Lean, Six Sigma, Quality Transformation Toolkit (LSSQTT)*

LSSQTT Tool #15 Courseware Content
“Genealogy Of Selected Lean, Six Sigma, Quality Management Systems’ Tools”

1. Lean Six Sigma Quality Transformation Toolkit
2. LSSQTT organization and structure
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Lean Six Sigma Quality Transformation Toolkit

The highly competitive global economy is characterized by organizations with high quality products at competitive prices with just in time delivery. Frequently production of one product occurs at various locations around the world, composed of various supplier and customer relationships. The days of one facility providing all functions, and all elements of production being at one location, are rapidly becoming a thing of the past, as is production at the pace of the producer rather than the pace required by the customer.

Excellent quality, obviously, must be accounted for, as part of production, and clearly, organizations cannot ignore the cost of this quality. Customers will definitely require competitively priced products, delivered at high speed and with high quality. Passing along the cost of quality, to customers, simply “buried” in the product cost, as we may have been able to do some years ago, will not work any longer in the competitive future. Organizations wishing to be competitive, now and in the future, must provide high quality products, at low cost, faster than their competition.

The bottom line is that organizations that simply produce products or services without accounting for quality, in cost effective ways, will not be competitive and they will not survive in the global marketplace. Put another way, organizations must integrate quality systems into their production systems, and this must be done in seamless and value adding ways. International standards must be foundational as part of the quality systems for production globally, and the organization must effectively apply lean and six sigma principles in the quality and production systems.

All of this must be done increasingly as part of the broader system. Quality systems cannot be thought of as an “add on”, another element of what we must attend to because someone says do it. Quality must be a way of life in all that we do, integrated from top to bottom as the overall management system. Management cannot be thought of as a separation from actual value adding elements in production. All must be viewed as value adding systems, collectively identified as the quality management system (QMS).

Part of the key to this rather substantial paradigm shift is to truly empower workers. Particularly at the workplace level, where product is actually having value added, directly, the workers must now increasingly be managers. Changes throughout the organization must be attended to and bring about a cultural paradigm shift necessary to actually shift control and decision-making, in doable and respectful ways, into the workplace. While much will continue to be at the supervisory level, much will be as teams and workers in what used to be shop floor, or if not in manufacturing, the “firing line”.

The QMS focuses on production, rather than manufacturing solely, since much of what the world demands today is produced but not necessarily manufactured in the traditional sense. Production takes into account virtually any act which attempts to add value, and is not limited to only traditional manufacturing value added functions based on changes in materials. The nature of value adding has shifted to include changes in information as value added, systems for moving information, and assuring effective communications in all that we do as value added services. This is also true since any service industry function can be production, including construction, health care, transportation, recreation, academia, government entities, and so on.

QMS’s are applicable to all functions and whether a traditional material based product is
manufactured or produced is perhaps irrelevant. What is important is that we are adding economic value to the base of productive activity. While the main interest is on the QMS, obviously other elements and sub-systems are relevant and important as productive outputs. Production is the synthesis of infrastructural and organizational principles and methods used to produce products—relationally interconnecting the QMS. This also acknowledges the extent to which QMS principles and methods have permeated the organization.

The various systems rely on standardized processes to assure production of quality products and reduce counter productive forces in the systems and on workers. By being involved, workers have the opportunity to have a direct impact on the design of their production system, the performance required of them and continuous improvement. The QMS, thus, provides the framework for the implementation and further development of other systemic methods. Through consistent, ongoing, implementation and modification of the QMS, organizational competitiveness will be continuously improved.

A model to help facilitate what is being discussed 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.

The seven part toolkit series was developed through work with 100's of industries since the 1980’s in various environments. The LSSQTT courseware system, as a template in model form, is the basis for structured discipline, explained graphically on the previous page, and further now.

The outer ring represents the broadest of culture or infrastructure required to conduct quality management system functions and productive work organizationally. Beginning on the upper left, advanced problem solving and decision making; and applied research and innovation projects in the lower right, define technical requirements for an organizational culture, to function as a disciplined system. Human and technological infrastructure are arranged to facilitate technical work of the organization via teams and projects. Information analysis and communication systems, internal and external, provide for e-commerce in the future, both shown at the lower left and upper right, since work in the toolkit is designed to be in electronic teams.

At the center, connected and inter-related data, documentation, service and synchronous tools are required to understand and do QMS’s foundationally. Facilitating basic problem solving opportunities which lead naturally to teaching and learning in team projects, change and growth occur, based on continuous improvement through empowered knowledge, individually and collectively. The nature of change that implementation of QMS’s entails requires involvement of virtually everyone organizationally. Although the QMS can and should be applied across many aspects and functions
organizational, primary focus is team at work place level. Although much of the QMS is broad-based, requiring higher level management decisions and impetus, the team and workplace level are the primary interest in the toolkit model.

The QMS has been initiated under ISO 9000 rubrics, and in many cases now serves as a “umbrella” for the broader quality system. As ISO 9000 certification and registration systems were introduced and implemented in the 1980’s and 90’s, and beyond, around the US and world, this has driven the cause of quality to new heights organizationally and functionally. What was intended to serve as a vehicle for growth and change in the global marketplace was also a catalyst for change toward a quality focus for all of us in much that we do. This includes our workplace, but also many of the local community-based institutions which we are part of.

Various quality initiatives have come, and some have gone. But most have stayed in one form or another, and their impact continues to be felt as part of the broader quality movement and QMS. The quality tools which have risen to the forefront today, now a part of the broader QMS, include statistical process control tools such as variable and attribute charting, capability and gage R & R indeces, generally identified as six sigma or data-based systems; industrial engineering tools such as standardized work analysis, capacity analysis, corrective action, 5’S’s, and others commonly now called lean systems; and, quality planning tools for new product development such as process control planning, quality function deployment, part qualification and others commonly identified as synchronous. There are others, and depending on the nature of industrial activity, products produced, resources used, and so on, the point must be underscored that the quality field has contributed huge tools which continue to be refined and applied.

Today’s environment of change is a strong and substantive global emphasis, with overtones that cannot and ought not be ignored. The QMS model, defined as LSSQTT, enables and helps us prepare for this global reality. Part of what we must do is use the tools we have evolved in the quality profession in novel and innovative ways to help improve well beyond our workplace only. We must be continuously changing for the good, and developing a culture of learning and transfer of knowledge, grown based on problems solved day-to-day, turned into improvements. When we solve a problem today it should be documented in ways which can be shared electronically with others to help them avoid the same pitfalls, and to therefore enable all to move forward collectively in a partnership for competitive growth. This is certainly also true at the community level. We will see an upsurge in changes at the infrastructural level in the future—changes which will need quality systems and certainly reflective of the QMS type rubrics being discussed here.

The LSSQTT uses data and documentation as the main communication vehicles, collected and housed electronically wherever possible. Data and documentation, are at the heart of the system, used to solve problems and add value in ways which disciplined and knowledgeable workers can do. The best emphasis in the LSSQTT is at the worker and workplace level, recognizing these people are the one’s needed to be empowered and grown for future activities and leadership functions. Leaders at all levels will have been groomed out of and based on workplace functions, “where the action is”.

Everything in the LSSQTT is about teams. Since we understand that teams composed of diverse and varied talents, many whom will look and speak different from ourselves in the future, will increasingly be our strength organizationally. Teams will be electronic increasingly in the future, and while production will be fixed place, we must understand that learning and growth for individuals first, and then teams, will come increasingly not from the person next to you only in the workplace. Increasingly, we will learn from persons who we are connected to based on a project or systemic workplace change—but done electronically—and from around the world.

Teams will focus not only on getting product out the door in the future, required to pay bills day-to-day. But we will also work synchronously with data and documentation collected and built around day-to-day production in fairly mundane, yet sophisticated and disciplined ways. Information collected must be used for longer term planning and decision-making issues related to new products, innovations, and how to do broad-based organization change as improvement. Teams must focusing increasingly on use of what is learned day-to-day in basic production, and documented in data-driven ways, but we must also be applying what we learn and know in production, as value adding potentials to advance the organization in the future.

