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Synchronization Context, Lean Six Sigma

A model to help facilitate what is being discussed in this tool is shown nearby, identified as the Lean, Six Sigma, Quality Transformation Toolkit (LSSQTT). While not a pure model for production, the LSSQTT is a blend of QMS and production elements. Based heavily around the QMS, the LSSQTT is an integrated process and system design, implementation and sustainability model.

As has been established previously, the LSSQTT model describes how to add value in the process of producing products. The description as a model is deliberate to help illustrate integration of individual principles within a holistic system. Each part is not fully functional as an individual entity, and the resulting integrated model is one that is greater than the sum of its individual elements. The LSSQTT is also a functional courseware designed to help define and do continuous improvement and change organizationally, within a context of the QMS. The LSSQTT courseware provides a template for organizations wishing to transform and change the collective culture, through workers.

The essential technological function related to the current discussion is production, a basic requisite for making a profit within the context of change and improvement. The technological change model illustrates production and change based on data and documentation. Production functions, as part of the change model, provides the opportunity to isolate transformations, or processes. While the broader model has technical teams, data, documentation and synchronous leaders at the center, current interest is the act of production, critical to financial survival.

Data, documentation and leadership must be synchronized for production to happen competitively. Processing is pivotal to production, built on information relevant to solving problems. Not only is process a requisite to production, but it is where much opportunity for improvement lies. Variation in process must be reduced to bring, and keep, production under control.

Production is defined as continuous or intermittent. Intermittent is also called job-lot. Continuous production is "Detroit" style, with assembly lines and high lot-size volumes, lines highly dependent on the other, with highly specialized work tasks and dedicated equipment. Job-lot, or intermittent, can be single person production, cottage industries, construction of one-of-a-kind structures, or a manufacturer, building a small lot of the same product. Intermittent production may use general purpose process, requiring functional, predictable, qualified, scheduled and managed for optimal outputs. Intermittent production is also called custom, particularly in construction or manufacturing. Intermittent uses general purpose, non-dedicated processes. Workers in intermittent production operate many different machines, providing flexibility.

Continuous, or "Detroit", production is contrasted to intermittent. Each process, specialized and dedicated, is contingent on the others. Before a process can proceed, the previous process must be completed, in sequential order. This requires operations at each process to have predictable and
pre-determined levels of production with minimal defects and wasted product. Continuous production is organized using assembly lines or work cells and mass production techniques for producing large numbers of product. Just in time (JIT) production relates to continuous processes reducing lead times, inventories and costs, tightly scheduling work in process (WIP). People working in continuous production specialize, running one or two machines. This is changing due to broad job descriptions, work cells, and teams, consistent with JIT. Continuous production machines perform special operations, not general purpose work, usually fixed in position and fixed-path, not easily or frequently moved.

The key in synchronous production is that we acknowledge that there will be various types of products and production occurring, yet we must align all work and balance the flow. Regardless of size of lot, nature of the product order, sequences required to produce, or type materials, we must manage the effort to have a balanced flow of productive outputs. This is the heart of lean and kaizen: continuous improvement through waste and variation reductions.

**Synchronous, Best Practices, Summarized.**

This briefly discusses the substantial impact being felt from the Japanese, within the synchronous context. This acknowledges that much about the “lean” environment is rooted in Japanese culture. This is being felt in many ways, predominantly competitiveness and balance of trade issues, often manifesting itself as competition, change, or worst case, loss of jobs. Regardless of impacts, we must better understand Japanese synchronous methods. Emphasis is data and documentation; Kaizen, simplicity, and waste reduction methods; Poka Yoke, just-in-time (JIT) inventory reduction; failsafing, benchmarking, auditing; total productive maintenance; designed experiments and applied research.

**Data And Documentation As The Base.** One of the key points related to synchronous functions, and production, is that data and documentation form the base of all else. The enhanced tools and approaches being discussed in tool E are best pursued in an environment of success with data-based tools that are being well documented in mature and systematic ways. Realistically, competition continues to evolve in such a way that requires organizations to continuously get better at making improvements. This is true since theoretically there is less and less area for improvement. Over time, as we conduct projects, we must do better with the way we pursue and implement projects, if we wish to remain competitive.

The implementation of synchronous concepts, waste elimination, and all other efforts toward continuous improvement require problem solving prowess. The creativity required to ask the right questions, look at the right problems and see them differently is something that is a must for real WC success. Real improvements are incremental, implemented in a systematic, continuous, program which engage all persons in a team based technical problem solving infrastructure.

**Discipline.** People must be consistent, systematic, and alert to opportunities for improvement. Being the best does not come by accident, requiring disciplined and systematic approaches to incremental improvement. Details are a key driving force in all Japanese approaches. No matter which technique, all point to the need to continually ask why, why, and why? The five why's are designed to net additional details for analysis--commonly in the form of information as data documented over time. Details ultimately convert to cost reductions for enhanced competitiveness.

**People.** People are important in the system--but it is assumed that their brain is fully engaged and focused on work at hand--with the organization and co-workers being of prime importance. Effective workers do not leave their brains outside the plant when they arrive each day--brains must be engaged:

- Listening to, using input from, operators and teams, striving for continuous improvement;
- Assuring employment security and long term relationships; and,
- Long term supplier relationships based on certifiable quality, internal and external.

**Technological simplicity and waste reduction.** Waste reduction and simplicity are cornerstones of the techniques. If it can be done satisfactorily with an older piece of equipment or with modest change to the system, it is OK--and should be encouraged. The simpler approach will generally be the more acceptable, based on documented and justifiable data and information--ultimately cost driven data.

- Emphasize product performance based on strong customer demands and specifications;
- Establish preventative maintenance programs in a context of total productive maintenance;
- Strive for simplicity in all that we do, based around group technologies; and,
- Use "high tech" only where quality is demonstrably improved;
Inventory issues. Best practices has much to do with reducing inventory to the bare bones. This saves on stock and makes less clutter and better housekeeping. Other inventory related specifics are:

- Reducing set-up and changeover times;
- Zero inventory, stockless production;
- Using pull systems based on Kanban;
- Focused sub-plants around products; and,
- Uniform load, balanced production;

Controlling quality. Quality is important as best practices. This has to do with the previously identified philosophical points, noted as:

- Control quality at the source of production based on visual inspections and poka yoke;
- Strong SOP's assuring standard procedures for operators and others in production;
- Making decisions based on documented data that we all believe in; and,
- Monitoring process and results for variation reduction on critical characteristics.

Change. Change is expected in best practices. This is planned for and built in by design in virtually all that is being done, based on improved conditions in production. Change is essential to any organization wishing to remain competitive. Ongoing improvements are generally knowledge based, and tied to technology. Implementation of change requires leadership at various levels. Although top leadership is critical, this will not see the change through. The most important leader is thought to be the supervisor, particularly the front line supervisor.

