantification of a process.

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ISO, LEAN, AND SIX SIGMA IN THE 21ST CENTURY

In a business world in which companies focus on being as effective and efficient as possible, keeping costs low, and distinguishing themselves from their competition while satisfying customer needs, there are many management tools that, if implemented correctly, will help a company to run smoothly. Among these tools are ISO, Lean Manufacturing, and Six Sigma (ILS).

A current debate among those in industry is whether a company can successfully be ISO certified and implement lean initiatives and/or six sigma (lean sigma). Some believe the structure of the ISO standards may be an impediment to the flexibility characteristic of lean sigma organizations. This paper briefly discusses the backgrounds and contents of ISO, Lean Manufacturing, and Six Sigma, discusses potential conflicts, examines by detailed case study how two companies spanning a range from aerospace fasteners to extruded plastics are implementing lean sigma initiatives in a quality management system environment, and discusses each of the characteristics needed to successfully integrate the three tools.

In today's business environment, many businesses are trying to do what they can to compete. They are trying to trim costs, operate their business as effectively and efficiently as possible, and keep customers coming back for more of their parts and/or services. There are currently many management tools and business systems fueled by this competitive environment that claim to be able to assist companies operate their businesses more smoothly.

A short list of these tools and systems would include ISO, Lean Manufacturing, and Six Sigma. Almost all multinational businesses have tried at least one of these three tools and most have experience with more than one. Sometimes these tools are not successful for many reasons and leave the participants wary of trying any new systems or tools.

Three of the programs that are currently growing in popularity are ISO, Lean Manufacturing, and Six Sigma. The number of companies certified to ISO worldwide is nearly 500,000 in the year 2003. A matter of great debate, both in business and academia, is whether or not a company that is ISO certified can successfully implement lean sigma (a common practice of combining lean manufacturing practices with six sigma programs) initiatives. There are certain characteristics of both tools that would leave one believing that conflict would arise that could lead to discrepancies in quality audits or slowness in implementation of lean-driven change.

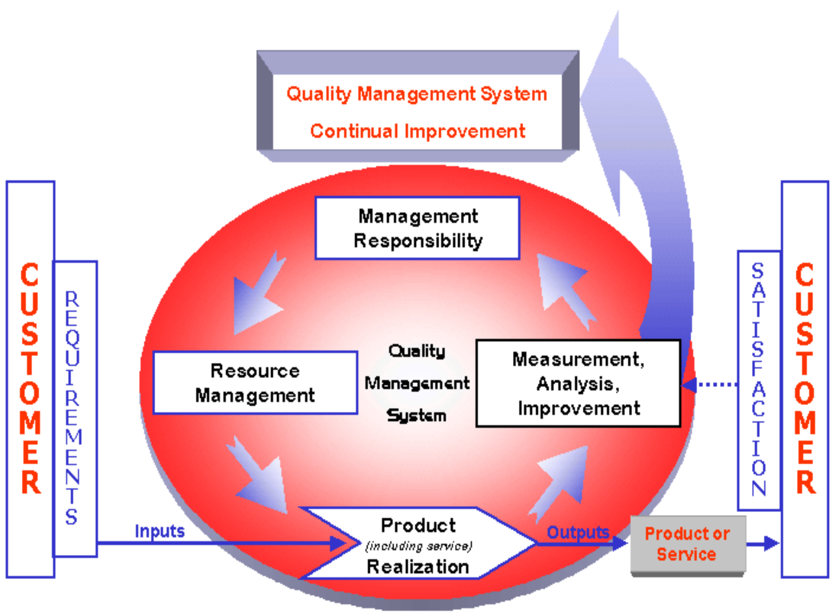
One potential conflict of considerable interest is how the quick changes resulting from *Kaizen* events in lean sigma would co-exist with the traditional documentation requirements associated with ISO certification.

> There are two elements that construct KAIZEN®, improvement/change for the better and ongoing/continuity. Lacking one of those elements would not be considered KAIZEN®. For instance, the expression of "business as usual" contains the element of continuity without improvement. On the other hand, the expression of "breakthrough" contains the element of change or improvement without continuity. KAIZEN® should contain both elements. [12]

After working with two world-class organizations, the author found a striking absence of perception of such conflict by these companies that have actual experience at managing the interaction of ISO, Lean Manufacturing, and Six Sigma. In fact these two companies report experiencing positive results from integrating the lean manufacturing and six sigma initiatives with ISO certification.

ISO DESCRIPTION

ISO - **ISO 9000 series standards:** A set of international standards on quality management and quality assurance developed to help companies effectively document the quality system elements to be implemented to maintain an efficient quality system. The standards, initially published in 1987, are not specific to any particular industry, product or service. The standards were developed by the International Organization for Standardization, known as ISO, a specialized international agency for standardization composed of the national standards bodies of 159 countries. The standards underwent major revision in (1994) and 2000 and now include ISO 9000:2000 (definitions), ISO 9001:2000 (requirements) and ISO 9004:2000 (guidelines).



Graphic courtesy of ISO [10]

ISO BACKGROUND

ISO - In 1946, following WWII, delegates from 25 countries met and decided to create a new international organization, of which the objective would be "to facilitate the international coordination and unification of industrial standards". The new organization, ISO, officially began operations on 23 February 1947. [10]

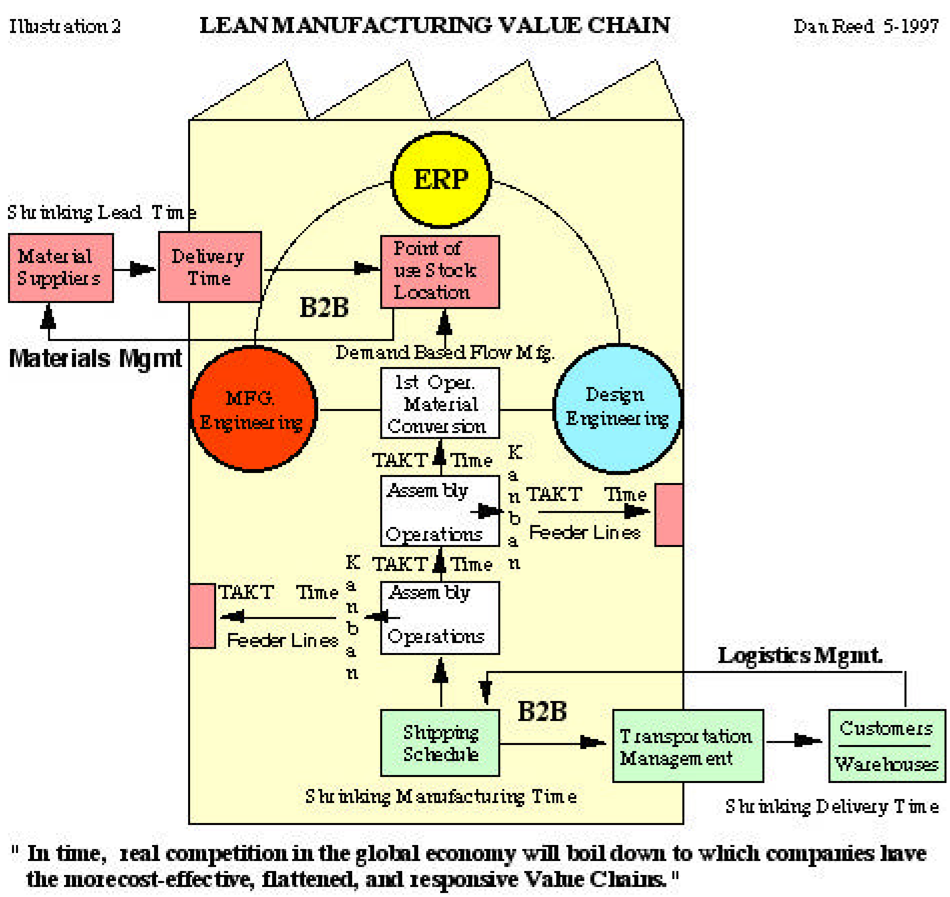
The ISO 9000 and ISO 14000 families are among ISO's most widely known and successful standards ever. ISO 9000 has become an international reference for quality requirements in business-to-business dealings, and ISO 14000 looks set to achieve at least as much, if not more, in helping organizations to meet their environmental challenges.