**LSSQTT Organization And Structure**

The toolkit is organized around seven separate sets focused on slightly different aspects of the model and QMS. Each set is used in different courses, as described briefly below.

**Primer Tools (1-6): Technology Systems Introduced.** Primer tools introduce and overview Technology Systems and the toolkit system,
explained at a rudimentary level. Primer tools are for introductory courses and persons just getting started.

1. Technical Foundations For Industrial And Technological Systems
2. Materials And Processes For Technical Managers
3. Process Engineering, Design And Innovation
4. Cost Analysis And Productivity Improvement
5. Quality Systems
6. Automation And Computer Integration

**Foundational Tools (7-12): Assessing Technological Innovation, Change And Improvement.** These tools provide understanding about technical management, innovation and assessment for change, within broader global forces.

8. Technological Systems’ Leadership For Change And Improvement.
9. Infrastructure For Managing Innovations, Problem Solving, And Creativity.
12. Lean, Six Sigma Tools: Decision Making As The Engineering Economy.

**Data Tools (13-18): Statistical Process Control, “Six Sigma” Improvement For Lean Systems.** Data tools focus on improvement and enhanced decision making and problem solving via data applications for process improvement and variation reduction are the focus.

13. Statistical Foundations For Data Based Improvement, Lean, Six Sigma Solutions.
15. Variable Data, Comparisons To Attribute Charting For Six Sigma, Lean Service.
17. Gage Repeatability And Reproducibility (R & R): Inspection And Measurement.
18. Capability, Charts And Quality Characteristics Analysis For Six Sigma And Lean

**Documentation Tools (19-24): Genealogy of Lean, Six Sigma.** These tools build on data and foundations via documentation for analysis and problem solving in technical management. Systematic analysis focuses on Kaizen techniques for lean environment variation reduction.

22. Synchronous And JIT Production, Lean Six Sigma Best Practices.

**Documentation Tools (25-30): Communication, Management Systems, For Lean, Six Sigma.** These tools build on data and cultural concepts via documentation for analysis and problem solving. Systematic analysis focuses on Kaizen for lean environments and variation reduction.

29. Failure Mode And Effects Analysis (FMEA) And Quality Functions Deployment (QFD).

**Service Tools (31-36): Lean and Six Sigma For Non-Manufacturing Industries.** Service tools apply data and documentation principles to non-manufacturing and technical service environments for improvement via six sigma and lean for variation reduction in systematic ways.

32. Culture For Service, Communications And Management As Disciplined Opportunities.
33. Documentation For Quality And Productivity Improvement: Lean Foundations.
34. Data, Basis For Kaizen, Six Sigma, Quality Systems, Service.
35. Information Technology, Maintenance And Safety.
36. Innovative Leadership: Managed Service For Change In Lean Environments.

**Synchronous JIT Tools (37-42): Time-based Management For Kaizen And Future Planning.** These tools help grow talent to lead new product development and robust technical management systems for the future, built on existing data, documentation and service tools, synchronously.

37. ISO 9000, Quality Launch Systems: Supplier Relationships Guiding Our Synchronous Future".
38. OPCP, FMEA, QFD Synchronized As Documentation For Advanced Problem Solving.
40. Robust Design, Reliability And New Product Development.
42. Advanced SPC, Reduced Variation And DOE As An Improvement System.

**Genealogy of Systems Management, Work, Culture of Production**

Management is a system that requires knowledge of the interrelationships between the sub-processes within the system and everyone that works in it. All entities and relationships must be considered as part of the system in a “whole part whole” type approach. That is, in order to understand the whole, and be effective in improving the entire system, we must understand each of the sub-parts.

Any productive act is a set of processes and operations linked together to form a system, all based on or around standards. Systems thinking in a process culture, or therefore virtually any productive circumstance, requires that we consider all elements and levels in the system. This provides the following, each to be further elaborated:

- Systems
- Processes
- Operations
- Standards

Operations thinking, for improvement purposes, requires analysis of flow as people perform work on physical objects, actions done to material by machines, workers. This includes the work performed to accomplish the overall action for transformations (fit, form and function), both those which add value and those which do not. These operations are those that alter fit, form, function or quality, including:

- Altering form- changing shape of an object, casting, forging, machining, in a traditional manufacturing application. Others which could be of interest might include mixing food products to make a cake, or whatever; the pharmacist mixing materials to prepare a drug; or a housekeeper who cleans a room for the next customer.
- Altering quality- changing state; heat, tempering, cure, in the manufacturing sense; but this could also be baking the cake; heating the drug to achieve a phase change; or bringing in new linens or towels to the room in housekeeping.
- Assembling-joining or welding in manufacturing; packaging of food product or drug; putting linens or towels in place in the housekeeping operation.
- Disassembling- dividing, cutting, shearing, in manufacturing; slicing or serving the food product; removing, preparing and using the drug; and tearing down and preparing the room for housekeeping.

What all of the operations have in common is that time is being consumed and value added when the work is being done. Or at least that is the goal. Obviously, if the operation is not being handled well, or as we say if it is out of control, we need to take corrective actions to assure that variations and waste are diminished or removed.

Processes, as contrasted to operations, are the flows transforming raw materials to finished products, including processing, inspecting, transportation and storage. The flow of material in time and space is considered to be a process. Unfortunately, we have frequently neglected processes to look solely at operations, and yet it should be clear that production is not equivalent to operations only. Production is the combination of operation and process. The realization that production is a network of processes and operations frees us from the obsession with streamlining operations and focuses our attention on making processes more rational and efficient.

A process is a continuous flow of activity by which raw materials or other value adding activities are converted into finished goods or services, which includes operations. The challenge is to avoid the following type scenario:

- Store raw materials in warehouse
- Transport materials to machines
The whole operation should be built and planned with a single thought, that being to simplify the handling of material. The extent to which we can reduce the handling, or transport function, the greater the overall improvement in efficiencies. We must design a layout where worker activities harmonize, rather than impede the flow of production. A working group varied in strengths and perspectives, operating in harmony, will be more creative and have more effective solutions than people in isolation.

Old layout concepts where production is organized around type of machines, or talent of people avoided. The challenge is to design process-based one piece flow around a single product. This provides a need for balancing alongside other products for multi-product or mixed production.

Plant layout embodies four types of machine or equipment layouts. These are process sequenced; product based; homogeneous; or similar equipment; and, irregular layout. Process sequence may be a single process, stand-alone; a shared process which incorporates multiple related functions in sequence; and similar processes which may have relational value adding potentials by locating together.

Product based layouts are focused on being organized around the equipment similarities, or similarities in part production and/or function. Product based layouts may also involve clusters or families of parts organized around equipment. Grouping machines or similar parts almost always results in transportation waste—eliminate forklifts.

Homogenous layout engages similar types of machines as the main determinant in how to plan and organize the layout. While this may “look cool” or give the appearance of more capacity than we actually have. Irregular layout placed wherever space permits, with no reason, including improper or unsystematic growth with no plan.

Therefore regarding layout approach for improvement, what may be correct in one application, may be way off, depending on how the system is being used? When similar machines are grouped together and equipment is difficult to move, it may be effective to install overhead transport devices (connected hoist with sectional conveyor) to move pieces one at a time, as WIP. If the layout was changed so that machines are arranged to the actual order of processes, transportation, inspection and waiting times are shortened. This is also pivotal in moving toward single item flow in smaller, more controllable lots. Layout considerations to achieve optimum flow for production may be:

- Focus all work around product or work families
- Consider all movement and design for least travel
- Look for potential or real bottlenecks, stoppages
o Modularize utilities, work area tools, materials, and equipment for rapid, easy movement
o If you don’t achieve 50–75 percent reduction in floor space, you haven’t succeeded

Focused work layout for continuous flow is part of how we can achieve production with a purpose. We must look at long-term growth, always with an anticipatory view to future growth. Remember, current size and functions are only a stage in the evolution. If it is operation dependent, we must still remain as flexible as possible within the broader market and competitive demands. We must also understand the organizational structure and why and how we got this way, so we can change and improve.