Lean Six Sigma Systems Applied: Kanban, Takt, SMED

Continuing the earlier discussion, another way to define production is push or pull. Push production systems are where processes are driven or controlled by traditional schedules and inventorizing systems. Demand for product is not a key factor and products are stockpiled, pushing inventories toward a maximum capacity. This provides a stable and "automatic" production scenario where quality may be easily achieved but productivity is left wanting. Fat is designed into the system to help cover shortfalls, mis-management, oversights and waste. All processes require inventory to cover and hide waste, to have plenty on hand at any given moment. In many cases this may be essential, but it costs dollars and reduces competitiveness. Push contrasts to pull systems where orders or demand determine production schedules, even to the extent that daily production runs may change based on the need for "special" products.

Kanban. The key differences in push and pull systems lie in pull requiring greater flexibility and reduced lead and set-up time, as well as reduced inventories. Pull is often referred to as just in time (JIT), or in Japan, a Kanban system. Push systems may be the lessor well planned while pull uses detailed material requirement specifications shown with materials and components in production. Push represents traditional industries which evolved without careful planning and detailed analysis while pull systems are the more recently designed approach. Pull production requires an order or request for product, leading to a "pull" through the process by request. Synchronous techniques are pivotal to better production, requiring elements of push and pull. Push is easier to start and transition to pull production as we enhance efficiency. We typically begin as intermittent and move toward continuous production as volumes go up, costs down.

Kanban order-based production is achieved through pull systems, where demands of the market are pulling the act of production. The orders drive production, and rather than being pulled from a warehouse full of other stock, the orders are being filled all along the production line. This is different from conventional systems which feed a warehouse to build inventory, or push production. Product is literally pulled through the production line and production schedules are determined by demand. The production system used is determined by market projections or customer demands. The kanban signals need to be pulled from one part of production to another may be totes that are full or empty, lights that go on or off, some type of tagging system, or other ways to communicate in straightforward ways that we are ready to go to the next station to demand production.

Producers may not have the luxury of choosing large lot or mass production, as dictated by market. But we can mass produce in small lots, shorten the production cycle, and reduce the need for mass or speculative production. This generally produces more models in smaller quantities, mixed model production. Mixed model production in assembly is made possible by rapid setup and changeover. Work in process (WIP) is reduced through small lot production based on kanban orders. Consistent flow from parts to assembly is accomplished when production takes place in small lots. Small lots create a continuous or one-piece flow from one process to another, all based on kanbans.
WIP is reduced to a minimal level required as smaller lot sizes are introduced. More changeovers and setups for different mixes of production are required—and these must be done in highly efficient ways.

Segmented production refers to distribution or breakdown of work load to eliminate unnecessary inventory. The production is segmented into monthly, semi-monthly, weekly and daily production scheduling. By knowing the demanded production load from either market forecasting or actual orders, we are better able to divide production into different segmented lots. Small lot production and shortened production cycles must be in place to achieve production to kanban orders. Shortened setup times must be sought in order to reduce lot size. This also relates to leveling, or Nagara, used for balancing in synchronous production. Layout to achieve small-lot production must be flexible, compared to fixed path mass production, all aimed at the balanced production, lean environment.

Waste reduction, takt analysis. The objective of the synchronous system is the elimination of waste, any operation which does not add value to product. Waste takes on many forms, reducing efficiency, typically classified into: overproduction, delay, transport, processing, inventory, wasted motions, and defective products. Identification is the primary step in elimination of waste. When we see an operation not adding value it can and must be changed to improve. This relies on understanding differences inherent in process and operation. Process relates to the material being worked on or transformed. There are four categories of process: processing, inspecting, transporting, and storing. Operation refers to actions done on the product by a machine or worker. Processes combine operations for synchronization.

Processing, inspecting, transporting and delays are given symbols when used in a process flow chart to analyze production activities. Process improvements result from a combination of time study, flow charting and analysis of standard procedures. Operators, and others, write SOP’s, to: force workers to look at each movement objectively; and provide supervisors and teams with concrete procedures for training workers. As time, flow and procedures are documented, waste is flushed out.

Muda, Mura and Muri are all key Kaizen wastes. The most common and significant form of waste was Muda. Muda was identified as waste in:

- Overproduction.
- Inventory.
- Transportation.

Overproduction produces excess inventory, taking away from other activities which could be done in Gemba, the work area. Inventory wastes by costing to carry, using warehousing space, taking away from lean production. Transportation wastes by not adding value to perform. Waiting wastes since it provides work in process (WIP) or other down time in process. Motion without added value is waste since it does not necessarily result in product. Over-processing wastes, building beyond customer specifications. Correction, perhaps necessary, is to be avoided.

Mura is unevenness in production. Identified as imbalances in the line, where multiple machine or processes are a part of the larger operation, if the machines are not properly sequenced and grouped, the outputs will not converge in an efficient and balanced manner. Mura, an imbalance, results in waste by causing inventory to build at one location and shortages elsewhere, confusion and lost good will due to poor planning and management. Mura also often accompanies the final waste, Muri, or strain. Muri is confusion and strain associated with Mura, primarily due to imbalances and poor planning. Muri is overwork due to poor planning and management--making up for weaknesses in the system.

Related to waste analysis, takt time was a target value based on the average of all work capacity or cycle times of processing. For example:

- Operator 1 = 50 seconds.
- Operator 2 = 40 seconds.
- Operator 3 = 60 seconds.
- Operator 4 = 70 seconds.
- Operator 5 = 30 seconds.

Operator cycle times added together show total process time at 250 seconds, a mean takt time of 50 seconds. Based on takt time, working to identify Muda reduces takt time from 50 seconds to a lower and more efficient level. A larger takt calculation, if, based on 8 hours of production, 16 units are produced, we would say the average production takt time per hour is 2 units. By knowing the takt target, 2 units per hour, we can analyze and improve balancing issues using various worksheets shown nearby.

Standardized work relates to the previous Kaizen elements by reflecting a well organized and
balanced flow of work in Gemba. After removal or reduction of muda, leading to takt time reductions, mura and muri balanced for even work flows, and other indications of standardized work in process, we can reflect this all in a standard work sheet, or standard operating procedure (SOP). Standard procedures must be clearly visible, including information discussed relating to conditions of waste, takt and so on. These are commonly prepared with strong input from operators in Gemba, or else they will likely be ignored. Safety, quality tips, and other process flow information is included as graphical and easily understood guides to help standardize for all.

**Multi-Machine, Multi-Process Handling.**

Rather than one dedicated worker to a single machine, the synchronous concept is one of workers capable of operating several machines simultaneously. This maximizes efficiency by having fewer persons doing more jobs. Group technology tends to provide similar gains especially as automation becomes more prevalent. Capital equipment depreciation eventually gives a company relatively “free” use of a machine, but an operator must be paid indefinitely and wages will rise over time. The worker is carrying out tasks more efficiently, and more of them. Multi-process handling is similar to the multiple machine handling concept, but instead the worker is performing two or three (or more) successive operations which previously would have been performed by three separate workers. This is analogous to groups or families of parts, or operations warranting combining.