The vast majority of ISO standards are highly specific to a particular product, material, or process. However, the standards that have earned the ISO 9000 and ISO 14000 families a worldwide reputation are known as "generic management system standards". "Generic" means that the same standards can be applied to any organization, large or small, whatever its product – including whether its "product" is actually a service – in any sector of activity, and whether it is a business enterprise, a public administration, or a government department. "Management system" refers to what the organization does to manage its processes, or activities. "Generic" also signifies that no matter what the organization is or does, if it wants to establish a quality management system or an environmental management system, then such a system has a number of essential features, which are spelled out in the relevant standards of ISO 9000 or ISO 14000.

ISO 9000 is concerned with "quality management". This means what the organization does to enhance customer satisfaction by meeting customer and applicable regulatory requirements and continually to improve its performance in this regard. ISO 14000 is primarily concerned with "environmental management". This means what the organization does to minimize harmful effects on the environment caused by its activities, and continually to improve its environmental performance.

LEAN DESCRIPTION

Lean - **Lean Production or Lean Manufacturing:** Lean Manufacturing is a systematic approach to identifying and eliminating waste (non-value-added activities) through continuous improvement by flowing the product at the pull of the customer in pursuit of perfection. It is a business system for organizing and managing product development, operations, suppliers, and customer relations that requires less human effort, less space, less capital, and less time to make products with fewer defects to precise customer desires, compared with the previous system of mass production.



Graphic courtesy of Dan Reed [11]

LEAN BACKGROUND

Lean – Lean-manufacturing techniques is an amalgam of best manufacturing practices that evolved chiefly during the industrial revolution. After the Second World War, the United States invested heavily in the democratization of Japan, and along with that came the reorganization of the economy to one based on free markets. Programs such as the CGS (civil communication section) for top management, the MTP (management training program) for mid-level managers, and the TWI (training within industry) for lower level managers were instituted and taught by the United States occupation forces under General Douglas MacArthur. Although CGS seminars were ended in 1974, both MTP and TWI are still widely taught today in Japan. [11]

Ironically, US firms in favor of mass production methods necessitated by the war were abandoning these organizing business principles that were largely developed in the United States by the likes of Henry Ford and others. The fact that manufacturing flexibility is a must for satisfying the specific consumer was temporarily lost to the US leaders of industry.

Some of the same flexible production technologies that had been recently developed in the US were now being handed over to the Japanese who were facing serious issues such as limited; resources, space, work force and market size. It was thought that the production methods being taught to the Japanese were probably a good fit for the craftsmanship minded culture. At the same time, the US was facing an abundant domestic market and chose to maintain their current work practices in favor of the quality minded lean initiatives.

The typical lean organization has two building blocks as its foundation. First, identifying waste in typical operational areas like: work standardization, batch reduction, WIP (work in process) reduction, more productive maintenance, setup reduction, improved housekeeping, visual controls, better design for manufacturability, and better plant layout. Second, Kaizen, which means the relentless quest for a better way, or the daily pursuit of perfection.

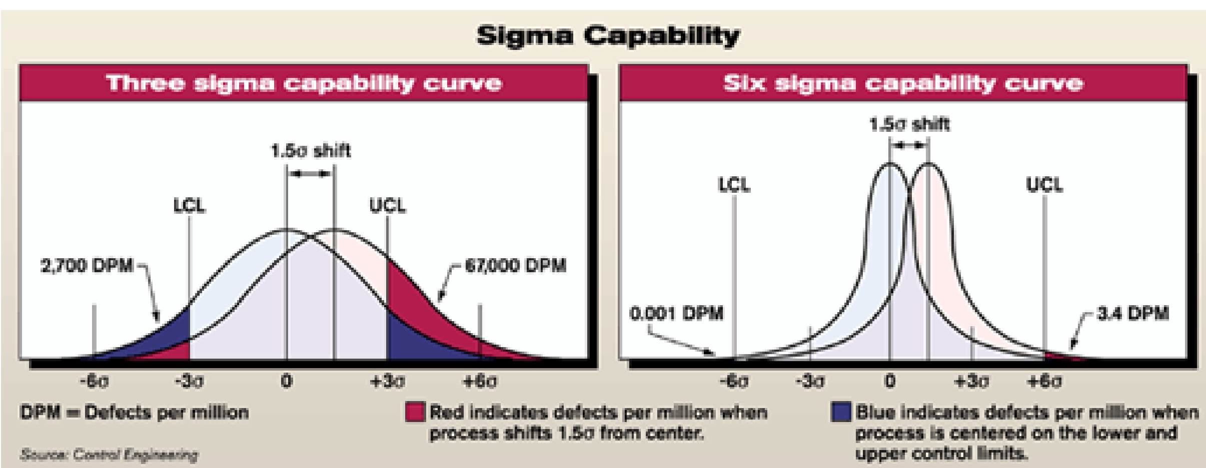
SIX SIGMA DESCRIPTION

Six Sigma - **Six Sigma:** A methodology that provides businesses with the tools to improve the capability of their business processes. The increase in performance and decrease in process variation leads to defect reduction and improvement in profits, employee morale and quality of product. The objective of Six Sigma Quality is to reduce process output variation so that ±six standard deviations lie between the mean and the nearest specification limit. This will allow no more than 3.4 defect Parts Per Million (PPM) opportunities, also known as Defects Per Million Opportunities (DPMO), to be produced.