Our systems are the key foundation for this growth, and generally in rapid growth they are usually last to be attended to. Continuous flow and processes inherent in this dynamic will challenge us even more as we grow since this is dedicated to minimal numbers of products to get the volume up and bring costs down. Systems definitely dictate many behaviors noted as needing changed and improved over time—thus we must think in systems’ terms—cannot change, improve in the absence of understanding systems.

Plant infrastructure, mechanics of the space, must be understood to provide a general understanding of how buildings work, including:

o Air handlers, movement, maintaining pressure and quality of air
o Utilities and other, done least intrusively
o Lighting and needs for optimal human comfort
o General space and temperature, square footages
o Why are certain processes done as they are?

We must know and understand the background circumstances for general work flow balance and cost improvement. How and why did production grow to become what it is? What type of equipment and/or other changes in layout will be needed to bring operations together for continuous flow?

Isolation of processes and operations, and productive work is the enemy and is to be avoided. That which is hidden becomes masked and is to be avoided by bringing all work out into the open. It is critical that people who can influence change actually stay in touch with the workplace—walk through—perform the tasks and do the work. Create a map of the current flow which can be studied and analyzed.

What would you do if you started over, particularly to improve flow in work, adding value to production? Where are maintenance, receiving, shipping, tool and material storage, the next operation, security issues? Production must be designed to bring operations together, can’t achieve cells or one piece flow. What large equipment, security, controls, utilities, bottlenecks or other issues or constraints need considered?

We must be careful not to confuse movement with positive action or progress. Movement may be masking much inefficiency and must be carefully analyzed to determine how to reduce and/or eliminate. Movement must be required and known to be a value adding feature, and if not, it should be eliminated. This requires that we observe an operation or function, watch people at work to determine motions, very carefully, addressing:

o Value added
o Incidental work
o Waste

This is a fundamental key to improvement, determining these, and then moving forward armed with the facts to make changes which actually improve overall value added, reductions in incidentals and waste or variations in production.

Continuous flow is the goal, uninterrupted production, knowing balanced production which is seemingly flowing OK, can still be inefficient. Consider that incidentals are motions that people must do, but that do not add value in production. This may relate to how we get parts/tools/materials, or how we setup for work—all which may be necessary but which must be minimized.

Sustaining and improving relates to how consistent standardized work rates and/or time used for work circumstances are created. This is all based on accurate and reliable methods for documenting and tracking information in production. Audits may be a good way to determine if standards are correct and if they are being met, or perhaps even exceed based on changes being made as improvements.

Understanding Takt Time

Takt is a German word for meter or rhythm, pace or beat, as in a conductor’s baton, used to establish a “pulse” to guide the music. When used in production and work related activities, takt dictates the rate of production or units per hour (or some other rate of measure which be more appropriate for a given type work). Viewed another way, takt time is the rate at which customers require finished units, as a fundamental customer demand. We must remember, after all, the customer only wants what they want when they want it. Takt, therefore, is the basic customer demand translated into production.

Takt, as a constant variable, allows for a pull flow system to only replace as customers consume,
Takt = Operating Time Available

Values shown above, would be as follows: If customer requirements were 10 per day, a simple calculation for takt, using and in seconds, 50,400. If customer requirements total or net operating time in minutes would be 840, two shifts per day, based on what has been stated, the minutes or 25,200 seconds, per shift. If there were seconds. This provides a net operating time/shift 420 breaks/allowances account for 60 minutes or 3,600 production time, or 28,800 seconds; and added breaks, personal time, meetings, housekeeping, machine efficiency to cycle time, and so on as part of the calculation. We use seconds per unit rather than pcs per hour to describe actual production rates compared to cycle times. Spikes in demand will cause you to hold a safety stock or initiate O.T., both added costs. Revising cycle times at cell, adding people, changing frequently is inefficient, disrupts pace and standards, and increases poor quality.

Assume 1 Shift has 480 minutes of production time, or 28,800 seconds; and breaks/allowances account for 60 minutes or 3,600 seconds. This provides a net operating time/shift 420 minutes or 25,200 seconds, per shift. If there were two shifts per day, based on what has been stated, the total or net operating time in minutes would be 840, and in seconds, 50,400. If customer requirements were 10 per day, a simple calculation for takt, using values shown above, would be as follows:

Takt = Operating Time Available
      Daily Requirements
Takt = 840 minutes
      10 per day
Takt = 84 minutes per unit/day

While this is helpful to determine internal capacity for meeting external customer demands, a different way to approach takt is the time needed to make one product per day, obtained by calculating reverse operable time, numbers of employees, time per process, or other important measures, and again as divided by required pieces per day. If we assume similar values from above, where the total production operation has 12 employees, arranged around 6 key processes, all working within the 840 minute scenario. As alternative takt measures, we could say we have 1.2 workers per unit of production per day, or .6 units of production per process.

Important uses of takt time can become readily apparent. This time reference should not only be used in production, but also in the design of new products, processes, purchasing of equipment, assessing suppliers of material, manpower, money and so on. Takt becomes one of our important tools for assessing virtually all we do, as a baseline for improvement. This is clear, since if we produce at a rate slower than takt, we eventually lose our customer! Yet, if we produce faster than takt, overproduction becomes an issue.

Takt also relates to quality in several ways since running to takt is all that is needed to meet customer demands. Over producing can cause quality problems, assuming all else remains constant, since running faster and harder than we are capable of will fuel quality issues. Another way of saying this is that running to takt keeps us out of shortage schedule issues, again leading to better quality since we are not “running to catch up”. Generally where takt is known and adhered to, 5-S housekeeping is part of the paradigm, and a cleaner facility effects quality in positive ways due to orderliness, knowing where things are and being able to use the right tools for the job, and so on. Takt as a key measure in producing our work also lends itself to immediate response to issues, again positively effecting quality due to having issues and opportunities out in the open and being dealt with rather than “brushed under the rug”.

Takt time and cycle time are not the same, and this distinction must be clarified. Takt time is allowable time to produce one product at rate customers are demanding it. Cycle time is the normal time to complete an operation on a product. Cycle time should be less than or equal to takt time. If cycle time is greater than takt time, we must make adjustments to address this, such as adding duplicate stations for the operation; redefine the operations so that each is elementally less than the takt time, essentially rebalance the line; or, find and eliminate the causes for the excess time. Cycle time will us determine how many employees are needed when compared to Takt. Cycle time is how often a part is finished, frequently faster than control/bottleneck pacemakers. Bar charts can visually contrast operator cycle time and takt time for specific work to help determine the proper number of operators, and for other “quick” and effective analyses.

When customers for a product are highly dispersed geographically, it may make sense to split up products and locate geographically near the customer. Shipping costs are essential to factor in, calculated with exchange rates, infrastructure costs.
Problems with conventional WIP and flow relate to two types of overproduction: Quantitative, which is too much production, more than needed; and early production where we make it before need. The solution is JIT. Overproduction is done to be on the safe side, as excess inventory, before, or as anticipated production—goods are produced before needed. After is excess inventory which compensates for lack of acceptable finished goods due to defects. Small lot reduces accumulation of excess inventory.

Order based production corresponds to actual demand. Difference is when demand increases, a seller’s market develops based off confirmed orders (allocations). This is geared toward fast, flexible delivery of wide array of items. The chief difficulty with order based productions is fluctuation in demand level. Responding to fluctuations in demand require setting capacity to a min/max level and doing increases through OT, excess capacity and temporary workers.

Flow and capacity considerations provide additional insights into balancing and synchronizing production. Two types of inefficient operations result in stock build-up, machine breakdown or defective product being identified. One typical reaction in either case are pushing for larger lots for longer set-ups, to cover defects, or due to breakdowns based on poor maintenance planning. Regardless this leads to creating what is known as buffer stock—more WIP to cover our mistakes and poor management.

