Referance Material

Introduction to Operations Management

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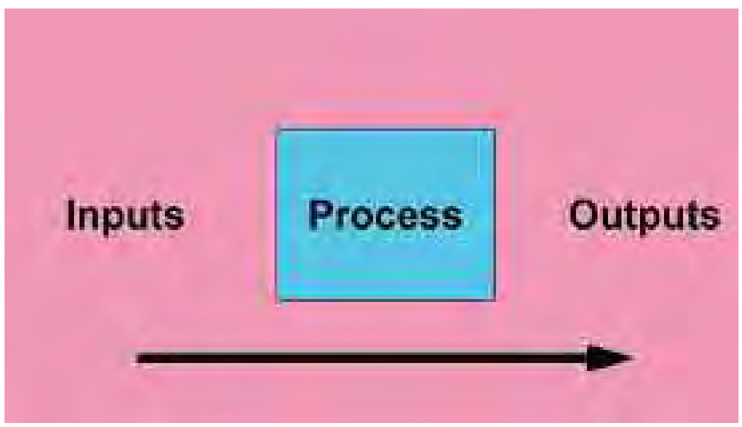
Introduction to Operations Management

What is Operations Management?

Operations management is about the way organizations produce goods and services. Every book you borrow from the library, every treatment you receive at the hospital, every service you expect in a store, everything you wear, eat, sit on, use or read — all have been produced by someone.

The essential nature of Operations Management is concerned with organizing the process of getting things done.

An operation is a transforming process converting a set of resources (INPUTS) into services and goods (OUTPUTS). The input resources may be raw materials, information, or even the customer themselves. These resources are transformed into the final goods or services by way of other transforming resources — the facilities and staff of the operation.



Inputs

Examples of Types of Inputs:
Customers
At an airport, you are one of the many resources being processed. The operation in which you are involved is processing your ticket and baggage, moving from ticket desk through security check points, and onto your awaiting plane. The next time you stand on a moving walkway, imagine yourself as a part moving along a factory conveyor!

Raw Materials
Plastic pellets are melted and forced under pressure into a mold. The plastic is cooled and a finished part is ejected from the mold.

Information
A financial advisor gathers and provides information to clients, and assists in developing a financial plan. Information also includes feedback to control or improve the process.

The Transformation Process

Process
The steps needed to transform inputs into outputs. This can be a series of steps or this can operate as a decision tree.

Capital Equipment
The tools needed to support the transformation process. Structures, machines, computer hardware, computer software and information.

Labor
The personnel needed to execute the transformational process.

Outputs

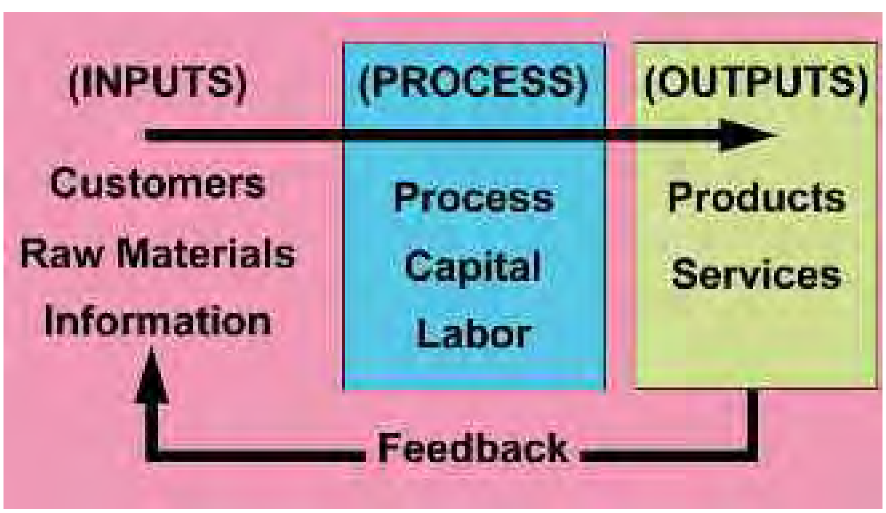
Output
The output is the product and / or service required by the customer. (Customer is used in the broadest sense of the word.)