Visually, Six Sigma would look like this –

Process Sigma Level	Defects per million Opportunities	Quality Yield
1σ	690,000 dpmo	30.9000 %
2σ	308,537 dpmo	69.2000 %
3σ	66,807 dpmo	93.3000 %
4σ	6,210 dpmo	99.4000 %
5σ	233 dpmo	99.9800 %
6σ	3.4 dpmo	99.9997 %

or graphically illustrated –



Graphic courtesy of Blum [12]

SIX SIGMA BACKGROUND

Six Sigma - The roots of Six Sigma (6σ) as a measurement standard can be traced back to Carl Frederick Gauss (1777-1885) who introduced the concept of the normal curve. Six Sigma as a measurement standard in product variation can be traced back to the 1920s when Walter Shewhart showed that three sigma from the mean is the point where a process requires correction. Many measurement standards (Cpk, Zero Defects, etc.) later came on the scene. Incidentally, "Six Sigma" is a federally registered trademark ™ of Motorola. [12]

In 1986, Motorola introduced the concept of Six Sigma to standardize the way defects are counted. Since then, the impact of the Six Sigma process on improving business performance has been dramatic and well documented by other leading global organizations, such as General Electric, Allied Signal, and Citibank. The average level of American companies is 3σ to 4σ. Thanks to the likes of Six Sigma programs at Motorola, quality improved over a period of three years from 3σ to 5σ.

Six Sigma at many organizations simply means a measure of quality that strives for near perfection. Six Sigma is a disciplined, data-driven approach and methodology for eliminating defects (driving towards six standard deviations between the mean and the nearest specification limit) in any process – from manufacturing to transactional and from parts to service.
The statistical representation of Six Sigma describes quantitatively how a process is performing.

To achieve Six Sigma, a process must not produce more than 3.4 defects per million opportunities. A Six Sigma defect is defined as anything outside of customer specifications. A Six Sigma opportunity is then the total quantity of chances for a defect. Externally, the original intent of Six Sigma was to reduce process variations. Internally, Six Sigma uses an improvement methodology that consists of five steps. The DMAIC-circle visualizes this methodology. DMAIC means **D**efine, **M**easure, **A**nalyze, **I**mprove and **C**ontrol. There is a clear analogy with the Plan-Do-Check-Act quality circle found within the work of Dr. W. Edwards Deming.

FINDINGS IN INDUSTRY

(Presented in simplified format)

Integrating the three tools –

- Build the system's foundation using ISO principles
  - A chronological approach – ISO them Lean then Six Sigma
  - Documentation structure of the process
- Stretch the process applying Lean Manufacturing practices
  - A logical flow of processing results in superior performance
  - Physical layout of the process
- Solve the problems of deviation from the stated standards
  - A quantitative approach to decision making will prove sustainable
  - Watch the "deltas" process changes
- Ensure maintenance of the improved status using Six Sigma programs
  - A strong follow through mentality will keep the project on-going
  - Statistical verification of the process

Avoiding pitfalls using the three tools –

- If the system and subsequent processes are too ill-defined, stretching them could further damage them. In this case Lean Sigma techniques should be applied to solve some of the top line problems before stretching the processes.

- Apply the documented ISO quality management system to retain the records of events and to track the on-going results.

- Begin with a top-down approach – this will ensure that top management is perceived as the initiator and champion.

- End with a bottom-up continual improvement style – this will ensure that the entire staff has bought into the tools and will continue to use them.

COMPANY 1: AEROSPACE FASTENERS

The blind rivet – and Huck International, Inc. – grew from General Motors' decision to enter the aviation market. By early 1943, the aluminum blind rivet and the pneumatic tool used to install it were ready for commercial production. They were first used at Ford's Willow Run plant in Detroit on the B-24 bomber. Today, **Alcoa Fastening Systems (AFS)** is a leading designer and manufacturer of high-performance, proprietary fasteners and fastener installation systems.

Huck fasteners are designed into nearly every current U.S. and European commercial aircraft and most military aircraft. The company's fasteners are also used in heavy-duty trucks and trailers, automobiles and recreational vehicles, school buses, railroad cars and intermodal freight containers, bridges, mines and commercial buildings.

For more than 50 years, the company Lou Huck founded has been refining his two basic designs: the blind rivet and the HUCKBOLT®. Today, Huck International has 1,600 employees and plants in Arizona, California, Texas, New York, France and England. Huck's fastener catalogs show more than 900 part numbers. All of it grew from Lou Huck's drive to find an easier way to put rivets in airplanes.

Huck is pursuing commercial business growth through product innovation, market development and diversification, and selected acquisitions.

(The author has worked with the: Tucson, AZ & Carson, CA facilities)

The case study in Appendix A shows a lean sigma effort in Carson, CA

COMPANY 2: PLASTIC EXTRUSIONS

Southern Plastics Company was founded in 1941 at the time the plastics era was just starting to come of age. Following World War II, the company continued to expand. Today, **Bunzl Extrusion plc (BUNZL)**, has over 20 extruders producing both sheet and profile products in a modern 140,000 sq. ft. facility located in West Columbia, South Carolina. A subsidiary of Bunzl plc, a $4 billion public corporation located in London, Bunzl Columbia is the largest of its plastic extrusion operations.

Sister companies are located in Massachusetts, Illinois, Arizona, Washington and Pennsylvania. Collectively, this group is considered one of the top five custom profile extruders in the U. S. In addition, Bunzl Extrusion has manufacturing operations in Mexico and Holland.

Bunzl Columbia is a world leader in extruded Lighting Diffusers and is prominent in the Signs and Display market. Bunzl Columbia's custom designed extrusions are supplied all over the country to such diverse markets as the Refrigeration, Home & Office and Recreational markets.

(The author has worked with the: Phoenix, AZ, Columbia, SC & Philadelphia, PA facilities)

The case study in Appendix B highlights a lean sigma effort in Columbia, SC

CHARACTERISTICS OF SUCCESSFUL INTEGRATION

As demonstrated by the previously cited two companies (see appendix A & B), it is possible to be ISO certified and successfully introduce lean sigma concepts into your business environment. Several good ideas can be learned from these two companies for successfully integrating ISO, Lean Manufacturing and Six Sigma. Below is a list of the prevalent themes from both case studies. The company representative from each of the two companies addressed these concepts in some form.

- Get Top Management Involved (early)
- Don't Make Documentation Too Specific (value-added)
- Integrate Quality and Lean (lean sigma)
- Quality and Lean Work Together to Show Employee Benefits (consistency)

Both companies listed above have found a way to get top management to champion their programs. One of the best examples is Company 1 (AFS) which has its senior manager named ISO Management Representative. Top Management acceptance and visible commitment will lead to greater employee participation.

Although the documentation requirement in ISO 9001:2000 has been lessened from the ISO 9001:1994 standard, how a company documents its process can be very important. The document writer needs to make sure they do not write the documents too specifically so as to make it harder to implement/maintain lean concepts.

Both companies are using their lean programs to fulfill an ISO 9001:2000 requirement. By using the three programs in such a way, the success of each program becomes dependent on the others.

Have your quality systems group and lean group work together and show the employees how they benefit from the systems. Not only will this eliminate the stigma of the "dreaded quality department", but it will also help promote the ideas as a company philosophy and responsibility instead of a departmental responsibility.