By contrast, what is needed is to reduce the WIP, buffer stocks at all locations, and this is suggested to enhance the likelihood of lead time/cycle time will reductions as well. Reduce that which is masking the problems and the problems become more apparent and able to be dealt with. This is why increasing numbers of organizational scenarios are advocating stockless or non-stock production, or single piece flows. The lower we can go toward reduced WIP the more readily we will be able to understand and balance our production functions for profitability. Reasons for stock accumulation, WIP buildup as buffers, may include any of the following, all which tend to “mask” real issues leading to balanced flow for synchronized production:

- Poor production management leading to variations in interpretation, non-use of standards and adherence to the same information.
- Bad process engineering where we do not have the production scenario properly designed, and changes must be done (identified as E-storage).
- Differences in shift or team resources, inefficiencies due to inconsistencies in planning, supervision, scheduling, etc.
- Delays by teams, associates for various reasons, some possibly legitimate, but all requiring elimination and or shifting to allowable time.
- Inspections, leading to defects identification or other issues which must be attacked at the source and eliminated to circumvent interruptions in work.
- Safety stocks are built into the system by various individuals, particularly operators to enable them to have more flexibility and latitude—control.

Storage is four separate categories for further analysis, each with a unique character and behavior. Each requires attacking and resolving in unique ways, as in so many issues for improvement, but all only based upon getting the data for improvement. Types of storage commonly identified are:

- Raw materials/assemblies: due to one or more components, assemblies, raw material or other missing item, the other parts of product are held up.
- Finished product: finished product has not been placed in the hands of the customer. Common among this would be product in transport or some distribution phase.
- Waiting for a process: entire lot of product is held up because previous lot, although completed, was not “released” to next work area or process.
- Waiting: production lot is in transit or being assembled, prepared prior to moving to next area or process, but was not completed.

Again, regardless of circumstances identified, once these issues are documented, it is critical that we move on them to resolve and move product into the hands of the customer. Note as previously pointed out, the lot size is key since while larger lots tend to provide an economic level of critical mass for production, the larger lots also tend to “mask” errors and faults in flow as a balanced, synchronized action. Part of the challenge is to understand and standardize around lot sizes. For example, small lots are commonly thought of as 500 or fewer; medium lots are 501-5000; and large lots have 5001 or greater. Standardized WIP requires understanding lots, how to containerize the work, and/or how to mistake proof the WIP and work to a minimal size which supports production but also “unmasks” errors and mistakes.

Eliminating excess storage requires balanced level quality through standardizes process, and balanced process, with standard WIP. Typically work capacity not balanced among operations/processes, leading to inventory build up between higher/lower capacity and all are generally operated at 100 % capacity. Even with leveling/balancing in work there can be unnecessary storage, commonly called buffers or cushions, characterized by:
Flow continuation; problems in work not understood, require overproduction, often to become embedded as a “necessary evil”, a “change resistor” requiring added effort to change, the longer we do not take appropriate actions.

Change in production plan: frequently done at the point of production by a worker, overriding Kanban #, which was preset as part of the lot size and containerization program, leading to a key reason for failure in production.

Cushion stock, while known to need minimized (eliminated) in the system, will generally remain a reality, even as we make improvements. Some of the ways to get started, and to make progress on reducing the cushion or buffers in production include:

- Identify kanban levels and stick to them, only borrowing if absolutely needed, replacing any borrowed from the next kanban upon arrival.
- Force problem awareness to the lower levels by holding firm on kanbans, and lots, rather than changing and masking behaviors.
- Begin integrated flows by equalizing consecutive process and synchronizing with other functions such as allowances in work.
- Since one piece flow increases frequency of movement, improve layout and provide conveyors where necessary.
- Strive to save in distribution, storage: reduced delays in finished goods, floor space being consumed while waiting, expediting costs required due to other waits, etc.
- Apply principles for reduction of process delays: reduce process time, level/balance quantities, understand worker allowances and reduce, synchronize flow to one piece
- Reduce lot delays, size in standard WIP ongoing, using TPM, improved housekeeping, mistake proofing, to “unmask” realities in workplace.
- Reduce production time by using time studies to eliminate time and unnecessary motions, assuring value adding work in all that is done.
- Employ layout, line forming, all full work stations with no unnecessary down time, using layout to eliminate transportation, link process with conveyors and proximity.
- Strive for faster quality feedback to reduce defective, reduce lots, process delays, shortened production time, and to increase communication.
- General problem is different capacities or cycle times; all must be synchronized and maintained around takt as baseline, using minimal stock levels.

- Critical to establish takt time to help ensure flow between processes, synchronizing operations, absorbing and adjusting deviations in buffer stocks;
- Establish and work to standards in all that we do, minimizing and reducing deviations, realizing one compromise leads to another, and so on.

Ultimately, we must understand at various levels and in various ways that many of the traditional cost accounting rules and methods may require modifying in the future to address changes in the costs of doing business. This is definitely true if, for any number of reasons, we are looking at inventory costs as a positive (perhaps due to charges back, amortization costs, and so on) in some traditional sense. Inventory, whether by the title of storage or distribution, is a liability and not an asset. We must increasingly evaluate inventory according to the cost to produce when placed in the hands of the customer.

**Traditional Industrial Engineering Inputs**

Several traditional industrial engineering tools have been used to address productivity in an attempt to make improvements over the years. While traditional, these tools represent tremendous opportunities for extracting and defining process. This begins the processing function, also begins the discussion about the ongoing process control plan (OPCP) and the standard operating procedure (SOP). The OPCP and SOP are presented as broad-based systemic documents, relating to everything involved with process, as opposed to simply an engineering or production department document. All must take a broad look at what the sources are for the OPCP and the SOP, and use them for improvements.

The basic relationship of these tools to quality is that we must detail out process in terms of time and method relationships if we wish to better understand processes and operations involved. Once identified and documented, we can then be in a reasonably good position to begin analyzing for improvements. But if we do not know the facts, how can we improve upon the process? The entire basis for benchmarks, comparisons, and future references for evaluations related to both quality and productivity are, to a great extent, inherent in these traditional tools. The basis for establishing cost of product for estimating and bidding on future customer's work is directly related to our understanding of time and method.

The purposes for inclusion of this type information and analytical approach are solely for persons at any level, operators through top management, to be better prepared to assess their
own performance and document the same for ongoing improvement over time. These tools are not being shared from the perspective that a traditional industrial engineering department will "set standards" to determine who is doing their quota and who is not. Rather, these tools are used, similar to any other tool, to help empowered persons make improvements, for the direct and indirect benefit of the organization, their customers and suppliers, internal and external, upstream and down.

The tools have a natural relationship to productivity, since as we improve in any manner, we should logically expect productivity to improve. As process is improved, it seems logical to anticipate safety and quality to improve, for example. Through time studies, work methods and other traditional tools, ergonomics of work should naturally improve. As safety and ergonomics improve, quality should improve, all tracked and confirmed with data and documentation. This is all true since the tools and systems relate to the following underlying principles:

- Time waste differs from material waste in that there is no salvaging of time.
- Human waste of time is hard to recognize, correct since it does not litter the floor.
- Time = human energy, or the “shadow of motion” in a time and motion context.
- Delay is identified as differences in motion and sequence required to do work.
- Time is simply a reflection of motion, heavily related to the human side of work
- Improving human motions, or motion studies are best analyzed alongside time.
- Time studies require further analysis of work and related facts in detail.
- We must pursue with goals, determine tasks scientifically, relentlessly ask why?
- There are generally multiple answers, we must keep an open mind, be objective.
- We must identify a best way—but based around a stubborn refusal to give up.
- We must establish solid standards based on work not motion structure.
- Focused improvement comes in part by knowing times, standards, where we are.
- Division of labor and evolution of work are important elements in improvement.
- Decisions in simple repetitive tasks must be done by reflex, quickly, automatic.
- If we can simplify motions, all learn quicker, sustained quality is easier.
- Motions involving picking and placing objects need eliminated or reduced.
- Movements like stacking, loading, unloading, combining are not value added.
- Work synchronized around machine motions, combined, can reduce total cycle.
- Mechanizing human work, loads/forces, any unnatural position, is value added.
- Eliminated waste in travel, elements leading to bottlenecks, is value added.
- Improved load/unload and multiple machines managed simultaneously, value added.