The advantage lies in eliminating waiting time between operations, waste. This is done since it eliminates motions executed for temporary storage between processes. It can also absorb line imbalances when per-piece processing times differ from one process to another. Demand fluctuations can be simplified by increasing or decreasing the number of machines for which a single worker is responsible. One of the keys to handling multiple machines or pieces of equipment is automation. This is a blend of mechanization and automation where equipment can be left to run once started. Based on known cycle times and rates of production, equipment can be balanced with other production elements, and productivity can be enhanced. Operators tend to the equipment is running. The SMED system relies on the ability to turn internal into external, thereby eliminating waste, done by following four principles:

1. Identify, shift, internal and external setup.
2. Use one touch, quick release, devices.
3. Eliminate adjustments.
4. Identify, reduce margin allowances.

Each is discussed in the following paragraphs.

**Identify, shift, internal to external setup.** We must separate and distinguish between internal setup (when equipment is shut down) and external setup (when equipment is running). Obviously, we must convert as much internal setup to external as possible. Setup should be done nearby while equipment is still producing product. This means pre-heating molds while the machine is running, prior to changeover, and shortening the steps between getting one mold out of the machine and the other one in. This shift is achieved, in part, through use of devices and systems which encourage quick changeover and parallel operations, most which are discussed in this and other tools. Parallel operations explain the balanced approach to production, providing changeover (or other) functions roughly equal to the processing time consumed in a cycle of an operation.

**One touch, quick release, devices.** Intermediary jigs are attachments and quick release devices which are common from one transfer to the other as quick and smooth as possible. They are "universal" in nature, and more readily accommodate multiple setups, again reducing waste. Functional, or alternative, clamping devices can also reduce changeover time. These include one-turn, one-motion and one-touch clamping devices. When an operation relies on a screw-type clamping device the only time you are tightening the clamp is on the last turn and the only time you are loosening the screw is on the first turn, so all the other turns in between are wasted. Efficient clamps tighten and/or loosen in one move.

**Reduce operator adjustments.** We must reduce, or eliminate, the tweaking of adjustable settings that goes on between setups which insure that the machine will run properly. Elimination of
adjustments will come, to a large extent, through providing the disciplined and consistent approach being reviewed in all tools in the toolkit. Primary methods for reducing adjustments come through SOP’s and automatic controls, with some judgment by operators removed.

Eliminate over production, Nagara. Over production is making more parts or product than are needed to fill customer demands. This is viewed as waste rather than prudence in synchronous production systems because the extra parts are inventory, a cardinal mistake. Early overproduction on the other hand is as is implied: making products before the customer requires them. This is waste since unneeded inventory is created, value is lost.

When implementing the use of single lot production this principle alone can dramatically reduce production time. The real savings are realized when multiplying the amount of production time eliminated by the number of parts produced. Four principles used to realize single lot production are:

- Level production lots, synchronize process.
- Reduce transportation of lots.
- Improve layout, accommodate frequent lots.
- Reduce lot size to one.

Each of these principles will be further discussed below within the context of ongoing improvement.

Leveling production lots, synchronizing process, means using data gathered during production to demonstrate imbalances in process. The aim is to redistribute processes and functions to provide better balance in the total production sequence. Leveling processes and production is accomplished by reduction in transport lot size, improvements in layout, and reductions of lot size to one. Each lot in production should be reduced to the bare bones necessary to sustain the individual and total process. This will reduce confusion and activity in the actual production scenario, leading to seeing more clearly other problems and circumstances which require adjustment. Each lot should be reduced to one, facilitating minimum requirements at a given transport opportunity. Smaller lots make for an easier flow of product and in itself serves to facilitate the synchronization and leveling of process.

As the number in each lot goes down, the frequency of movement will tend to go up. It is intended that we will work against this natural shift upward in occasions of transport, although it will be difficult. Part of the waste to be fought against is in this "tension" among transport opportunities of lot size and occasions of movement. The overall intention in approaching single lot production, is to reduce WIP, and inventory overall, reducing costs of inventory and clearing confusion in production for greater efficiency--translating into better productivity and quality. While theoretically this is quite possible, obviously theory does not always translate into real gains. The way we evaluate and analyze the theoretical potential and actual gains is through the use of data tracked and collected with various documentation forms and Kaizen systems provided throughout the toolkit. Based on data and other information collected and analyzed we should determine and provide waste reductions.

Nagara is a system of simultaneous flow between two processes, achieved through leveling or synchronization between and among processes. Again, when setting out to eliminate waste, we must analyze the processes of the operations in order to realize any real changes. Leveling refers to the flow of product from one process to another. By leveling or synchronizing production quantities between processes it seeks to achieve a more even flow of product. By so doing it may be possible to eliminate non-value adding storage delays between processes. This may sound easy and simple enough but realizing the principle takes planning. The basis for understanding and controlling the leveling in synchronization is determination of takt, based on capacity and standardized work.

Failsafing And Poka Yoke Design: Enhanced Problem Solving Tools

Poka yoke is mistake proofing, designing all systems to be mistake-less or fail safe. Fail safe is not only a approach in quality and reliability, but in the way we produce the product. The way we build fixtures, design work areas and procedures for tooling changeovers, move materials, all must be re-thought for minimal effort, time, waste, and mistakes which raise overall cost of production. This is done through poka yoke design and effective problem solving:

- Identify the problem.
- Set parameters.
- Analyze the problem.
- Preliminary ideas selection.
- Decision identification.
- Analyze decision.
- Prevention.
- Future planning.

Enhanced brainstorming can be piggybacked on problem solving, an idea generating conducted in groups of 3-12 people. The basis for brainstorming is that groups typically can be more creative and
productive relative one, based on a synergistic affect. The human imagination applied to a problem with some reflection and freewheeling assists in the success of brainstorming. It is necessary to have a group leader to focus groups' efforts, and someone or some method for documenting ideas generated. We also must have a relatively comfortable atmosphere and agreement on the topic or problem. When the process is conducted all members should participate, providing only one idea per turn (to reduce dominating). People should be sequenced regularly to help provide ideas, and no criticism is allowed.