A system's outputs can be inputs to another subsequent process.

Steel panels are used to make car fenders.
Car fenders are used to build a car.

Outputs can be inputs to the same system.

Quality control data to improve system operations.
Complaints about a bland hamburger may result in the recipe being changed.



Overview of Operations Management Functions

Operations Management involves a lot of different disciplines. To be effective, Operations interfaces with many different disciplines within an organization. The following diagram provides a few examples.

Production and service operations have a central role in most firms (services and manufacturing). They typically account for 70 - 80% of an organization's assets, expenditure and people.

A major part of total revenue and capital investment expenditure is spent on production operations.

Functions briefly defined

- SELECTING involves the determination of what product(s) or service(s) will be produced, and by what processes.
- DESIGNING involves the creation of methods of production.
- OPERATING involves the actual production process—meeting of schedules, satisfying of production quotas and standards.
- CONTROLLING involves testing for adequate performance — with respect to quantity, quality, and timeliness — and taking corrective action as necessary.
- UPDATING involves the revision of procedures within the organization, in response to stimuli from inside the organization or outside the organization.

Operations Management Functions

The operations manager is responsible for the success of the producing unit. This person needs a solid knowledge base (technology of products and processes) and human relations skills (decision-making, communication, motivation.)

Because of the complexity of operations management it is usually assigned to several departments or teams. The degree of cooperation may range from non-existent to highly integrated. The advantage of the highly integrated team is that it minimizes interdepartmental conflicts.

PLANNING
- determine future course of action. Examples include layout, capacity, location, products and services.

ESTABLISHING ORGANIZATIONAL STANDARDS
- set goals and design; set schedules for projects; determine a means for accomplishment.

STAFFING
- selection and training of personnel; the required skill level of personnel; choosing a larger workforce vs. choosing overtime, full-time vs. part-time.

DIRECTING
- giving orders, motivating, formulating incentive plans, writing work orders, assigning jobs, measuring results, checking for acceptability, taking corrective action.

CONTROLLING
- inventory management, quality assurance, process capability.

ORGANIZING
- administrative structure; degree of centralization, make versus buy.

Who, What, Where, When, How

The organizing function entails, in addition to setting department structure, deciding how resources will be allocated. Allocation is to be as "efficient" (profitable, cheap, timely, etc.) as possible within given constraints. This is clearly an area where compromise will be necessary.

- Who: manpower assignments
- What: product line decisions
- Where: facility location, product distribution, and sources of supply
- When: timing of inputs, outputs; hours of work; manpower schedules; inventory supply problems
- How: what technology to apply

Thus the organizing function is far broader than mere structuring. The organizing function can involve substantial use of quantitative techniques such as linear programming, forecasting, inventory modeling, etc.

Comparing Production and Service Operations

What is different about service operations? Most services have an element of product-based operations integrated with service delivery. A pure service operation does not exist. Methods which may be used to design, implement and evaluate product operations are relevant to service.

Situations faced by service operations managers may be less significant and/or less frequently encountered by the production/manufacturing manager. The points at which comparisons can be made include:

Customer Presence and Participation.

Production operations change materials into finished product. Then, after storage, transportation and stocking, the customer is supplied with the product. Unless the customer is consulted about the product specification and has the opportunity to inspect and give advice during production itself, production managers seldom meet customers. (The exception is the plant tour, when clients and other interested parties visit the production floor.) The public relations and customer care aspects of production operations are minimal. Operations have room to function without worrying about direct customer interaction and complaints.

Such customer encounters are commonplace for service operations managers. Even the manager and staff of a computer services operation are constantly facing situations where customers complain directly and forcibly - not from a distance, but being present, while the staff is working.

In a service organization, the customer is an active part of the process. In a charter bus or taxi, the customer talks to the staff and shares information and feelings. The staff responds to the customer's detailed requirements and handles their anxieties. The staff can also offer their own opinions.