Systematic industrial engineering, in the traditional sense, is an analysis of systems and methods used in operations and processes. This engages human elements of “man and machine” scenarios. Industrial engineering also acknowledges the complex relationships inherent in data and documentation being a fundamental requisite for solving problems, adding value, doing changes as improvements.

**Machine Time vs. Cycle Time.** It is important to separate operator and machine or equipment time. Once equipment cycle and times required to do the cycle is understood then people work can be balanced against and consistent with this. Once equipment is understood, we will strive to fill equipment cycle time with value-added labor. Nagara means maximizing work, every second, synchronized acts as effective utilization of time integrated as one-piece flow.

Best case, movement of operators becomes actual operation for improvement, with further analysis disclosing those movements that add value and those that don’t. Value added results in some transformation or change in a productive way. The difference between work (value added) and motion (waste activity, no value added) is clearer.

Worker motions must be analyzed and improved thoroughly, moved effectively through point of becoming standard operations. Standards sheets should reflect cycle time, work sequence, and standard inventory of materials and equipment used. We cannot overlook superficial aspects which may include human time, machine time and the need to balance all along side human intelligence and needs. Machine Cycle Time is further defined as load/unload labor time + machine cycle + any human assembly time + change + number of pieces.

**Automation, Cycle Time.** Higher labor productivity is achieved by improving work methods and adding multi machine handling: automation further increases productivity. There are six stages, or levels, of machine work which accentuate this:

- Handwork, where all functions are by hand with no automatic feed or automation.
Cycle time should be analyzed for micro-seconds (micro-motion) and taught to organization, as a higher level time study tool. Micro motion provides work combinations broken down into work elements. Actual times required for each element; timed separately and broken down in fine detail, the used to take an overall time for checks and balance in operation. Collection of accurate times requires a stop watch with sampling at different times. It is recommended that four different samplings of at least 10 times per element be done. Cycle times can be determined and used as a basis for standard times.

**Time and Motion Study.** Time study is a procedure used to measure the time required by a qualified operator, working at the normal performance level, to do a job using a standardized method which is best suited for the conditions involved. Times established can lead to standards representing time required by a qualified operator working normally to perform a defined job. Factors such as interruption, delays, fatigue influence the operations in several ways.

When combined with motion analysis, this results in trying to finding the motions and coordination that enable a particular element of an operation to be done with the least effort in the shortest time. There is a difference between evaluating performance and actually watching process flow in actual production. The natural reaction is judgment and critique, and this must be kept in proper perspective. Time and motion study is a tool to measure work, not to determine who is working and who is not; that is the job of supervision. Rates cannot run the plant, but can be one indication of performance.

When conducting time and motion studies, remember you are a guest; introduce yourself appropriately, explain what you are doing. When finished, show them all the data, explain what it means, and thank them. Immediate findings should be reviewed with the worker and calculations performed for review. This is essential for development of trust, and a positive relationship for future changes based on data collected and analyzed.

Protocol suggests no interruptions, all in the work area must understand, including supervisors and workers. This type measurement of time and analysis of motions, when done properly, can be used in virtually any operation or process of the organization, and is also appropriate for ergonomics and safety relationships.

Operator selection should include a focus on cooperative, qualified and well-trained persons who represent workers under normal working conditions. As part of the process, it is common practice to study an experienced operator and an average operator, and perhaps others at random for comparative analysis. The standard is evolved, usually expressed as a 100% performance, maintainable by average workers.

It is important to always break work into the smallest elements. Smaller incremental times will lead to additional details in the analysis, but don’t forget about the total process. Essential to identifying and eliminating waste that may be buried in the total process, is the independent element study, but related to the broader work. As part of this, it is important to determine the work elements in time required to make one piece (in the smallest increment in time). That is, determine individual elemental operations, and create list. Then based on the list, what are the times involved? What are wastes which can be identified, particularly as wasted motions? Based on the analysis, redefine the overall process in flow chart form, and eliminate waste. All of this is done using a observation board, a clipboard type tool designed as a platform to write on while observing times, with the watch in line of vision on the board. Person doing the analysis must be positioned to see all movements of material, hands and equipment; may be mobile; part of the key is to remove obstructions.

Elemental study is where we define operations into simple, smaller and smaller elements, for detailed analysis. This is also called the snapback method, or work sampling study where we record reading at end of each element, resetting to zero. This is only precise where there is a great deal of repetition and consistency in the work. By contrast, the continuous method involves starting the watch at the beginning of the study and recording to the end of the study, without analyzing specific elements. Continuous requires determining average time and calculate overall for checks and balance.

Elemental breakdown allows the motions to be reviewed as times and studied individually. Separation of elements will allow for more accurate line balancing by identifying individual operations. It allows for moving from operation to operation and doing independent but related studies. But to be accurately timed, the time study should identify the end of the element; then look at watch and review
time; accurately record time on form (or in computer); and then return to next step in operation.

Some guidelines, or important issues and considerations, to keep in mind as a time and motion study is being conducted, follow. These also help do effective time and motion studies:

- **Objectivity**: It is important for the analyst to be free of biases, and to have no political ties to the work area, reducing likely immediate tensions.
- **Halo effect**: Workers will “perform for the test”; must be sure that the work is leveled out and is actually representative of the average.
- **Observation methods**: Use best times, methods can be duplicated or repeated as needed to assure that these are in fact consistent.
- **Consistency of study**: Repetitiveness is a very important factor, that is how the person conducting the study (analyst) does their work.
- **Consistency of work being performed**: If the work varies significantly, from operator or worker to worker, then the study is likely flawed. The operation and process under analysis must be “under control” statistically at capability.
- **Standard sequence**: Must have a fairly standard routine in the work and motion sequence prior to doing the time study. Repeatability in statistical data being gathered should provide a degree of reliability to do the study.
- **Elemental sequence**: If elements are performed out of order, this results in inconsistencies, and this should shut down the study.
- **Maturity in program**: Keep the analysis in perspective regarding the “age” of the work being studied; a young program has kinks in it and the current analysis may be baseline to improve later.
- **Launch analysis**: Studies early in launch (or for data to design into launch) must allow “cushion” and as launch matures we improve naturally, get better, more efficient as “bugs are worked out”.
- **Restudy**: If the study fails, perform a restudy, retrain the operator, fix the problem.
- **Pre-study**: Review study with workers allows for initial consistency.
- **Observe cycles**: Operations are normally performed in cycles or in a repetitive sequence which should be identified and analyzed further.
- **Observe elements**: Operations frequently consist of number of smaller operations or elements which may surface and require further analysis.
- **Find waste**: Waste may not always be apparent, and will generally require additional interviews and observations with workers, teams and so on.
- **Allowances**: Usual, normal delays and interruptions in work flow need accounted for, identified, and “allowed” for; but to be followed up on for improvement as well.
- **Operator allowances**: Operator allowances (fatigue, bathroom breaks, getting drink) critical to performance must be identified and noted as times.
- **Shift allowances**: Time of day and other environmental nuances noted must be noted and explained as may be needed, allowed for as times.
- **Leveling**: Work abnormalities, unusual variations, may require leveling to get accurate times and consistency; establish trust; from analyst experience, knowledge.
- **Performance rating**: If substantial leveling is involved, could require some type internal “performance rating” to communicate to all, unique circumstances involved.
- **Interviewing workers**: Best method is video of the entire operation, then discuss pace of work; order and timing of work in process; which operations are standard, which are non-standard; and so on.
- **Filming**: When reviewing film of operations invite worker, supervisor, improvement team, all involved; after observing themselves for improvement employees likely will have suggestions which are implemented immediately.
- **Team implementation**: Team is the vehicle to actually make the improvements happen, based on analyst objective involvement.