LEAN SIGMA COMPARED TO ISO

(Limited Comparison Only)

ISO	Lean Sigma
5.2 Customer Focus: Top management shall ensure that customer needs and expectations are determined, converted into requirements and fulfilled with the aim of achieving customer satisfaction.	First principle of lean is start with the customer.
6.2 Human Resources: Personnel who are assigned responsibilities defined tin the QMS shall be competent on the basis of applicable education, training, skills, and experience. Training needs shall be identified, training provided, and training evaluated for effectiveness.	Lean has a major stress on cross training and an operator's ability to do several jobs, not only one.
6.3 Facilities: The organizations hall identify, provide, and maintain the facilities it needs to achieve the conformity of product including workspace and associated facilities, equipment, hardware, and software, and supporting services.	5S
6.4 Work Environment: The organization shall identify and manage the human and physical factors of the work environment needed to achieve conformity of product.	5S (sometimes termed 6S to include safety)
8.5 Improvement: The organization shall plan and manage the processes necessary for the continual improvement of the QMS, take corrective action to eliminate the cause of nonconformities in order to prevent the recurrence, and identify preventative action to eliminate the causes of potential nonconformities to prevent the occurrence.	Many companies are using lean sigma to fulfill this requirement. Mistake Proofing Method Sheets

Source: Ms. Kristin Marshall

SOURCES OF INFORMATION

Web Sites:

01) ISO – http://www.iso.ch/iso/

02) Lean – http://www.factorylogic.com/

03) Six Sigma – http://www.sixsigmaforum.com/

Case Study References:

04) Mr. Bill Carrigan, VP operations – Alcoa Fastening Systems Carson, CA

05) Mr. Simon Tan, Focus Factory Manager – Alcoa Fastening Systems Carson, CA

06) Mr. John Kemmer, Project Manager – Alcoa Fastening Systems Tucson, AZ

07) Mr. Tom Husky, VP Operations – Bunzl Extrusion Columbia, SC

08) Mr. Joe Marple, Engineering Manager – Bunzl Extrusion Columbia, SC

09) Mr. Brian Harris, Project Manager – Bunzl Extrusion Columbia, SC

Background Research:

10) ISO – International Organization fro Standardization, Geneva, Switzerland

11) Lean –The NIST-MEP Lean Network

12) Six Sigma - Motorola University, Blum & iSixSigma

Reference Books:

13) Lean Thinking, Womack & Jones, Simon & Schuster, 1996

14) Learning to See, Rother & Shook, Lean Enterprise Institute, 1999

15) The Machine That Changed the World, Womack, Jones & Roos, Harper Perennial, 1990

16) Toyota Production System, Ohno, Productivity Press, 1988

17) Pocket Guide – Six Sigma, Brassard, Finn, Ginn & Ritter, Goal/QPC, 2002

18) Pocket Guide – Lean Enterprise, MacInnes, Goal/QPC, 2002

19) Pocket Guide – 9000/2000, Peach, Peach & Ritter, Goal/QPC, 2000

APPENDIX – A

Case Study #1 – Alcoa Fastening Systems Carson, CA

Heat Treat Pull System – Process Improvement (Lean Sigma)

1.0 Procedure for the Heat Treat Pull System:

As a means to properly and formally control the WIP in heat treat (and hence lead time), it was important that Alcoa employ a pull system to do this. In this system, heat treat's supplier, the headers, and its customers, the production cells, will be linked through a simple kanban card system. The purpose is to limit the WIP and also the integrity of FIFO (first-in-first-out) in the entire system.

The success or the failure in a kanban system lies with the use and the integrity of the kanban cards. The key was to balance the variations in their process with the number of kanban cards in the system. The more cards used means more inventories. If the cards were lost or misplaced, Alcoa could be working in an environment with a WIP level that is lower than what the system can support. If this happened, efficiencies will decrease and production targets will be very difficult to meet. On the other hand, if Alcoa finds that the processes were getting more consistent and reliable, they could then reduce the WIP level by removing cards from the system.

Furthermore, the frequent and reliable movement of kanban cards is essential. The water spiders play an immense role in this. These employees must perform their routes consistently and reliably. This system will crash if the cards are not circulated timely and regularly. In any pull system, one always start with the customer, in this case, the production cells. Alcoa also needed to define the move quantities. The attached diagram (see 3.0 below) shows how the system is suppose to work in its normalized state. Please note the following nomenclature:

Move Quantity: Always equal to 1 shift worth of parts. For instance, if Cell 401 has to make 30,000 pcs per day and it runs for 2 shifts, then, its move quantity will be 15,000 pcs. The move quantity can exceed the limit only if it is made up of a bigger work order size (like 25,000) or if the move quantity is made up of several work orders of various sizes (example: 12,500 and a 25,000 work order). The move quantity is to be maintained throughout the system.

Cell Kanban Cards: This is the signal that travels from the cell's queue to the washer and vice versa. When the cells pull a move quantity into its production, they have to release the Cell Kanban Card to the washer. The cell kanban card gives the washer the signal or permission to start on the next move quantity in its queue.

Cell WIP: This is the amount of work-in-process (WIP) that the cell maintains in its queues. It is the factory's decision on what level of WIP to maintain. The more WIP you maintain, the more Cell Kanban cards you use in the system. The drawback is that your manufacturing lead-time increases.

Heat Treat WIP: This quantity is always equal to the move quantity.

Header Kanban card: This is the signal that travels from the washer's queue to the header's queue and vice versa. When the washer pulls a move quantity into its production, they have to release the header Kanban Card to the header. The header kanban card gives the header the signal or permission to start on the next move quantity in its queue.

Header WIP: This is the amount of work-in-process (WIP) that the header is allowed to maintain in its queues. It is the factory's decision on what level of WIP to maintain. The more WIP you maintain, the more Header Kanban cards you use in the system. The drawback is that the manufacturing lead-time increases. But this may be the lesser of 2 evils if you have substantially long setup times.

2.0 Roles and Responsibilities for the Heat Treat Pull System:

In this pull system, there are many "hands" that gets involved with this pull system. It was very important that everyone involved understood his or her roles and responsibilities in this system. They were as follows:

Water Spiders – Very critical for this process
1. MUST not lose the kanban cards. (If lost, please let the planners know)
2. MUST move the kanban cards every 2 hours from cells to wash and from wash to headers.
3. MUST follow Water Spider Standard Operating Procedures (SOP).
4. MUST maintain the integrity of the Move Quantity.
5. MUST maintain the FIFO sequence in both the cell queues and the header queues.

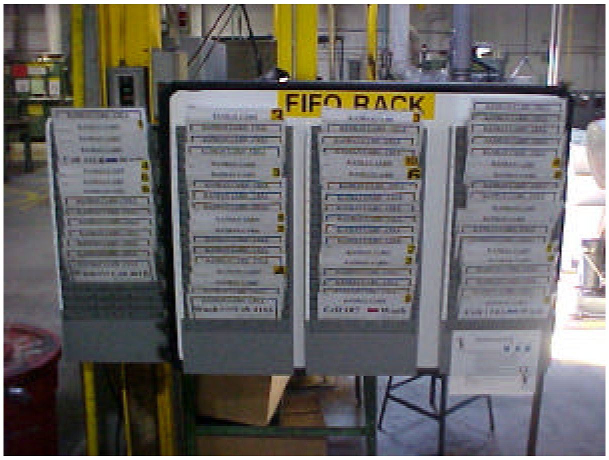
Cell Operators, especially the ones who immediately receive the jobs from heat-treat.
1. MUST maintain the integrity of the Move Quantity.
2. MUST release the Cell Kanban Card **only** when the Move Quantity is broken into.
3. MUST maintain the FIFO sequence in the cell queues.