Using Customers as Labor

In self-service situations, e.g. a modern supermarket, customers are extensions of the staff of the store. Supermarkets are even experimenting with scanning devices that have the customer process their own selections and calculate shopping totals. The customer becomes the check-out person. The aim is to reduce the waiting time and the number of checkout staff, and to provide the customer more information. Remaining store staff carry out back-office functions and become advisers to customers, instead of automatons at the checkout.

Self-service requires customers to be physically and mentally able to help themselves. They must lift, carry, process information and willingly engage in the service process. Information absorption, overload and underload can be a problem and service systems must be designed according to the needs, abilities and preferences of differing customers — the young, the old, the pregnant, the confused. If these conditions are not met then customers may perceive poor quality.

"Last night I spent five minutes and walked up the aisles of my local supermarket several times before I found the Parmesan cheese. It had been shelved with pasta products, not with the cheese!"

When using a self-service photocopier, a customer found the instructions for reduced, double-sided copying to be so complex that 16 sheets were wasted out of 24 that had to be paid for!

The customer who cannot understand the instructions on how to assemble a bicycle or set up a computer system may be lacking in skill and knowledge, but if this results in dissatisfaction, this ill-feeling may be passed onto a wider public - their family and friends.

The automation and depersonalization of some services may have gone too far. Here we can distinguish between a "premium" service which gives direct staff support to customers and a DIY service which emphasizes customer independence - the intangibles become apparent.

Retaining existing customers is much cheaper that the costs of winning new customers. The loyal customer is an asset. Thus the significance of customer satisfaction is obvious. People hate changing their dentists, hairdressers and local car mechanics. Personal confidence in the situation, familiarity, rapport and environment are often valued over more objective measures of operational performance.

When the Product is an Experience

Whether at Disneyland or when travelling on a train, the ambiance and responsiveness of the service are produced and consumed as one. The depth of planning and preparation which enable the "product" to be consumed are hidden from the customer's view. The customer sees and feels only the delivery phase of the product/service.

Some customers may not mind waiting. Many will not wait and respond with varying degrees of irritation. If the customer knows of another service provider within easy reach, they may get up and seek other options.

With the customer consuming "the deliverables", we need to control service quality **by design** before it is actually delivered. This is why the quality-specification approach to service design is so attractive. In a factory where a zero defects policy is applied, defects should not leave the factory. In services, a process-planning and a zero-defects approach to service design which is supported by a trained, loyal staff is essential to customer satisfaction.

Difficulties in Stocking a Service

Service capacity is wasted if not used. Service providers keep spare capacity to meet peak demands yet need to keep such costs to a minimum. Demand can be subject to rapid change which can be either short or medium term.

An example: Short term variation is a computer help desk person who, on average, can advise and sort out the problems of 6 clients an hour. This person may have no calls between 15.00 and 16.00 a.m. followed by twelve clients from 16.00 to 18.00. The first ten were handled with an average of 5 minutes service time. The eleventh client needed over an hour's attention, leaving the final client waiting and worrying about a solution to their problem.

Medium term variations are often due to seasonal and cyclical patterns. Many are regular and predictable. Snow removal in the winter and lawn care in the summer are examples of a seasonal variation.

Intangibles

Intangibles in the service transaction mean that it is often difficult to specify and agree completely about the exact nature and dimensions of the service. Customers will vary as to their perception of what they want out of the service and what they are getting.

- Do you like a sales clerk greeting you and offering help the moment you enter a shop or do you see this as pushy and an intrusion into your space?
- Do you mind waiting in line or even being asked to line up at the entrance to a restaurant while the waiter finds you a table?
- Would you ask a waiter to turn down the volume of music in a restaurant? Would you not give a tip because the waiter did little in serving your table?
- Most patients surveyed in a hospital outpatient clinic may feel it unacceptable to wait 20 minutes. Older patients, however, who visit regularly may enjoy the opportunity to chat and may be content to wait much longer.