Part of the design system relies on a technique referred to as failsafing, the practice of installing steps and/or tools to help eliminate known or anticipated unconscious errors. Failsafing cannot eliminate "mischief" errors. But it may assist in designing for a more robust process or product. The Japanese also refer to this process as poka yoke or mistake proofing--systems and devices in place which only work one way. This strengthens through elimination of weaknesses. If the only works in one position, we have mistake proofed--failsafed for proper use and quality. Failsafing steps are:

- **Error reviews.** Review anticipated errors, if a new process or product is being failsafed, or errors which have actually occurred in a process or product. Corrective action and FMEA forms, based on customer complaints, provide good clues regarding where to begin.
- **Study work area.** Study work area where error or failure has occurred--or where it is anticipated to occur. This may be flow charts, SOP's, OPCP's, and so on. If no sketches or layouts exist, this should be done, at actual work area for observation, analysis. Man machine analysis techniques could be used.
- **Visibility?** As part of step 3--based on step 2--address the question, is the error, and error circumstance visible, or can it be made more visible? If we can not see where error or failure is occurring, we must rethink this, indicating where further analysis is needed.
- **Clear and uncluttered?** As part of step 4--based on steps 2 and 3--address the question, is the work area where the error or failure occurs clear, and uncluttered, or is the area well organized and logically laid out? Clear visibility is key--but also, what is seen when at the situation? Housekeeping and overall maintenance relationships are important.
- **Operator input.** Have we sought operator input--and in what manner? Has this been an after thought or done systematically over time, and through a team approach--with the operator involved up front? Routinely rather than just when failures or problems occur.

- **Use existing resources.** Did we use existing tooling, fixtures, equipment and systems for the solution, rather than seeking to "acquire the solution"? This should be routine rather than a "knee jerk" to the problem. Have solutions been simple, including lighting, rearrangement, flow balancing, combining tasks, and so on?
- **The right way.** Are there ways to place a physical barrier in the system to cause operators to use the system only one way?
- **Upstream management.** Review proposed failsafing techniques to assure the approach does not create other problems down stream--a solution at one location may be a problem elsewhere. Have all been communicated with?
- **Why, five times.** At regular intervals, ask why five times. How much time was spent brainstorming? Have we looked for broader relationships all forms of documentation?
- **Team, trained, used.** Train all team members, and assure all use it as check points in all that we do. The team should be the focus, enabling stronger synergistic techniques and systems.

Failsafing is a common sense Kaizen approach to be used and practiced by teams and others.

**Best Practices, Bench marking, Auditing**

Synchronous methods and tools are intended to be used for group and individual analysis and improvement as well as for broader work area improvement. This is true because with each step we take, incrementally, toward personal improvement, we are also helping our organization. This not only improves us and our fellow workers, but it also enhances the likelihood that we stay in business for future generations of workers. Each bit of time saved, defect reduced, distance less traveled, inventory reduced, and so on, contributing to our improved process or operation, is a step toward individual and company wide improvement, ongoing. We must do this ongoing over time, each day, every day. This is, after all, what empowerment is about--taking the ball and running with it in a systematic and organized way.

Three areas are addressed in this section as fairly powerful analytical tools to use for individual, team and organizational improvement. These are:
○ Best practices.
○ Benchmarking.
○ Auditing.

Each of these are presented as synchronous areas to explore for process improvement and team building.

**Best practices.** Best practices and suggestion systems are used for team approaches to technical problem solving. These are commonly voluntary, with fixed periods of service, rather than being ongoing, and they support multiple teams. Commonly focused on a specific technical problem or project, and formed within the system, they also tap into external sources of expertise beyond immediate available sources. A typical suggestion system is:

○ People being the strength of the organization.
○ Continuous improvement, short and long term.
○ People learning and growing technologically.
○ Ideas put to work--knowledge in action.
○ Rewarded and recognizing good ideas.
○ Management and control at the lowest levels.
○ Positive proactive teamwork and collaboration.
○ The need to continue growing and coaching leaders and technical staff and personnel.
○ Evaluating data-based improvements.
○ Improving the overall return on investment.

Typical roles and functions in suggestion approaches include several levels of interaction to assure that ideas are moved forward in a timely manner for evaluation, possible funding and implementation:

○ Originator (team or individual).
○ Originator's supervisor.
○ External suggestion coordinator.
○ Implementor/originator.
○ Steering committee.
○ Team leaders/members.

Each of these is discussed in the broader context of moving projects and problem solving forward.

○ **Originator.** Either as a team or an individual, ideas for improvement are developed, including providing appropriate documentation and cost analysis, as well as implementation plans and other inputs. The originator works with their supervisor and other support persons to develop the idea. Depending on numerous circumstances, the originator, and others on the team may be part of the implementation process. Originators may actually do the implementation, but implementors and others on the team also have other responsibilities.

○ **Originator's supervisor.** The direct supervisor of the originator will need to be supportive and helpful in the process, mentoring the originator. The supervisor may or may not be on the team, and may have authority up to several hundred dollars for implementing some projects. If the project exceeds the funding limits of the originator's supervisor the approval process requires approval of other elements and/or groups in the system. The supervisor may also disapprove an idea.

○ **Suggestion coordinator/supervisor.** A suggestion coordinator/supervisor, external to the originator and the originators' supervisor, may assist in developing ideas and in mentoring the originator and their supervisor. This person assures that ideas are logged in centrally, external to other functions. Coordinators may fund or disapprove selected projects, again with constraints identified depending on criterion in the organization.

○ **Implementor/originator.** Implementation may be by a group beyond the team, the team itself, or most likely, some combination of both. The maintenance, quality, production or engineering groups, and others will be involved because of their expertise and talents. As much as possible, the implementation will follow originators' plans, in conjunction with other team members input.

○ **Steering committee.** A organization-wide steering committee will typically be essential in such a process, enabling broad representation of hourly and salaried persons. This is important, enabling a "holistic" view of organization-wide needs and issues. This group would also generally reserve the right to disapprove ideas which are deemed to be inappropriate. At the point of recognition and reward, upon completion of the project (some non-funded projects receive non-monetary recognition), this committee may facilitate.

○ **Team leaders/members.** The originator may or may not be a team member or the team leader. As with any team, the makeup of the team, including team leadership, will be a function of the necessary skills and talents required, and those who wish to volunteer to serve. Team leadership requires calling and running the meetings, delegating responsibilities and tasks, managing the overall efforts of the groups, leading evaluation for all involved, and filing any necessary reports along the way. The team leader is generally in charge of educating all members in necessary ways, including primary interest in rules and procedures...
which are in force within the culture of the organization.

One additional approach for teams would be to treat them similarly to what formerly was department. Rather than being part of a department when joining an organization, individuals would join a team which becomes their sense of identity in the organization--and certainly their work function. The team then becomes responsible for most worker needs, including training and education, benefits, and so on. More important, perhaps, for technical problem solving purposes, this becomes the fundamental driver of the team. The purpose is to solve technical problems within our team work area, and facilitate ongoing improvements in quality and productivity.

**Bench marking overviewed.** Bench marking is a structured and systematic approach to use in measuring various circumstances or situations in organizations or groups that are identified as representing the best practices for their services or products. The practice of benchmarking may be particularly useful in developing new processes or systems to aid in ongoing improvement, or when establishing goals or "stakes" in the ground.