**Fatigue.** Three general types of delays are frequently identified in time and motion studies, also having much to do with fatigue. Complexities involved in fatigue relate to quality, safety and productivity issues as noted:

- **Personal requirements** – hygiene, getting drink, bathroom, snacks.
- **Fatigue** – depends on working conditions, job, ergonomics, inspection, mental strain, light, noise, temperature and other physical conditions.
- **Unavoidable delays** – poor quality, repair color dots, material handling or other technical process issues involving supervisor, engineer, equipment failure, etc.

Personal fatigue delays (PFD) = overall fatigue delay factor, and this may be given a numerical rating, as an estimate. These may be generally in the following ranges: Personal 3-5%; Fatigue 0-15%; and, Unavoidable delays 3-5%. Other related fatigue factors are related to the work should never be more than a person can do reasonably in an eight hour period. This is based on working 8 hours a day, not because its 33% of a 24 hour day, but because it is the length of time to be respectful to the worker.
Unusual motor skills should be avoided for several reasons, including if they are difficult to learn, measure or repeat. If motor skills require special procedures and tools and are usually not ergonomically friendly, these too should be avoided. Similarly, we should avoid motions requiring much coordination, senses (feeling and touch), or if they are hard to learn. Those motor skills requiring much physical effort, or being a high degree of strain on the body, usually time consuming, costly and may lead to injury, all can increase fatigue level. These type considerations may lead to a need to review material handling equipment, rotate jobs, and even to redesign other elements of the work to reduce fatigue.

**Time study.** Time study is the commonly used stop watch technique for documenting and analyzing time involved in a given process or job. Increasingly this is being used for process planning and other positive purposes—rather than for punitive (analysis to find out if people are doing as much as they should be) purposes. Several steps should be observed when conducting a time study, and these are summarized below. First, it is important to learn about the job to be studied. Obtain process sheets, drawings of parts, plant layouts, existing standard data, and so on. The person who conducts the study must know as much of the history of the job as is possible prior to conducting the study. The analyst should go to the work area and study how the job will be done. They may wish to list out steps and procedures which appear to be necessary to complete the task.

It is important to obtain permission from the front-line supervisor to conduct the study. This can be quite important since the analyst will not have control of the people whereas the supervisor should be able to gain control and cooperation of workers for the analyst. If cooperation is not obtained, workers will be less likely to perform in a manner necessary for successful time studies. After the supervisor gets the worker's cooperation, the analyst should talk to the worker(s) to explain the process of time study. This is done to help the worker be at ease and function in a manner representative of normal procedure. The fact is—supervisors or workers themselves—should conduct the study.

We must be aware that some workers may attempt to work at a non-normal pace, providing less than accurate data. It is increasingly important to obtain the cooperation of the worker, to keep the worker from getting a negative attitude, and again, providing inaccurate data for the analyst. Workers may think if they work "too efficiently" they will be expected to perform this way at all times. They are more likely to "drag their feet", working at a slower rate than normal, reducing expectations by all.

A stop watch should be used to actually time the task at hand wherever possible. Several different types of stop watches can be used, including wrist watches for non-sophisticated circumstances, standard stop watches, stop watch on clipboard, multiple watch clipboard, and, electronic devices. Although the standard stop watch can be used, it may prove inadequate since the small hand may not provide sufficient ability to record a lengthy task. It may also be that when a stop watch is stopped and started over the time required for the sweep hand to return to the start point will drag down the overall efficiency of the operation. This is one of the key reasons for development of the multiple stop watch system. Three watches are typically used to avoid second-hand return inefficiencies, and other problems associated with using single stop watches. Electronic devices are popular for a variety of reasons since they can be easily used and are relatively precise.

Actual times are recorded on a form similar to what is provided for applications. Times are either determined and documented based on elements, or continual time increments. Continual timing uses the entire job as a whole and provides one overall analysis. Element analysis, by contrast, provides times of key parts of work as separate functions. This is important since some jobs require more detail relative to a broad overall analysis—or it may simply be important to focus on one or two elements.

After individual times are recorded for the task, specific areas appearing to be inefficient are determined and analyzed for improving. The task may be timed for several trials, and averaged. If standards already exist, the times gathered may be compared to standards which have typically been arrived at over many trials of the same task. Of course, if no standard exists, the analyst can time enough trials of the task to permit a similar value to occur from the average worker. Although standards are costly to develop, due to extensive trials required, the advantage is one of providing a baseline.

**Work methods.** While time study is used to determine, analyze and improve time spent on tasks, work methods improve the methods involved in completing tasks. Over time, after many trials, the primary objective is to improve and standardize methods. It should be noted, regarding time study as previously presented, that generally there is a column for description of the task which is being performed. While that listing is primarily for purposes of time study, it also provides the basic requirement for work methods analysis, a listing of current methods for
performing a task. When time study and work methods combine, it is time and motion study. Work methods are conducted to determine as many of the details involved in the task, or work, as possible. Tasks are analyzed for human and mechanical movements to determine if they are necessary and productive. Human inputs are the more significant for methods analysis since wasted movements mean direct added cost due to non-productive time spent on unnecessary outputs. Wasted motions and movements by machinery and mechanical devices can be costly since machines cost dollars as a capital expenditure, despite what its return on investment may be. Cost of utilities, maintenance, down time, and so on, adds up, leading to concluding that wasted machinery movements must be avoided. Work methods principles include:

- Use the shortest path between two points.
- Consider safe work methods top priority, even when appearing less productive at the outset.
- Avoid "dead-head", empty-handed trips.
- Plan a task prior to starting, identifying and obtaining needed tools at one time to avoid making numerous trips.
- Sequence parts of the task to take advantage of existing logically following steps, rather than completing a step, backtracking to something unrelated, and going back to the previous step.
- Use machinery and work areas compatible to people, wherever possible. The machine should be fitted to the person rather than forcing the person to comply to the machine.
- Combine steps which are difficult and easy, providing some "breathing time" for people to work with a rhythm which can help sustain satisfactory productivity without fatigue.
- Do not combine possible hazardous conditions with fatiguing methods. As we fatigue, likelihood for a hazard to "catch us" increases.
- Methods for work should be analyzed for improvement, as the "big picture" of the work. At the same time, it is important and necessary to take the sub-tasks individually into account for analysis. Detailed, step-by-step identification of inputs must be a part of work methods analysis.
- When possible, sequences and/or individual tasks should be eliminated, combined or simplified. If it does not need to be done it should be identified, accepted and acted upon.
- Although a straight-line motion of human effort is generally most efficient, a curved motion from point-to-point may be more productive in terms of worker's comfort and lack of fatigue. If a worker has momentum in moving, this is used, not wasted.
- Hand motions start and stop at the same time to help maintain "body balance". The hand motions should occur along with one another. Keeping two hands busy is more productive than having only one hand busy. Use right-hand, left-hand analysis.

Many organizations use a standard work area design to facilitate use of proper work methods. This is employed to aid workers in accommodating cross functions and broad job descriptions which require teams in new areas. This is a basic platform or bench, backdrop for hanging SOP's, standard lighting fixture, and other standard elements cost effectively located and assembled--standardized. This also has obvious advantages for quality as well as productivity and safety for positive ergonomic relationships.

**Therblig analysis for value added.** One of the traditional work methods analysis tools is the therblig. Therbligs are motion descriptions which can be used to assist in identifying and describing work. Therbligs and their symbols are: reach (TE), move (TL), release (RL), grasp (G), preposition (PP), use (U), assemble (A), disassembly (DA), search (SH), select (ST), position (P), inspect (I), plan (PN), unavoidable delay (UD), avoidable delay (AD), rest (R), hold (H). The typical approach for using therbligs is to identify a task and analyze each movement according to its therbligs. Further analysis is provided by identifying the therbligs which are effective and ineffective.