Headerman
1. MUST head only when header kanban card is available.
2. MUST maintain the integrity of the Move Quantity.
3. MUST maintain the FIFO sequence in the header-out queues.

Planners
1. MUST administer the number of kanban cards in the system.
2. Perform periodic audits of the system.

Heat Treat
1. MUST wash parts according to the order in which the cell kanban cards arrived.
2. MUST maintain FIFO throughout heat treat.
3. Measure daily, the turnaround times from heat treat for Type A, B and C products.

Factory Manager
1. Provide help and resources to the system when needed.
2. Periodic audits of the system.



FIFO (first-in-first-out) Rack at heat treat.
Water spiders place the Cell kanban cards in these racks in the order they were released from the cells.

3.0 Countermeasures for the Heat Treat Pull System:

In the event that the normalized state did not exist for certain cells or for certain portions of the heat treat operation, below are some possible scenarios and its associated procedures.

Point	Symptom	Countermeasures
1	If there is a dramatic increase in the demand from a particular cell.	1. Increase the move quantity to reflect these changes. New Kanban cards must be made to reflect this change. Remember that the move quantity must always be kept to 1 shift's worth of work.
2	If the system is choking itself of inventory and cells and headers are constantly running out of work.	1. This is a sign that the amount of inventory is not sufficient to balance the variations in the process (for instance, if setup times are excessive). 2. Planner could increase the number of kanban cards into the system; thereby increasing inventory and lengthening the manufacturing lead-time. Remember to update the log that track the number of kanban cards in the system. 3. Planners to count the number of kanban cards in the system to ensure that the cards have not been lost/misplaced. Go to point 4 below. 4. Long-term solution is to reduce variation.
3	If the system is constantly having excessive WIP and queue lines are constantly overfilled.	1. This is a sign that there is an excessive amount of inventory for the level of variation in the process (for instance, if the cell is running a steady product and there is little variation in their processes). 2. Planner could decrease the number of kanban cards in the system, thereby reducing inventory and shortening the manufacturing lead-time. Remember to update the log that track the number of kanban cards in the system.
4	Kanban cards are lost	1. The integrity of the kanban cards is critical to the success of any pull system. A periodic audit of the cards must be performed. There can only be a few places where these cards should be. For instance, for the Header Kanban Cards, they are either at the header, the washer or with the water spiders. 2. If it is determined that the kanban cards are lost, a spare one may be injected into the system. Remember to update the log that track the number of kanban cards in the system.
5	Heat treat equipment is down.	1. No change to the system. 2. Heat treat to bring the equipment back on-line ASAP.
6	Some cells are running dry on WIP.	1. Planners are allowed to go to the FIFO rack at the wash to re-prioritize the order of the jobs by re-arranging the order of the kanban cards. Planners are only allowed to arrange the cards that pertain to their factory. 2. If planners require the re-arranging of cards from another factory, both parties must agree before any card can be moved.
7	If there is an AOG or aircraft-on-ground situation.	1. Planners to use the "Hot Job – Aircraft On Ground (AOG) Card" to facilitate parts. Follow instructions on card.
8	If there is a need to pump up inventory (for instance, if you are anticipating a future kaizen or if there is a vacation issue)	1. Planners can treat this condition like as if it was point 1. Increase the move quantity.
Point	**Symptom**	**Countermeasures**

4.0 Production Plan for the Heat Treat Pull System:

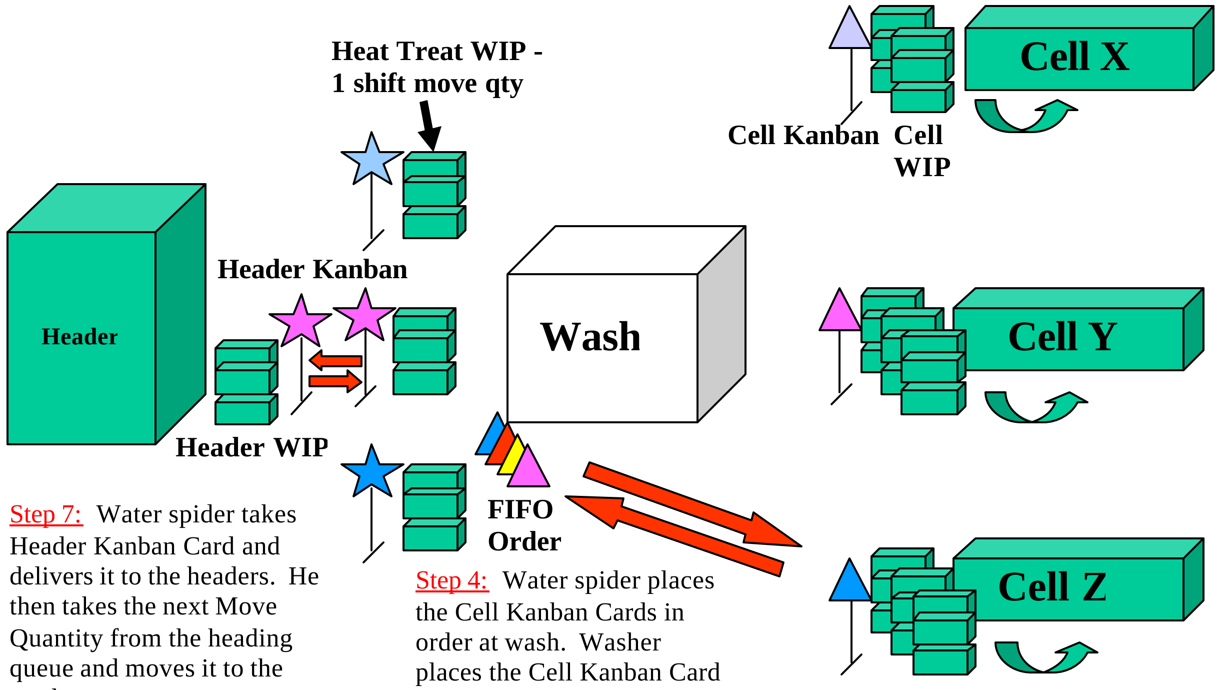
Production Plan for FF100 and FF400

Cells	Headers	Daily Pieces Required	Number of lbs	Number of Shifts In a Day	Type of Heat Treat Process	Move Quantity = 1 shift (or 1 work order)	Number of days of inventory at Cell	Number of days of inventory at header	Number of Cell Kanban Cards In Use	Number of Header Kanban Cards in Use
101A	79	14000	75	1	A	14000	2	2	3	3
101B	87	14000	233	2	A	7000	2	2	5	5
103	79	53000	265	2	A	26500	2	2	5	5
106	84	10000	48	1	C	10000	2	3	3	4
107	85	34000	300	2	A	17000	2	1.5	5	4
110	110	57000	400	2	C	28500	2	3	5	7
148	87	19000	361	2	A	9500	2	2	5	5
401A	86	10000	130	2	A	5000	2	3	5	7
401B	86	10000	130	2	A	5000	2	3	5	7
402	98	22000	176	2	A	11000	2	3	5	7
403	72	32000	96	2	A	16000	2	3	5	7
404	72	32000	96	2	A	16000	2	3	5	7
405	72	22000	110	2	A	11000	2	3	5	7
406	105/106	25000	50	2	A	12500	2	3	5	7
407	105/106	25000	75	2	A	12500	2	3	5	7
408	86	1105	10	2	A	600	2	3	5	7
409	105/106	30000	30	2	B	15000	2	4	5	9
410	107/108	20000	140	2	B	10000	2	4	5	9
		430105	**2725**						**86**	**114**

Type A product through

Header Out and Cell Queue Lines with Header Kanban Posts and Cell Kanban Posts.