Our assessment of what is or is not acceptable may differ considerably. Understanding customer need is essential and in this regard good market research and mechanisms for customer feedback are important for service deliverers.

Defining Expectations

Clearly establishing the outcome of a process is highly desirable … but it is often overlooked.

Benefits of Defining the Expectations for a Process

Establishes a standard for decision making.
Provides a mechanism for resolving interdepartmental conflicts.
Allows for "Thinking Outside the Box"
Useful in evaluating new technology

Who is the Customer?

A customer can be an individual or a group.
A customer can be the next step in the process. (Providing Raw Materials)
A process can have multiple customers with differing needs.

Expectations Should Include

Cost
Time between demand and delivery
Environment
Level of service
Level of customer support
A description of the customer's experience
Quality of the product or service

Determining What the Customer Wants

Focus Groups
Demographic data
Customer History
Industry Trends
Customer Surveys
Complaints / Feedback

Degree of Customer Control Over the Operations Function

The 'Operations Function' is generally seen as isolated from the customer. In this context, output requirements are passed from the customer to the operations manager to other departments in the organization. This concept implies that the customer has little contact with the actual production. For example, the purchaser of an automobile may specify quite precisely which accessories are to be ordered. But they have no contact with the assembly line floor—the order is passed through the dealer, through the sales desk of the manufacturer, to the factory floor. The customer has no control over the sequence of assembly steps, the timing of manufacture, the training of the employees.

This model is not always true. Isolation of the customer is often less true for services than for goods. A rider of a city bus or other form of mass transit has no control over the route taken, the speed driven, or the placement of stops. However, a more customized service such as a taxicab may provide such features. Similarly, isolation exists for the traveler who flies a commercial airline, but does not exist when a chartered aircraft is used.

When personal service is offered the customer is more involved. Customer reaction is more immediate and less predictable so such systems demand more sensitive, more personal control. The degree of customer contact influences system efficiency. Productivity is more difficult to measure and quality involves more subjective assessment.

The Designer-Maker Interface

A poorly designed product or service can fail to meet market needs and expectations. Often operations managers may be excluded from the actual design process. Their task may be confined to just “make to specification and to cost”. The interface between designers and makers/deliverers is the point at which conflict can occur. It can also be an opportunity to improve the manufacture of a product or the delivery of a service. It is important to note that the design and delivery process are closely linked.

“It’s a nice design but can we build it or deliver the service at a profit?”

There is tension between the creative ideas of product designers and product makers. The conflict can occur if designers produce designs which are imposed on the product makers, i.e. “you must do it this way”.

Producers are experienced with materials, equipment and people. They know what can be done. They comprehend the problems associated with implementation problems and the limitations of current process techniques. There is a natural inclination to prefer tried and tested old ways instead of developing new, leading edge methods.

Creative designs, new products or services, cannot be successful without including the problem-solving ability of the producers. Designers must work together with the producers to achieve a successful introduction of a new product or service.

Distinguish between these:

Design - conceiving the product/service and drawing up the specifications

Process design decisions- how to make the product or deliver the service

How does this happen in your organization?

Without analyzing producibility, a beautiful design may need to be modified for manufacturability. If designers regard their work with passion, they may object if the factory changes the color, shape, material, dimensions, taste etc. The factory may say that they cannot produce it as designed. This is one reason why a clear definition of outcomes is important to resolve this type of conflict.

Often minor changes in a product’s design can dramatically improve its producibility. These changes are most effectively done as part of the design process. It is ideal if design engineering and manufacturability are parallel operations rather than sequential steps. This means designing the product and designing the implementation processes are done simultaneously.

Can we make it or must the design change to fit what we can do? If a parallel process is used these issues can be worked out on paper rather than as changes to a tested design or as changes in hard tooling.
A design change at the final stage of product implementation is costly. The bulk of production set up costs have been incurred. “Patch and make do” may undermine quality and performance objectives.