The traditional effective therbligs are: select, grasp, release, use, assemble, and, disassemble. Therbligs as ineffective movements are: preposition, reach, move, search, position, inspect, plan, unavoidable delay, avoidable delay, rest, and hold. Ineffective therbligs are non-value adding and should be eliminated or reduced. Effective therbligs are generally more value adding and should be enhanced in the work analysis and design.

By identifying and classifying therbligs it is possible to know which movements to begin working to eliminate, and where the savings will likely occur. This is true since the ineffective therbligs are traditionally the less necessary movements, and can often be eliminated more readily than the effective. An alternative method is the left-hand right-hand method. The major difference with the two methods is that the left-hand right-hand method provides a more in-depth analysis based on detailed analyses of each hand. Forms and approaches for the systems are provided in the applications section.


**Work sampling.** Project managers, supervisors, and others are expected to investigate projects and work areas continuously to find better methods and control cost. Results of their efforts cannot be expected to have the same degree of accuracy, value, or results obtained by industrial engineers or technologists. Managers may be interested in activity ratings on projects. Work sampling is a technique that can provide answers in a relatively short time for effective actions.

Work or activity sampling as it is sometimes called, was developed in the English textile industry in the late 1920's. The technique was originally called the snap-reading method after the snap-shot concept of photography. In the 1930’s, it was renamed the "ratio delay technique." In the 1950’s, the name "work sampling" was coined largely replacing the earlier nomenclature. Work sampling was a more descriptive term covering a more general application and varied uses of this technique. Work sampling is generally only limited to the investigation of the time when a person is working or not working. Studies cover elements such talking, idle, location concerns, and other potentially nonproductive elements. Other interesting factors may be discussed by using this informal on site work analysis technique. The technique represents an excellent tool for use by teams and individuals for self evaluation purposes.

**Operation, process, capacity determination.**

As we improve the gemba, or workplace, we apply the traditional time and motion analysis tools as well as non-traditional Kaizen tools. One technique which can help us improve is the determination of process capacity based on operations within the process. Once individual capacities are determined, we can better balance our total organizational capacity through improvements at individual operations and ultimately collectively through improved process.

Determination of capacity also assumes we understand distinctions in operation and process.

Process is commonly thought of as being broadly based and composed of multiple operations. The process subsumes operations. The process involves all activities in the production sequence, including those which appear necessary but may be wasteful, and thus, should be eliminated through Kaizen. The nearby graphic shows the four classic processes of storage, inspection, delay, and transportation. These are shown separate from the process side since these are non-value adding categories of process, yet they will exist. Our function, or goal, and certainly task, in Kaizen, is to reduce these process inputs and maximize on the operations side of work, where value is added.

Thus, part of the distinction between process and operation lies in the question of where value is being added, or if value is being added at all. Kaizen is about waste reduction. If we wish to reduce or eliminate waste, as must be done to be successful in Kaizen, we must identify the capacity of the operation for adding value, and use the operation to its optimum performance capacity. A work sheet is provided in the applications section to assist in this determination, targeted to further analyze the specific operation as part of the previously determined and analyzed process. Again, there will be delays, transports, and other wastes in the operation, needing to be identified and improved upon as waste. What is being pursued here is the need to identify and provide an optimum operating time for production within the broader process. Individuals or teams will do the following to determine capacity:

- Make the distinction between operation and the broader process.
- Identify and describe the distinction in writing and with flow charts and layout diagrams.
- Detail the steps in our operations--likely based all or in part on standard operating procedures which we have in some phase of evolution.
- Provide pertinent support/additional documentation as appropriate.
- Analyze and detail specific operation processes and functions as manual work, processing work, and other time and/or distance related information.
- Calculate sub totals and a total time from step three-five above, this being current capacity.
- Based on observations and capacity analysis, identify potential waste reduction possibilities.
- Repeat the capacity study process over time for improvements ongoing.

This process analysis technique, while still macro, is extremely close to being a micro technique. The operation capacity study is based on the assumption that we can detail out our operation processes and functions, all which will be studied further for improvement later. It should also be apparent that the capacity determination tool, while quite useful as an independent technique for improvement in any isolated circumstance, is a necessity for determining work loads for balancing and improvement through synchronous and JIT techniques in the broader Kaizen and improvement sense.

**Process mapping: Plant layout and flow diagramming.** Related to time and motion studies, and work methods, other tools useful for addressing productivity are plant layout, process flow charting
and inventory related approaches. Process flow charting uses symbols placed in a condensed format. The typical flow symbols, shown in the flow chart example provided, are usually placed in a progressive line format, connected, and numbers are placed in or near the symbol to correspond to a chart with all procedures for producing the product. The advantage of process flow charting is that the entire enterprise system (or a sub-component) can be analyzed from a graphical schematic. Times and costs can be placed alongside each process on the chart, permitting further comparison and analysis. After those processes or tasks where the greatest time and/or cost is incurred we will troubleshoot these tasks/processes for greater efficiency and productivity.

By placing plant layout in schematic diagram form, analysts can readily identify obvious trouble spots. For example, if in studying the layout diagram it is observed that some space is not being fully used, the prudent manager would attempt to better maximize on the space. As a general rule 75-80% of all space should be in use for optimum capacity planning to be prevalent. If this is not the case the industry may be losing money due to increased energy and maintenance cost, mortgage and interest cost, and perhaps other non-productive costs. Based on actual and simulated production problems, relationships in layout and flow diagrams can prove useful in resource allocation, both on a day-to-day basis as well as for future plant/capital expansion.

When this information is known and documented, it is pivotal that various inventories in storage, and work-in-process, are completed. Since much cost is associated with inventory, it makes sense to try to reduce and control these elements. Often labeled materials requirements planning (MRP) as discussed earlier, the idea is to know in very detailed ways where all materials, components, and assemblies are in the operation. This also relates to detailing times for set-up, changeover times of various products and components, throughput times and total time to complete a product. This relates to total time and costs to produce the product, much of what is driving profitability and competitiveness.

Relationships of people, machinery, and materials movement should be carefully analyzed to determine lengthy (costly) movements and potential bottlenecks or other down-time possibilities. Properly used time studies, flow charts, and plant layout diagrams can lead to removal of potential safety hazards, avoiding down-time, retraining of personnel, insurance payment increases, and so on.

**Performance Rating.** Many performance rating methods exist, including speed rating where the only factor considered is speed of activity. Another rating approach is effort rating, closely related to speed but different in that it goes at a different pace but has efforts identified, looking for “difficult operations”.

After days of running operations usually (traditionally) act as isolated islands. Operations begin to build up batches between operations. Kanban squares or standardized WIP locations are helpful since we can fill each operation with work timed to takt intervals in production. We then can divide the work among several operators moving between machines. Scheduling of customers and work overall is done based on the bottleneck or pacemaker part of the operation.

Amount of time from when material is released from cell or work area in pieces per container x seconds per piece = paced withdrawal. An example could be 20 pieces x 20 seconds for each piece = 400 seconds or 6.7 minutes for a paced withdrawal. We can learn how to set-up flow based on paced withdrawal by starting in warehouse and walking backward to track the pull in production, as in reverse flow. We then can use this to establish material handling route, general flow, and timing associated with balance issues. This is a key factor when producing large batches of one product family, and where leveling is important for balancing.

We can also visually contrast operator cycle time and takt time for a specific line or cell work area to help determine proper number of workers for a specific line or cell by visually displaying work load balance (or imbalance), and a possible need to keep balancing for improvement in cycle time. We can also determine crew size by dividing labor content as an aggregate amount of work to be done in a cycle by takt time. This can help determine available workers:

\[
\text{cycle time/piece} = \text{number of operators} \\
\text{takt time} \\
180 \text{ seconds cycle time/ 1 piece} = 3.0 \text{ operators} \\
60 \text{ second takt time}
\]

The example provides 180 seconds in the total cycle to complete a workpiece, with a takt required time of 60 seconds. This leads to the conclusion that 3 workers are needed under the conditions noted.