5.0 Illustration of the Heat Treat Pull System:



Step 7: Water spider takes Header Kanban Card and delivers it to the headers. He then takes the next Move Quantity from the heading queue and moves it to the wash queue.

Step 8: With Header Kanban Card, headerman heads the next Move Quantity and places parts in queue. The Header Kanban Card is placed with the lead hardback of the Move Quantity.

Step 4: Water spider places the Cell Kanban Cards in order at wash. Washer places the Cell Kanban Card in the lead hardback of the Move Quantity. Washer washes the Move Quantity.

Step 5: Washer places the header Kanban Card in holder.

Step 6: Water spider picks up Header Kanban Card to deliver to the header. This gives the header the license to head new product.

Step 1: Cell pulls a Move Quantity into cell.

Step 2: Cell places Cell Kanban Card in holder.

Step 3: Water spider picks up Cell Kanban Card to deliver to wash.

6.0 Summary of the Heat Treat Pull System for an AOG:

Step 1: Planner places this card with hard back.
Step 2: Headerman heads product and places work order at the start of the washer queue.
Step 3: Throughout heat treat, work order is to go to the front of every queue and it is to be worked on immediately. Kanban systems do not apply to this job.
Step 4: Upon release from heat treat, planner to be notified.

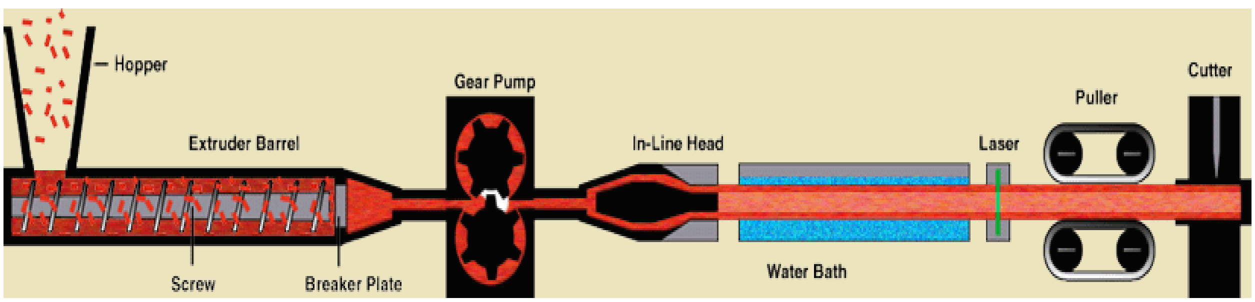
Source: Erik V. Myhrberg & Simon Tan

APPENDIX – B

Case Study #2 – Bunzl Extrusion Columbia, SC

Single Manifold Die to Triple Manifold Die – Process Improvement (Lean Sigma)

Extrusion is a continuous process by which the extruder mixes, melts, and meters the plastic. The melted plastic is then pumped through the desired shape die. Once the formed extrusion leaves the die it is cooled and supported by the water bath. The haul-off equipment pulls the extrusion through the bath. Upon exiting the bath, the plastic piece is solid and can be cut or spooled (see diagram below).



1.0 Background:

A Capital Expenditure (CapEx) request was made for a Triple Manifold Die that would allow Bunzl Extrusion Columbia, SC to extrude AB and ABA capped materials in a more cost effective (lean) manner on current products produced and provide the technical capability to produce target products with the quality demanded by the market.

Bunzl Extrusion Columbia, SC is continually going through internal process improvements in an ever-increasingly competitive global marketplace. There have been losses (low statistical confidence) of large portions of their core business in the lighting and picture glazing industries that will be essentially impossible for them to recoup. In fact, in all likelihood they will continue to lose market share in these areas as foreign competition (competitive advantage) grows.

As Bunzl Extrusion Columbia, SC faces the challenges ahead, it is crucial to their survival that, as a company, they respond swiftly (statistically reduce variation) in order to enhance their manufacturing capabilities. A first proposed step in getting back on track to profitability was to develop new core businesses in markets with greater growth potential. The critical surface co-extruded sheet business will be one of those core competencies.

Presently, however, Bunzl Extrusion Columbia, SC is unable to profitably produce (high statistical variation) this sheet due to limited flexibility in equipment. The key element that they are missing is the ability to produce a consistent co-extruded cap (top layer). Current capabilities require that they typically double the cap thickness in order to meet customer requirements, thus diminishing the product's profit margin. In addition, their dies are not equipped to deckle (reduce the edge trim), thus limiting their ability to make size changes cost effective. Mass yield improvements with automatic deckling technology would add tremendously to their cost savings initiatives.

In addition to cap control and trim scrap control, the die requested would allow for fast gap capability (set-up / change-over) allowing them to make gauge changes of .200" in about 1 hour, whereas they now typically take 12 hours.

The co-extrusion sheet line currently in place has the potential to lead them into profitable new markets. Without a die to match its capabilities, however, we will never see its full potential.

2.0 Proposal:

Two world leaders in the sheet die industry have offered a die that meets all of the requirements for Bunzl Extrusion Columbia, SC to compete in the critical surface co-extruded sheet business. This case study details four key elements.

1) The purchase of a 78" sheet die with three separate flow manifolds for precise control of cap thickness distribution.

2) The proposed die would include fast gap gauge control for "on-the-fly" adjustment of thickness. Currently, operations personnel take an average of 12 hours to make large gauge changes and generate thousands of pounds of unrecoverable scrap. Fast gap would allow gauge changes to be made in about 1 hour with manageable scrap levels that should be reclaimed during that production run.

3) The fast deckle feature is next. This feature will allow operators to change width from 72" to 52", in any increment, in a matter of minutes. The current process requires the line to be shut down to change width or continue to run with higher scrap levels if the order quantity does not justify the time to shut down and re-start.

4) The distribution block would also be required to replace the current co-extrusion block configuration on the line. This is where the operator controls the cap layer configuration (ABA, AB, BA, or monolayer) for flow into the die.

3.0 Marketplace:

This market was recognized by Bunzl Extrusion Columbia, SC several years ago. Based on their knowledge of the market from former accounts and prospective accounts, they believe that they can capture the balance of their line capacity of 5 million pounds without creating price erosion in the market place.