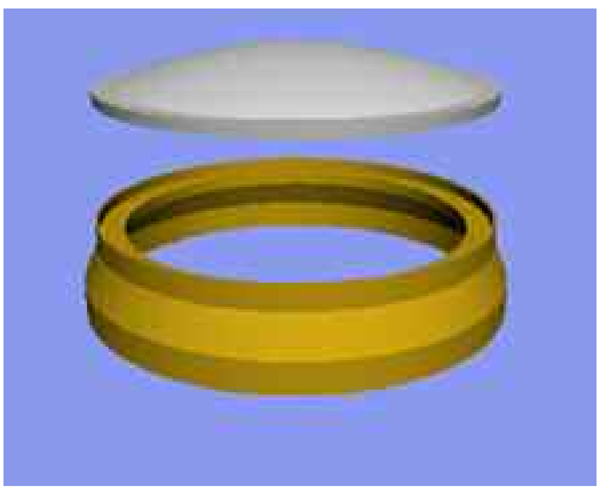
Service operations are not immune to problems associated in trying to make a service operation meet its objectives. In designing a service we must account for the nature of the customer's participation in the service process. A badly designed service operation e.g. lines, waiting times, inefficient service points - will soon have customers complaining.

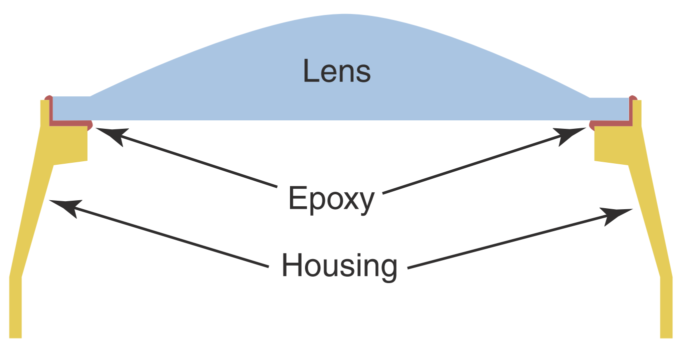
Design accounts for the limitations and constraints of existing equipment, capacity, facilities and expertise. New products may be made alongside old products using existing technology. Product upgrades with new design features may have a significant effect on the operation. As an example: The introduction of a new salad line into the menu of a hamburger chain means that additional refrigeration equipment may be needed in each store — which may not have the floor space, or the staff for replenishing the line.