**Standard Work-in-Process (WIP).** Standard WIP minimum running stock is measured at work stations so work is repeated, in the same sequence and with same movements, using standard work instructions. Standardized WIP helps maintain quality, productivity and safety using basic rules:

- WIP is usually calculated based on 10 % of daily production, maximum.
WIP measured by quantities based on standard totes, if one piece flow is not used.
Automatic equipment pace needs sufficient WIP to separate worker from equipment.
Use TPM as a key method to balance work, allowances, around standard WIP.
Consider outsourcing, adding equipment.
Leveling WIP quantity with equal amounts produced at each work area, balanced.
As broader operation WIP’s are leveled, must level at every process.
Excess WIP masks issues, others keep working, hiding problems.
Move WIP close to process to reduce, use only what is needed for daily takt.
Work with suppliers to receive and prepare WIP in correct totes, quantities, qualities.
Do not run machines to increase efficiencies—possible changes elsewhere will erupt.
Use fail safe assembly boards, poke a yoke to prevent wrong part assemblies.
Operators do not get/travel to restock parts—do outside/beside cell by others feeding.
Improve, shorten setup and transition time, decreases WIP.

Man-machine analysis—common sense approach. Man-machine analysis is presented as a systematic and informal method for improving quality and productivity of work areas by better understanding our personal situations. Designed to use data and information already discussed in time study and work method analysis, man-machine analysis is a common sense approach to “looking at how we work”? This can be done by hand drawn, self generated, sketches and other information, with the other forms and approaches, used by teams and individuals. It can also use simple CAD generated drawings, depending on equipment available.

Sketch or draw the work area, or the task/area. If no machine (in the traditional sense) is involved, then put the items which are involved in your work in the sketch. Use the following as guidelines:

- Keep the entire sketch on one 8 X 12 sheet of paper. This is done to show the entire work area or task in one glance, graphically, and to view it as an operation in the broader process.
- Lay out the sketch so that it is roughly proportional to the actual area being represented. If the total area is shown on the 8 X 12 sheet, and a machine is in the center of the actual work area, then it should also be in the center of the 8 X 12 sheet. If the machine takes up half the work area, it should also take up approximately half of the sheet of paper.

Measure distances in the work area, and show them as actual measurements and distances on your sketch. These are shown and symbols for transport and storage should be used as part of the analysis.
Show each major device or machine, bin or cart, desk or stool, and so on as a square or circle rather than trying to detail the art work. Try to get a graphical diagram for analysis—not a perfect drawing—but label each item so others will know what they represent, with notes to yourself as well.
Try to show time, space and distance relationships so that sufficient details are known to assist you and others in improving. As the proposal is "moved forward" for improving your work area, it will need to be packaged with other information in a neat and legible way to be communicated to others.
After current methods, times, and other details are shown on the sketch, and related to other information and forms, analyze what you have drawn or assembled for improvements.
Talk to others knowledgeable in your work area and try to determine if other approaches might be possible and helpful. Quality charts, inventory and cost information, and so on should be used to show relationships and benchmarks for improvements.
Using your knowledge of the method and task/work area, reflect on circumstances which cause fatigue, pain, or other problems, and determine ways to improve.

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Based on the analysis, and inputs, redraw the sketch on a separate sheet, and simulate all steps, distances, times, space relationships, and so on, to determine how your proposal will work.

Compare your new proposed approach to the existing method, looking for possible gains and improvements. This should be done in team with others you work with upstream and down.
Depending on various views and circumstances, try to implement your approach, and assess its effectiveness against various measures (time, defects, cost information, units produced, others).

This is a simple approach to improvement, a "common sense" method which relies upon well established approaches developed through years of work by the industrial engineering field. Regardless of how simple or complex, if used in conjunction with others on your team, and from other teams and work areas, you can make improvements.

Kaizen Workshop Improvement, Walk Through, Visual Analysis, Management
Walk through analysis and visual management techniques which can be used effectively in various ways to improve. The basic question to be asked, in various ways is equipment arranged efficiently to allow continuous flow and meet takt time, or other general requirements to address necessary throughput? The WTAVM can provide indications and highlights of issues for lack of balance, Kaizen opportunities to be studied in more detail. Areas analyzed and/or noted in the WTAVM relate to the 4 M’s: machines, material, manufacturing, and methods (measurement).

Possible abnormalities can be suggested based on the WTAVM and a more thorough review of controlled work instructions at the workplace to determine variations from standard work by a single worker. We may also be able to identify possible root causes for each case where work instruction information varies from the general trend, or what should be based on standard work. The work elements and time data are facts for problem solving which we must encourage all to develop comfort level with as a means to objectively approach and deal with changes for improvement.

WTAVM floor studies can be used for multi-disciplinary teams to review all equipment and process for safety and quality, general improvements. Depending on other more detailed information which may or may not be available, the WTAVM information can lead to quotes; baselines for improvement (standards); immediate or long term balancing; work analysis for layout changes; review against existing time and motion studies; among others. Standard forms should be used to provide a quick mechanism for team leaders and others to use, and results can be posted for all to see and improve.

As part of the WTAVM study, it is important to do sufficient preparation on paper, or conceptual setup to characterize the actual work area. As part of the “paper setup” work area general equipment and people, standardized WIP locations, conveyors, storage and bench systems, small batch assembly areas and other factors all need to be “mapped” out in a “man-machine” type analysis to be shared with others and used to analyze the area. Key cycle time and other appropriate information should be included in the WTAVM as part of the start point, if available. If not available, then this will become a key focus of the current study, to establish baselines for future analysis. This includes operator cycle time (OCT), machine automatic time (MAT), machine cycle time (MCT), perhaps others.

Time observation exercises should be completed by individuals or teams, perhaps in pairs to observe the processes. It will be important to time multiple cycles of the process, recording cumulative time observations on form alongside information which was prepared ahead of time for use. Based on WTAVM information prepared and applied, we can calculate elapsed times per step, and begin to do a detailed analysis for improvement.

As we do our analyses, it is important to remember that some equipment may be designed for batch processing, or rapid and large volume. These will likely be fundamental to the operations, and they will embody multiple processes which are pivotal to the product. We must analyze these to separate and use pull systems wherever possible, as opposed to assuming batches must drive the systems. For example, can we replace with smaller and less expensive machines at end of life-cycle? Or by juggling process, can we create a balanced work environment which can be better managed per customer requirements?

If large batch production equipment cannot be eliminated, can we apply continuous flow at take-off from the batch operation? Are there other ways to address lot delays connected to the batches, or are we assuming there can be no gains in efficiencies and process times since the batch processing inherent in the operation has been in control traditionally. Even where batches must be maintained, production cycles (lead time) are reduced by eliminating lot delays, leading to one-piece flow. One-piece flow transport can increase cycle time, but we must improve layout and overall equipment, whether around batch logic or not. Order delivery can be better managed to reduce storage between process, storage process delays, lot size, and processing time at all stages.

We must look at synchronization opportunities in all of the work. Supervisor or leader’s job, along with the team, is to balance all elements of the work in the workplace, the fundamental reason for WTAVM. Methods to reduce cycle time must be considered, to reduce work and possibly eliminate a step in the actual work flow. More specific to the challenge, reducing waste or lost time is the general goal in WTAVM. One way to do this is to utilize internal cycle times on machine control, when machines are going through automatic cycles, to do maintenance operations rather than simply being idle. Interaction of people in a system, using available tools and techniques for maintenance, results from choice not chance. This is a worker and management cooperative challenge, optimization of talents, new morale, attitude in life reflected in work.

The goal is to remove the distinction between operations at the equipment level and processes by people, such as time delay, wastes, inventory, transportation, storage—essentially any function which must be done, but which does not
necessarily value adding. This could be operation allowances, such as any work indirectly related to ongoing work, such as equipment cleaning, lubrication or other routine maintenance, housekeeping, and so on. Workplace allowances which may indirectly relate to many operations could be preparing supplies and work areas for a specific job, arranging skids, getting tools, and so on. Technology can help address human dimensions of the work, particularly by complimenting methods for decision making which can be made more routine and automatic through the application of technology.