The bench marking process is a structured and ongoing process, one that is generally formalized within an organization—not simply a knee jerk reaction to a problem. Several steps must be accomplished prior to, and as part of the process:

- **Identify what to study.** Is the benchmark a product, system, method, or what? This must be determined prior to proceeding.
- **Identify comparative groups or organizations.** Who is doing it the way we wish to become—where do we see it being done properly?
- **Determine data collection method and analysis system.** Is the method for analyzing a data driven approach, or can we simply perform a survey of persons' views at the site? The more robust methods involve data collection, and possibly performing a task similar to our own. Can the process make product according to our standards and specifications?
- **What are the differences?** What differences are there in the way we perform versus the group we are bench marking? If yes, in what ways, and to what extent? This also clearly points to the need to have a solid plan before we become deeply involved in the actual process.
- **Set new goals.** Based on what we have learned in bench marking, what new goals or targets are set?

What are the differences and implications relative to our current approach?
- **Communicate with all involved, concerned.** Based on our study, begin putting the findings together in a way that appropriate persons can begin to be involved and communicated with.
- **Establish functional objectives.** Set reasonable goals and objectives which will ultimately contribute to the larger group goals of moving forward toward our benchmark. These are broad-based objectives, strategic in nature, impacting the broader organizational agenda. Re-engineering may also be part of the agenda.
- **Develop and implement action plans.** Goals must be put into doable timeframes and deliverables as part of ongoing action plans. This also relates to the OPCP and other broader internal documentation.
- **Implement specific monitoring actions.** Based on action plans, follow up and work through plans to monitor and assure accountability.
- **Upgrade benchmarks and repeat.** Assuming success with our broader approach, and improvement, we should upgrade standards and systems over time, repeating the process.

Bench marking evaluation systems can have broad application for numerous circumstances. These are:

- Internal as well as external operations.
- Competitive analyses for comparative runoff's.
- Functional comparisons from industry leaders.
- Generic business or people comparisons—giving added basis for judgments.
- Requirements of objective input and analysis.
- Customer and supplier input and critique.
- Situations where we need to know more but do not know how to get started.
- Costly/high risk circumstances requiring a conservative approach.

Other situations may move forward with benchmarking. This is intended to help get us started, a basis for making improvements in a systematic way.

Realize the importance of documentation in the evaluation process. Regardless of who completes/uses this it, teams and others will need this information, in as accurate and complete a form as possible. Much of the information is numerical data. This relates to building and maintaining systems accurately, methodically, and in a timely manner. Benchmarking requires gathering and documenting
information and data to be used later for analyzing and solving problems related to quality in processing.

**Auditing Our Quality.** One of the ways organizations improve quality and overall operation is through the auditing process. The audit is essentially a survey which raises questions about what we are doing, why we are doing it, and so on. Audits can be conducted as self audits within the organization, external audits as a customer would do of suppliers and third party audits which are conducted by an unrelated objective group. The audit may be a rather formal process with robust and extensive documentation, requiring an entire staff commitment of several days, or it may be rather informal and loosely conducted for purposes of evaluating for improvement in rather quiet ways. Other approaches include contractual audits done prior to awarding contracts, or at the conclusion of specific contract stages. A general startup form is shown nearby.

General areas of questions or investigation in audits include many issues. Intended to be generic, these can be more specific based on the task:

- What processes are to be reviewed?
- Who should be interviewed?
- What specific issues have lead to the audit?
- What corrective actions may be required and what is the timeframe for completion?
- What recommendations for improvement may be needed as a result of the audit?
- What data and documentation will be reviewed in the auditing process?

Three general categories of audits are typically used. These are system audits, product audits, and process audits. Systemic audits are broad approaches to the system, looking at policies, general procedures and documentation approaches, standardized work instructions, and so on. Product audits are product specific, analyzing to determine if the product is meeting specifications and design criteria established in earlier contractual agreements. Process audits are generally focused either on the total process or some sub-system, to determine process capability and variation, or compliance to other standards at the process level.

**Why audit?** Audits provide a broad evaluative tool which is systematic and disciplined, consistent with other tools and approaches discussed in the toolkit. Audits provide baseline, objective, data and information for potential enhancements and improvements. Assuming the audit is used as an internal device for improvement, the audit can help prevent customer complaints by discovering and working on opportunities prior to turning into problems. The audit will typically encourage both long and short term improvements by persons directly and indirectly involved. Broad management information and decision making inputs will often likely result from audits, leading to changes which are of the strategic order. The audit provides a routine gage of "where we are in our "quality journey", a tool which we can ill afford to conduct and use. It should also be recognized that while generally quality oriented, the audit can be used to address all functions in the organization.

**Steps and procedures.** Basic steps and procedures used in the auditing process include:
○ **Initiation.** At some point, either contractually, or based on routine stages of evaluation, or unfortunately, due to issues which have emerged, someone in the supply chain will request that an audit be conducted. This is termed the initiation phase, and depending on the circumstances surrounding the request, will be a major determinant in the nature of the team and who leads the team.

○ **Planning.** Early on, individuals with responsibility and authority would plan the audit based on existing systems and procedures which are commonly used in the organization for the audit process. Typically a "lead" auditor and "team" would be identified and authorized to move the planning process forward. Planning involves identifying and organizing documents and procedures, scheduling all persons, and working with all parties and individuals at appropriate sites to bring the process together successfully. Specific objectives and scope of the audit are identified, background information assembled, a schedule determined, and preliminary assessments placed in progress as appropriate, all as a function of planning the broader audit.

○ **Conducting the audit.** Obviously, the audit must be conducted. Typically this includes physically assembling the team at the site, holding various "kick off" meetings, performing the actual survey, conducting interviews and meetings with and among auditees and auditors, formulating a report, and conducting exit meetings. As with any team function, consideration must be given regarding proper team representation, knowledge and overall ability to bring the audit to fruition. Depending on how far the plan had moved forward, clarification and fine tuning of the plan would typically occur, review and clarification of any ground rules, and general working relationships would be established. As part of the conduct of the audit the auditor may conduct interviews to establish baseline data and information. Various documentation will need to be traced back to their source to establish facts. Samples may need to be gathered as "tests" of capability based on acceptable statistical measures of confidence. Working papers and checklists related to the area being audited will also be important tools for gaining uniformity in the overall audit.

○ **Reporting.** This will typically be done by the lead auditor, involving all data and information gathered, and in conjunction with others involved in the actual on site audit. This would typically have been started at the on-site visit, but would be finished off site following the actual audit visit. The report is typically shared with the organization which has been audited, and of course, the organization who requested the audit, if different from the group being audited. Consistent with the broader final report, daily debriefings will be held with the auditee representatives, keeping all apprised of the overall progress. Significantly, if during the course of the daily functions in the audit, insufficient information is being located, auditee's may wish to pursue and present additional information immediately, rather than waiting, thus helping their position in the midst of the actual audit.