<u>Design/Implementation Examples:</u>

Glued in Lens vs. Ultrasonic & O Ring

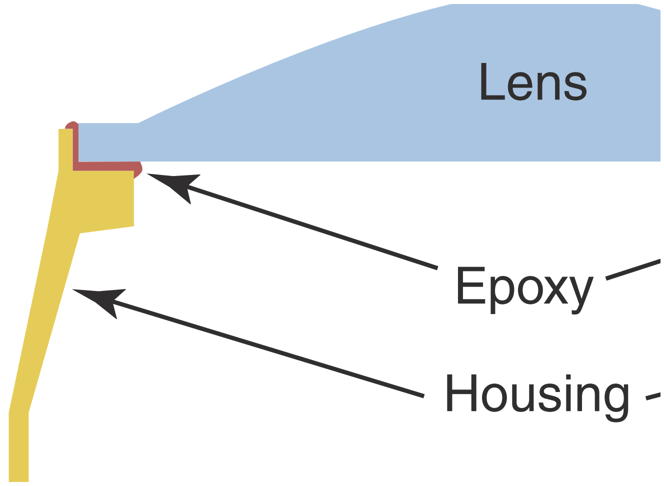
Design - Glued in lens





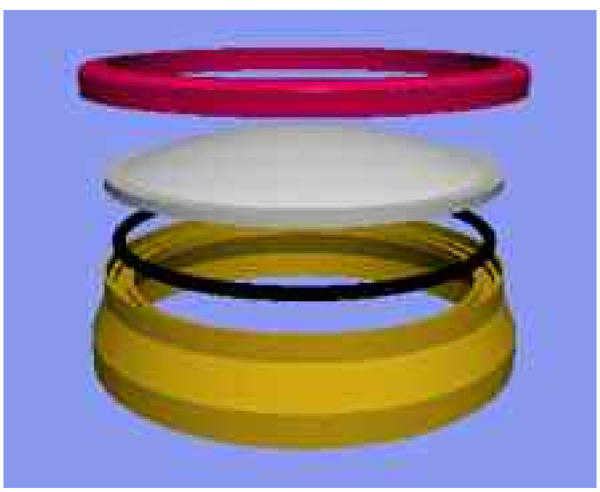
Glued in lens
Design is easier
It would appear that the manufacturing process is quite simple
Set and capital equipment costs are low

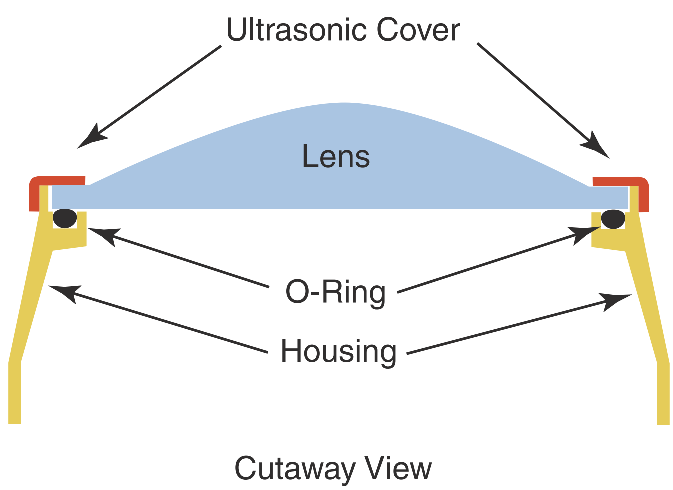
Implementation – Glued in Lens



The process is difficult to replicate
Variation in amount of adhesive from part to part and operator to operator
The process is highly dependent on operator technique
Maintaining the proper surface conditions is difficult to control
It is difficult to verify that the process has been done correctly

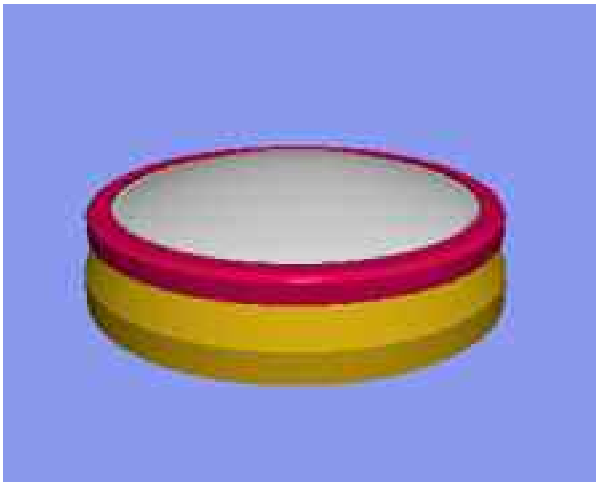
Design – Ultrasonic and O-ring

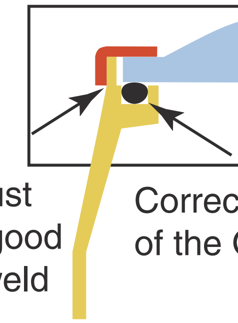




Design requires a more extensive mechanical analysis.
The design must compress the o-ring correctly and the must be designed for a good ultrasonic weld.
Capital equipment costs are higher.
Design may be delayed while waiting for an ultrasonic welder.

Implementation – Ultrasonic and O-ring





With fixturing the process is highly repeatable.
Process parameters can easily be monitored and verified.
Process quality can be verified easily.

An Engineering Approach to Service Operations

An important aspect of service design concentrates on utilization and efficiency in addressing demand variability and customer participation.

Service Design Issues

The presence and involvement of the customer, the intangible elements of service and the variable demand for services are significant for the design of such operations. We can approach these matters by:

- Engineering the procedures of service delivery and even automating the service.