4.0 Cost Summary:

The total capital expenditure for the triple manifold die and spare parts was considered confidential at the time of this case study. The payback period however, was estimated at < 4 months, at current production levels.

5.0 Cost Justification:

Based on historical mass yields and expected improvement, the material losses (in dollars) per pound of production would be dramatically reduced. Additional savings would also be seen with the gauge change capabilities not even included in this case study.

6.0 Summary:

Bunzl Extrusion Columbia, SC now has the manufacturing capability (low statistical variation) to produce 74" wide co-extruded sheet up to .300" thick with two completely different materials in multiple layering configurations. This is possible with the use of the new triple manifold sheet die. Cap layers on these new sheet products can be extruded as thin as .005" on either side or both sides while maintaining cap thickness consistency as low as +/- .001".

The triple manifold was designed with numerous timesaving features that now give Bunzl Extrusion Columbia, SC technical capabilities that are second to none in the sheet extrusion industry. Width and gauge changes that, in the past, typically took 12 hours to make can now be made in 1 hour or less. The die was also designed with color changes in mind. Color changes that used to take over an hour now take less than half that time.

All of this results in time and material savings that will allow Bunzl Extrusion Columbia, SC to provide its expanding customer base with cost-competitive sheet products of the highest quality.

With the additional capabilities (high statistical confidence) the new triple manifold die offers, the Bunzl Extrusion Columbia, SC commercial team will now be able to pursue new business opportunities that offer greater revenue potential.

Note: Management tools employed during this case study included ISO 9001, ISO 14001, Lean Manufacturing and Six Sigma. Each management tool respectively represents quality, environmental, physical distribution and statistical quantification.

Source: Erik V. Myhrberg & Joe Marple

APPENDIX – C – TERMS & DEFINITIONS

ISO - http://www.iso.ch/iso/ [01]

“Certification" and "registration" are used interchangeably in some countries – a practice which reflects different national, or business culture preferences. Likewise, the bodies, which issue ISO 9000 certificates – (certification bodies) –, are referred to in some countries as "registration bodies", or "registrars". Again, these different appellations refer to the same type of body.

"Accreditation" is the procedure by which an authoritative body gives formal recognition that a body or person is competent to carry out specific tasks. In the ISO 9000 or ISO 14000 context, it relates to the work of national accreditation bodies which have been set up in a number of countries to provide some measure of control over the activities of quality system or environmental management system certification bodies.

Audit - A systematic, independent and documented process for obtaining audit evidence and evaluating it objectively to determine the extent to which audit criteria are fulfilled.

Continual Improvement - A recurring activity to increase the ability to fulfill requirements.

Corrective Action - An action to eliminate the cause of a detected nonconformity or other undesirable situation.

Customer Satisfaction - Customer’s perception of the degree to which his/her expectations have been met.

Management system - A set of interactive elements (system) to establish a policy and objectives and to achieve them.

Preventive action - An action to eliminate the cause of a potential nonconformity or other undesirable potential situation.

Process - A set of interrelated or interacting activities, which transforms inputs into outputs.

Product - The result of a process.

Quality - The degree to which a set of inherent characteristics meets requirements.

Quality policy - The overall intentions and direction of an organization related to quality and is expressed by top management.

Lean – http://www.factorylogic.com/ [02]

Demand-driven Manufacturing

Demand-driven Manufacturing is an approach to production where products are made only when actual demand is known, as apposed to Forecast-driven Manufacturing where products are made in advance of actual demand based on a forecast and held in stock until actual orders are realized.

There are a number of variations of what companies consider demand-driven manufacturing, ranging from true 'build-to-order' (BTO) and 'engineer-to-order' (ETO) where no production is done until an order is taken, to configure-to-order (CTO) where certain subassemblies may be built in advance, to hybrid approaches such as 'build-to-replenishment' (BTR) where a pre-determined level of finished goods are stocked for immediate delivery replenished when they fall below a reorder point.

Flow Manufacturing

The production system Henry Ford introduced at his Highland Park, Michigan plant in 1913. The objective of flow production was to drastically reduce product throughput time and human effort through a series of innovations.

These included consistently interchangeable parts so that cycle times could be stable for every job along an extended line, the line itself, the reconfiguration of part fabrication tasks so that machines were lined up in process sequence with parts flowing quickly and smoothly from machine to machine, and a production control system insuring that the production rate in parts fabrication matched the consumption rate of parts in final assembly.

Continuous Flow

Producing and moving one item at a time (or a small and consistent batch of items) through a series of processing steps as continuously as possible, with each step making just what is requested by the next step.

Continuous flow can be achieved in a number of ways, ranging from moving assembly lines to manual cells. It is also called the *one-piece flow, single-piece flow, and make one, move one.*

Just-in-Time Manufacturing (JIT)

The Lean Lexicon defines 'Just-in-Time Production' as: A system of production that makes and delivers just what is needed, just when it is needed, and just in the amount needed. JIT and jidoka are the two pillars of the Toyota Production System. JIT relies on heijunka as a foundation and is comprised of three operating elements: the pull system, takt time, and continuous flow.

JIT aims for the total elimination of all waste to achieve the best possible quality, lowest possible coast and use of resources, and the shortest possible production and delivery lead times. Although simple in principle, JIT demands discipline for effective implementation.

The idea for JIT is credited to Kiichiro Toyota, the founder of Toyota Motor Corporation, during the 1930's. As manager of the machine shop at Toyota's main plant, Taiichi Ohno said his first steps toward achieving JIT in practice came in 1949-50. (Ohno 1988, p.31)

Pull-based Manufacturing

The Lean Lexicon defines 'Pull Production' as: A method of production control in which downstream activities signal their needs to upstream activities. Pull production strives to eliminate overproduction and is one of the three major components of a complete Just-In-Time production system.

In pull production, a downstream operation, whether within the same facility or in a separate facility, provides information to the upstream operation, often via a kanban card, about what part or material is needed, the quantity needed, and when and where it is needed. The upstream supplier process produces nothing until the downstream customer process signals a need. This is the opposite of push production.

There are three basic types of pull production systems: Supermarket Pull System, Sequential Pull System and Mixed Supermarket and Sequential Pull System

Supermarket Pull System

The most basic and widespread type, also known as a *fill-up* or *replenishment* or *a-type pull system*. In a supermarket pull system each process has a store-a supermarket-that holds an amount of each product it produces. Each process simply produces to replenish what is withdrawn from its supermarket. Typically, as material is withdrawn from the supermarket by the downstream customer process, a kanban or other type of information will b e sent upstream to the supplying process to withdraw product. This will authorize the upstream process to replace what was withdrawn.

Each process is responsible for the replenishment of its supermarket, so daily management if the worksite is relatively simple and kaizen opportunities are relatively easy to see. The disadvantage of a supermarket system is that a process must carry an inventory of all part numbers it produces, which may not be feasible if the number of part numbers is large.

Sequential Pull System

A sequential pull system-also known as a *b-type pull system*-may be used when there are too many part numbers to hold inventory of each in a supermarket. Products are essentially "made-to-order" while overall system inventory is minimized.