○ **Closing.** The closure portion of the audit provides the opportunity for the group being audited to correct any irregularities within some pre-established time frame which is agreed to by all concerned. After follow-up actions have been evaluated by the auditor, and assuming all conditions have been satisfied, the audit can be finished, or closed, as it is typically stated. The report then can be used as baseline for future audits and/or other evaluative functions, particularly to gage broader improvements upon. Typically, an acceptability level will be achieved by the auditee, according to "unconditional approval" which is rarely achieved, "conditional approval" indicating that minor adjustments must be made in the functions audited, "conditional non approval" meaning it was not approved but it may be elevated to approved status with changes, and "unconditional non approved" means major changes must be provided.

The basic guideline audit form, is useful as a planning and discussion tool. Specific questions and checklists will need to be developed and/or adhered to based on the nature of the function. The audit will usually result in various findings and observations. Findings resulting from the audit are factual non-compliance with standards and agreed to requirements. Findings require specific corrective actions to bring the non-compliance area into compliance. By contrast, observations should be investigated and attended to, depending on their severity, but specific corrective actions in writing are generally not required. Corrective actions may follow approaches provided in the toolkit, outlining specific procedure for addressing issues or circumstances requiring attention.
JIT, Synchronized Production and Other Lean, Six Sigma, Best Practices

Just-in-time (JIT) is a key subsystem in production, intentionally designed to meet, as precisely as possible, customer demands, in terms of amount, specifications, proper delivery time, all with minimal resources consumed. This directly supports the need to supply the highest quality product at the lowest cost and shortest lead-time within the context of waste elimination. JIT requires information and material flow that is simple, and uses efficient processes in a demand-based production environment with minimal buffers and shortened lead-times.

The resulting system is leaner, with little or no extra buffers or excess equipment and personnel, relative to a traditional production scenario. Smooth worker pace and flow of product, with consistent assembly and product output are also features of JIT. At the same time, however, JIT offers reasonable flexibility and development capabilities to adapt to short and long-term production requirement demands and other changes.

JIT is characterized by product volume and variation which are balanced to ensure a smooth flow of production and to enable a pull product system with efficient flow of material. Balanced volume and reduced variation for smooth operator workload are keys to enabling an effective pull system. Consistent production rates flowing through work areas, and reduced variations in requirements for assembly output are pivotal to making pull production successful.

Production Sequence Planning.
Production sequence planning is done to match up with process sequencing down the line, and detailed planning and in-line processes overlap. The production program plan is based on volumes projected through sales and marketing well into the future and the early production cycles are estimated and updated monthly. Production program planning includes the maximum number of components/variants per day and a fixed daily schedule is used. Deviations from schedule are permitted only under dire conditions and the process is subject to appropriate quality requirements.

This production planning approach evens out potential imbalances between market fluctuations and production program stability. It also provides a basis for planning internal and external supplier resources. Prior to going into production, custom variations and required products are placed into a fixed sequence. The sequence is formed into a line sequence process within a set period of time typically consisting of several work days, according product combinations defined by production, such as capacity, technical restrictions, colors as well as customer deadlines.

Production planning done in-line as is described here is also sometimes referred to as “string of pearls” since this represents the entire supply chain sequence for production. Suppliers know which parts are “in-line sequenced” and they use this information to set their own “in-line sequencing” processes and, where necessary, forward them to downstream suppliers to adhere to deadlines. If sequence is broken by an incident sufficient to cause work stoppage, a quality alert will be initiated. Fault corrections are not to be transferred elsewhere, such as a central inventory build-up area since the existence of this will encourage waste and reliance on this rather than empowerment of workers.

The fixed framework of in-line sequencing helps ensure a fully optimized production sequence, reducing peaks and troughs in the workloads of machinery and personnel, as well as reducing storage of finished goods. This forms the basis of safe and stock-optimized JIT delivery of materials and services. Organization and structure permits any geographic location for suppliers, with minimal difficulty in managing. Surface area requirements for storage of inventory are minimized, as are deliveries. Fault correction within the process is encouraged assuming the fault, once flushed out, is not transferred to a central finishing process. The system also increases adherence to production deadlines as well as adherence to delivery deadlines, while simultaneously increasing flexibility to meet customer requirements.

Pull Production.
Each process produces based on demand from next process, and movement of material is controlled by signal from user. This requires quick stabilization of all processes, consistently correcting failures. The most important principle is that material is supplied based on actual usage, not scheduled or predicted use. Material flow planning is organized based on extended materials requirement planning (MRP). MRP projects the entire procurement chain from the supplier to the point of use along with all necessary input factors such as personnel, equipment and packaging, based on standards and systems in place at the organizational level, rather than workplace level. The elements required for setting up pull production are taken into account and planned accordingly. The following are some considerations to bear in mind:

○ Use standardized delivery and supply forms, and electronic systems wherever possible.
○ Use standard modules with agreed to elements, shapes and sizes for logistics equipment, movement.
○ Use recyclable lot containers which can be moved back and forth with the products.
○ Do not repack (lot container changes) throughout entire logistics chain from supplier to destination.
○ Maintain close liaison and communicate with material supply and production functions.
○ Smaller lot sized containers should be used wherever possible, given their apparent cost-effectiveness.
○ Ergonomic considerations on lot containers and material zoning arrangements with work groups.
○ It will be important to form volume and variant loads as late as possible in the supply process.
○ Optimize container fill levels, avoid partial loads.
○ Minimize handling stages by optimizing distances covered in material flow process.
○ Factory layout should optimize material flow wherever possible.
○ Continuous improvement via feedback to procurement and materials groups will remain important.
○ Consistent process planning parameters must be specified for each family of components (inventory, time lines, emergency plans, etc.).
○ Logistics equipment, systems, must be designed to ensure that materials arrive undamaged.

The above considerations can assist in applying a standard approach to material flow. These principles also help us improve process stability and overall quality as we gain control of the materials movement issues. Bottom line, the standard approach used can help us reduce inventory.

**Tugger Transport, Mixed Loads.** Tuggers are small flexible trains pulled by electric cars, the number of trailers and number of levels in which can be varied to alter their capacity. Tugger transport with mixed loads is closely linked to use of order cards or other kanban related procedures. This subsystem uses small containers transported to assembly lines in fixed cycles by tuggers. The tugger travels between the storage area and the point of use in an assembly area. The route and frequency is determined based on ensuring minimal journey distances and security of supply with low inventory levels, generally about once per hour.

The tuggers carry mixed loads, various items and numbers of items, delivered in each delivery cycle to supply the customers at the work areas. Empty tote containers are removed and replaced with full containers delivered to each workstation in the work area. Manual order cards may be used, and tugger driver takes order card, either physically handed off or placed in empty container, and loads material into tugger and supplies workstation with materials required in the delivery cycle. The replenishment process can also be based on supplying full containers and removing empty containers and loading tugger trailers on the basis of the order cards.

○ The size of the tugger route depends on consumption/conveyor speed, amount of workers in a work area, the number of tuggers, size of components, and perhaps other factors.
○ Decision on use of tugger process must be addressed on economic grounds depending on size and consumption of components used.
○ Materials are assessed, classified by most appropriate delivery categories, such as:

  • JIT for large-scale, expensive components which may present some challenges to get them into the production work area.
  • Order cards for rapidly used consumable parts, relatively standard small to medium size.
  • Large lot containers can be coupled together on roller beds or “truck systems” to form a tugger.
  • Shelves on castors are used wherever possible, to reduce numbers of times requiring handling.
  • Greater distance at buffer and point of use may suggest use of electronic order cards, lowering lead times and reducing dead head trips.

Use of tuggers with mixed loads may provide some benefits. Movement at the assembly station can be reduced, thereby improving value-added efficiency in work space and other ways related to housekeeping and space in general. Costs are reduced due to smaller inventories on assembly lines and in the facility. Material supply efficiency is improved overall due to reduced number of handling stages and functions. Numbers of fork lifts are reduced, to cut costs and enhance work areas based on less noise and confusion. This type of tugger driven arrangement increases safety in the workplace based around several of the key points above, while also supporting a small lot container procedure.

**Withdrawal and fill-up.** The withdrawal and fill-up method is used to establish pull production and continuous flow production. This method requires that the supplier replenish only what is withdrawn by the customer. The signal to replenish may be order card, empty container, flag or light signal, empty floor storage location or perhaps others. Signaling may also be triggered electronically since it can be used in any materials department, not only at work station but also buffers and external suppliers.

One method of implementing withdrawal and fill-up is the order card, described as a separate method below. A 2-container principle can also be
used. This can be organized around some type container system which holds half the required components needed for one production cycle. Containers are placed on platforms or floor conveyance mechanism nearby or within production work area. When one container is emptied the tugger knows to replenish immediately.

By using withdrawal and fill-up overproduction and oversupply is immediately recognized and actions are clear to be taken. This is a fairly straightforward and simple way of ensuring that what is needed is what is actually supplied, and therefore readily managed. The simplicity of the process makes it easy to manage once it has been set up, and therefore it is highly reliable.

**Order cards.** Order cards attach to containers, with all necessary information, such as part number, designation, assembly point, storage place, supplier, number of units, card number, total number of cards and so on. When all material is removed from container, totally depleted, the worker removes the card and places it in an agreed upon location. The order card is routinely removed from the agreed upon location, and this triggers replenishing the supply of material. Supply replenishment occurs on regular, short intervals, fixed route schedule, or in some other configuration, and communication is what, how much and when, generally on a repeat basis.

The order card quantity is a fairly precise amount which must be calculated correctly according to the following formula:

\[ \text{Minimum lot size} + (\text{daily usage} \times \text{lead time} \times (1 + \text{safety factor})) \times \text{Container volume} \]

There are two main types of order card procedure. One is the transport order card method, used only between the point of use and the warehouse. Second is production order card at the point of use which triggers production, and the warehouse and supplier also operate the order card method. In either case, a “card” can also be an electronic scan, an empty container, or a defined place. The smallest possible lot size and order card quantity must always be used to reduce the quantity size to the bare bones minimum. If this is not done it is defeating the purpose of use of the card system.

Benefits of the card method include a consistent application of the order card method which helps avoid overproduction and oversupply. This supports the goal of JIT, that of producing and supplying only what you need, when you need it and in the amount you need. Card systems tend to directly control material stocks at the point of production. Smaller material stocks save space and avoid long journeys to replenish material, as well as minimizing dead head trips. Fluctuations in assembly plan can be easily reflected and adjusted by adding or removing order cards from the system. The method functions as a schedule for the production function and or supply department or group.

**More Continuous Flow Process Improvement Approaches**

Through the application of various continuous flow principles, production processes are organized to flow continuously at a constant rate from beginning to finished product. Optimal flow, one piece at a time, while difficult to achieve is a worthwhile goal since striving for this will undoubtedly lead to improvements in flow overall. If lot production is required, smallest lot possible lot size is used, based on various lean applications:

- Kitting
- Quick set-ups
- Smaller Containers
- Single piece production
- First in first out (FIFO)
- Single Stage Stock Strategy
- Takt and cycle time bar chart

**Kitting.** Kitting is preparation of “kits” in various ways to have only necessary materials for the defined task at hand. For example, a container may be filled with the correct amount of material in a central area close to the point of use in the work area. Parts or components are kitted and sequenced according to a customer build based on there demands. System implementation must be compared with conventional delivery system, and it is implemented only if it offers a clear economic advantage. Kitting can also be done in a group environment to encourage transfer of responsibilities, and facilitate deployment of all workers.

Several benefits can be derived from kitting. For example, kitting delivers multiple parts for assembly in one container. Provision of multiple materials in one place reduces walk and reach for worker and it reduces moving materials. Reduced stocks improve visual control at the line, as well as improving housekeeping simultaneously. Because of the way containers are designed kitting allows for error proofing, to increase process reliability based on consistency in prepared kits.

**Quick set-ups, changeovers.** Another effective way to enhance the success of production is through the use of quick set-ups and changeovers. Quick set-up and changeover systems use standardized, documented procedures done with
prepared tools, aids, exchange parts and related supplies along with others on the team. Improvements achieved in set-up procedures are documented, displayed and trained for. The set-up procedure is divided into internal and external time elements, with the goal being to prepare as much for the next set-up, as possible, during run time to help reduce idle time and increase productive time.

Where possible, quick-release systems are used to facilitate and assist in changeovers. Also where necessary, and possible, adjustable lift systems are used to help raise and lower difficult to handle elements. Effective set-up steps generally use traditional time analysis and motion studies to help analyze where we can improve. The process should also be evaluated in terms of waste based on ECCS analysis (eliminate, combine, convert, simplify) as a routine part of the system to assure the optimal setup as well as for continuous improvement. Individual set-up steps must be reinforced and trained for as individual entities, to strengthen the broader systems. Efforts must continuously be pursued to convert all steps to internal from external set-up steps, using the time of workers as wisely as possible.

Improvements in the remaining set-up steps, particularly positioning, securing, adjusting as related to reducing general setup times and for production overall. This will all necessitate use the 5S’s to assure that tools are close at hand for effective use. As practice, carry out the set-up using a pre-planned parallel procedure off actual work site to enable production to occur, but in a simulated manner. As with all else, standardize all set-up steps with workers, through training and proper documentation as SOP’s. Quick set-ups can significantly improve productivity and quality, as well as provide the flexibility to produce according to customer requirements in support of JIT production. Inventory levels can be reduced concurrent with reduced bottlenecks in changeovers, and the smaller lot sizes we continuously strive for can become closer to reality.

**Smaller containers.** Smaller lot containers are another area which should be pursued along with related to JIT principles being explored. Large containers are replaced by small, hand carried containers, particularly at the point of production in the work area. Smaller containers are often used with tugger delivery and prepared kits of mixed load products for batches of production. One key factor in smaller lot containment is delivery agreements with suppliers at the point of production. The base size of the smaller container is based on the delivery cycle, arranged according to 2-container principle and SOP’s, all consistent with standard work in process production cycle systems.