In a sequential system, the scheduling department must set the right mix and quantity of products to be produced. This can be done by placing production kanban cards in a heijunka box, often at the beginning of each shift. These production instructions are then sent to the process at the upstream end of the value stream. Often this is done in the form of a "sequence list", sometimes called a "sequential tablet". Each following process simply produces in sequence the items delivered to it by the preceding upstream process. FIFO of individual products must be maintained throughout.

A sequential system creates pressure to maintain short and predictable lead times. In order for this system to work effectively, the pattern of customer orders must be well understood. If orders are hard to predict, production lead-time must either be very short (less that order lead time) or an adequate store of finished goods must be held.

A sequential system requires strong management to maintain, and improving it may be a challenge on the shop floor.

Mixed Supermarket and Sequential Pull System

Supermarket and sequential pull systems may be used together in a *mixed system*-also known as a *c-type pull system*. A mixed system may be appropriate when an 80/20 rule applies, with a small percent of part numbers (perhaps 20%) accounting for the majority (perhaps 80%) of daily production volume. Often an analysis is performed to segment part numbers by volume into (A) high, (B) medium, (C) low, and (D) infrequent orders. Type D may represent special order of service parts. To handle these low-running items, a special type D kanban may be created to represent not a specific part number but rather an amount of capacity. The sequence of production for the type D products is then determined by the method the scheduling department uses for sequential pull system part numbers.

Such a mixed system enables both supermarket and sequential systems to be applied selectively and the benefits of each are obtained, even in environments where the demand is complex and varied. The two systems may run together, side by side horizontally, throughout an entire value stream, or may be used for a given part number at different locations along its individual value stream.

A mixed system may make it more difficult to balance work and to identify abnormal conditions. It can also be more difficult to manage and conduct kaizen. Therefore, strong management is required to make a mixed system work effectively.

Toyota Production System (TPS)

The Lean Lexicon defines The Toyota Production System as:

The production system developed by Toyota Motor Corporation to provide best quality, lowest cost, and shortest lead time through the elimination of waste. TPS is comprised of two pillars, Just-in-Time and Jidoka, and is often illustrated with the "house" shown below. TPS is maintained and improved through iterations of standardized work and kaizen, following PDCA, or the scientific method.

Six Sigma – http://www.sixsigmaforum.com/ [03]

1.5 -sigma shifts and drifts: The theory that over time any process in control will shift from its target by a value of up to 1.5 sigma. Allowing for the 1.5 sigma shift results in the generally accepted six sigma value of 3.4 defects per million opportunities. Ignoring the 1.5 sigma shift results in a six sigma value of 2 defects per billion opportunities.

Acceptable quality level (AQL): In a continuing series of lots, a quality level that, for the purpose of sampling inspection, is the limit of satisfactory process average.

Baseline measurement: The beginning point, based on an evaluation of the output over a period of time, used to determine the process parameters prior to any improvement effort; the basis against which change is measured.

Capability analysis: The statistical comparison of the actual performance of a process with its specification limits. "Capable" systems perform completely within specification limits as established by customer requirements.

Cost of poor quality (COPQ): The costs associated with providing poor quality products or services. There are four categories of costs: internal failure costs (costs associated with defects found before the customer receives the product or service), external failure costs (costs associated with defects found after the customer receives the product or service), appraisal costs (costs incurred to determine the degree of conformance to quality requirements) and prevention costs (costs incurred to keep failure and appraisal costs to a minimum).

Defect: A product or service's nonfulfillment of an intended requirement or reasonable expectation for use, including safety considerations. There are four classes of defects: class 1, very serious, leads directly to severe injury or catastrophic economic loss; class 2, serious, leads directly to significant injury or significant economic loss; class 3, major, is related to major problems with respect to intended normal or reasonably foreseeable use; and class 4, minor, is related to minor problems with respect to intended normal or reasonably foreseeable use (see also "blemish," "imperfection" and "nonconformity").

Defects per million opportunities (DPMO): The actual number of defects occurring divided by the total number of opportunities for a defect and multiplied by 1 million. Also referred to as ppm (parts per million).

Eighty-twenty (80-20): A term referring to the Pareto principle, which was first defined by J. M. Juran in 1950. The principle suggests most effects come from relatively few causes; that is, 80% of the effects come from 20% of the possible causes.

Five Ss: Five terms beginning with "S" utilized to create a workplace suited for visual control and lean production. *Seiri* means to separate needed tools, parts, and instructions from unneeded materials and to remove the latter. *Seiton* means to neatly arrange and identify parts and tools for ease of use. *Seiso* means to conduct a cleanup campaign. *Seiketsu* means to conduct *seiri*, *seiton*, and *seiso* at frequent, indeed daily, intervals to maintain a workplace in perfect condition. *Shitsuke* means to form the habit of always following the first four Ss.

Five whys: A technique for discovering the root causes of a problem and showing the relationship of causes by repeatedly asking the question, "Why?"

Hawthorne effect: The concept that every change results (initially, at least) in increased productivity.

Just-in-time (JIT) manufacturing: An optimal material requirement planning system for a manufacturing process in which there is little or no manufacturing material inventory on hand at the manufacturing site and little or no incoming inspection.

Kaizen: A Japanese term that means gradual unending improvement by doing little things better and setting and achieving increasingly higher standards. Masaaki Imai made the term famous in his book, *Kaizen: The Key to Japan's Competitive Success*.

Kanban: A Japanese term for one of the primary tools of a just-in-time system. It maintains an orderly and efficient flow of materials throughout the entire manufacturing process. It is usually a printed card that contains specific information such as part name, description and quantity.

Mean: A measure of central tendency; the arithmetic average of all measurements in a data set.

Mean time between failures (MTBF): The average time interval between failures for repairable product for a defined unit of measure; for example, operating hours, cycles and miles.

Noise: Inputs that cause random and expected process variation. Noise factors are usually the unknown source of variation and are not controlled.

Poka-yoke: Japanese term that means mistake-proofing. A *poka-yoke* device is one that prevents incorrect parts from being made or assembled or easily identifies a flaw or error.

Range chart (R chart): A control chart in which the subgroup range, R, is used to evaluate the stability of the variability within a process.

Sample standard deviation chart (S chart): A control chart in which the subgroup standard deviation, s, is used to evaluate the stability of the variability within a process.

Takt time: The rate of customer demand. Takt is the heartbeat of a lean system. Takt time is calculated by dividing production time by the quantity the customer requires in that time.

Upper control limit (UCL): Control limit for points above the central line in a control chart.

Value stream mapping: A pencil and paper tool used in two stages: 1. Follow a product's production path from beginning to end and draw a visual representation of every process in the material and information flows. 2. Then draw a future state map of how value should flow. The most important map is the future state map.

X metric: Measurable independent input factors that determine the outcome (Y) of a process. Six Sigma focuses on process X's to improve process output.

Yield: The percentage of defect-free units produced.

Zero defects: A performance standard and methodology developed by Philip B. Crosby that states if people commit themselves to watching details and avoiding errors, they can move closer to the goal of zero.