Smaller lots and innovative containers may be combined, for implementation purposes, with visual management techniques, along with a Kaizen improvement workshop. At some point in the planning and implementation, a systemic global approach should be used when calculating the costs and basic values for small lot containers. The broader analysis, at various points along the way, in the production cycle, should include production advantages as well as unquantifiable issues such as employee satisfaction, visual control, improved process quality, and overall reliability.

Much of the planning, implementation and ongoing improvement in small container utilization should be done in conjunction with TPM and 5S analysis, since much of the visualization relates to housekeeping, general orderliness, safety and ergonomics at the point of production. Smaller lot containers provide improved arrangement of material and occupy less floor space, leading to better worker comfort and satisfaction. Smaller containers, and the improved visual control brought about, provide opportunities over time, for incremental inventory reductions as well as improved flexibility and responsiveness to reductions in build plan. Concurrent workstation density, in all regards (workers, materials, assemblies, etc.), can be considered for increases in relation to other work areas and functions.

**Single Piece Production.** As has been established in other places and ways, the fundamental goal in JIT is generally to achieve single piece production. Single piece production is the continuous work flow from processing and assembly throughout all work areas, generally achieved by conveyors, linkage systems or robots.

Single piece production is determined by the customer demand rate, thought of as the production cycle. The principle of one part after another, i.e. no “overtaking”, is maintained throughout the production cycle. Single piece production does not specify specific numbers of parts or semi-finished products between two processes or functions. Rather, the build rate is synchronized to the takt time and equipment is arranged according to the processing and assembly sequence deemed to be most efficient. All subsystems (pre-assembly areas) are synchronized to the main production systems to respect the single production cycle.

Automated fabrication processes with transfer lines for sub-unit assembly automatically use single piece principles if there is no kick-out or over-ride capability between work areas. This, therefore eliminates (or at least reduces) safety buffer between two process steps or work areas. Reduced lead-times as well as set-up times are
increasingly achievable with single piece logic driving the production systems and cycle. Ergonomically, less space is consumed, based on less product and material/supplies to support, reduced congestion, and so on. Single piece production is a precursor for zero-defect targets, since a leaned out work area will lend itself nicely to visually identifying problems more quickly and effectively.

**First in first out (FIFO).** FIFO simply means that what is delivered first is used first. Consistent with previous points, the ideal lot size for FIFO is one piece since this is easier to manage at the point of production. FIFO also applies to block storage or multiple layers and rows of pallets as well as containers, and entire truckloads, where parts and supplies which have been stored or in transit for the longest time are consumed first. This may require systems for identification of time in process, depending on flow and overall production cycle.

FIFO must be applied across the board, to achieve the full benefit, assuring that every part or sub-component is used appropriately. Traceability can be improved and must be fully functional to support FIFO. Enhanced delivery and handling systems will frequently be required to facilitate FIFO, and like much else in JIT, the systems and sub-systems must be thought of holistically rather than segmented.

**Single store systems.** Part of the key to JIT and continuous flow is to supply maximum components in sequence at point of production, through one store. Like smaller containers and single piece production, single store strategy is the base for the supplier customer chain, managed preferably by the supplier, keeping the burden to minimize on them. Similarly, supplies should remain in the hands of the supplier until used (just in time/just in sequence) and again, at the point of production. The single store strategy also applies to parts supplied and produced or prepared in-house, with the overall aim being to eliminate (and manage/control) buffer storage for all parts supplied at a single store.

By placing control of supplies at one store location, reductions in losses can be brought about due to fewer shipment stages and interfaces for waste. Simplified flow and movement of material, as a general rule can coincides with fewer storages, hand-off’s and overall confusion as waste in the production cycle. Single store concept provides a base for universal process optimization from the supplier standpoint, enabling minimal costs incurred to enhance the competitive position through reduced logistics costs for all. Basic JIT principles of minimum stock levels with precise optimum control, and overall application and enhancement of production flow can be achieved with single store systems.

**Takt time determination, customer demands.** Build rates and line speeds are based on customer demand. Each process is designed so that process cycle time corresponds to takt time. Takt time is total available time minus breaks and known shutdowns, divided by number of customer orders. The ultimate goal is for a single takt time to link all process steps in the total production cycle. Takt time is fixed, virtually unaffected by minor changes in demand. For example, monthly production demand is smoothed to allow for a consistent daily production level. Adjustments to short-term fluctuations in demand are made by adjusting work area times and rates via capacity. Work areas are isolated from one another to assure discrete optimization of takt. Automated work systems use takt time set to the customer cycle time, designed to coincide with workers and capacities at work areas.

Fixed takt time provides the basis for standardization in work based on SOP’s, which provides consistently high quality, reliability and efficiency in process. Capacity can be more readily determined, resulting in reduced fluctuations in worker and work area requirements. Reliable and stable material flow with uniform consumption rates is one key outcome in takt controlled production. A massive reduction in inventory and reduces the overall throughput time with avoidance of overproduction.

**Takt and cycle time bar chart.** The takt and cycle time bar chart is a visual aid analytical tool for comparing allocation of work with cycle time. The takt and cycle time bar chart is useful for most work functions improvement, elementally and collectively, at the work area level, and throughout the production system cycle. The chart for a team in the work area displays each individual work cycle involved in a build cycle, ideally connected to specific SOP’s. The bars indicate time spent on each work process divided into the key categories of value-added; non-value added; and, waste. The work cycle is divided into individual variable work processes and functions.

Value-added activities are defined as those work processes that increase the value of our product. Non-value added are those secondary work areas or functions done to facilitate value added (picking up tools or supplies, necessary walking or movements, transport, etc.) where “necessary” means the minimum for these necessary activities. Waste is defined as anything that does not at least indirectly contribute to adding value, benefiting customer is eliminated without affecting the product (unnecessary transport, multiple handling, duplicated work, rework, unnecessary talking, etc.).
When recording the actual situation, only obvious waste should be identified as such and waste concealed in non-value added work processes can be defined and eliminated in a Kaizen work improvement project but should not be identified as such during the initial stages of improvement (or in the launch of a new product for example). When workers are optimizing or designing standards, elimination of obvious waste and of waste concealed in non-value added work cycles should be a priority, since workers can influence this directly (particularly when focused on Kaizen work improvement project.

The takt and cycle time bar chart is useful visual display for both operators and management, and it is particularly a helpful communications device for all. Waiting times and bottlenecks, adding to WIP, and non-value adding elements are easily identified and focused on. The takt and cycle time bar chart can be used by supervisors and workers to rebalance the line when takt time changes or capacity issues must be addressed. Based on enhanced communication upfront and ongoing, improved cooperation between teams and management on overall improvement issues can be more readily sustained.