This approach stresses efficiency. We must understand the effects of depersonalization and reduced levels of contact with customers — particularly if we move processing elements away from the point of contact with the customer to a back-office function. The introduction of automated teller machines by banks offers one illustration. Telesales services are another example.

Design objectives should focus on meeting the customer's expectations as well as utilization and efficiency to cope with demand variability. Customer participation makes demand variability more difficult to manage and unpredictable. Design may try to:

1.take the customer out of the process wherever possible and adopt industrial process design strategies for the processes not involving the customer.

2.if the customer's presence is unavoidable, use the customer as labor.

3.increase staff flexibility and balance capacity with demand.

Various strategies are possible:

Front shop/back room/office
Using the customer as staff
Staff flexibility

Strategies to Address Demand Variability

Front shop / Back room

A design for a service operation may seek to minimize customer participation by assigning a "front shop" to handle the face-to-face elements. This is desirable if you need to control variations in how a service is performed. By removing the customer from the actual performance of a service you can effectively limit the number of service options.

The actual service is removed to a "back-room" where conventional production principles reign. This allows for queuing of jobs to even out peaks in the demand for services.

Compare the sale of men's suits today at a department store with a custom tailoring establishment. At a department store the customer is presented with ready to wear garments, made a month ago in a clothing factory. He tries on the suits and chooses one, pant legs and sleeves are customized to the needs of the customer. Service content is minimal and impersonal (although a sales assistant may lend a hand). However the service design demonstrates high efficiency with delivery from stock.

At a custom tailor, the customer can:

discuss requirements with the tailor
select the cloth and style
be advised and measured
go for a fitting and perhaps even talk with those who are sewing the garments.

At the tailor, the transactions are high in service content. The staff is more skilled in garment technology and customer relations. The production system is a per order system with long and varied lead times.

At the ready to wear garment factory, an emphasis on back-room design elements aids efficiencies with a loss of service content. The staff is less skilled.

2.Customer as staff

Self-service operations use the customer as staff/labor giving flexibility in terms of coping with demand. Self-service combines a sharp separation of front shop/back-room functions.

Self-service designs are enabled by the application of technology. Supermarket staff must still replenish shelves and operate the cash registers - but even here experiments in retail technology are now allowing shoppers to scan their own goods in their carts. This illustrates how computer technology is exploited to enhance the self-service angle and bring added competitive advantage.

Self-service banking and payment using a bankcard at the gas pump both remove the need for service attendants.

Customer self-service operations are:
open longer
involve less waiting time
reduces cost for the provider and may reduce cost for the customer

Some customers may miss the lost help and advice. Unskilled and perhaps special customers become excluded - they become “problem” customers. Consumers who are not confident go elsewhere. This becomes a problem if there is nowhere else to go, if all other providers are also adopting the technology.
3.Staff flexibility

Services increasingly rely more on part-time staff to balance capacity with demand and to avoid carrying excess capacity to meet peak loading periods. What are the problems?

If part-timers are used instead of full time positions, the workforce size will be four or five times the full-time equivalent. Such staff may be less familiar with the company’s service systems, be less committed and less skilled. Staff turnover and reliability may be a problem — as it is for fast food restaurants.

This is a vicious circle. Workers who only do a few hours and who leave don’t justify expensive training. The operation needs a quality work force but investment is not justified – so the argument goes — so the operation lives with an unskilled, less than fully committed staff.

An alternative to part time staffing is to ensure all staff are multi-skilled and can swap jobs. This is common in retail banking and in department stores. At peak times back-room staff are pulled in and all customer service points are manned with back-room activities suspended or running on a skeleton crew. Success depends on how time-sensitive backroom tasks are and on the availability of skilled and flexible staff.

Quality of Service

The design emphasis here is understanding and enriching the customer experience. The overall objective is to ensure consistency and control over what is being delivered. The customer-oriented approach involves researching and determining relationships between perceived quality and the costs and benefits of various systems of service delivery, then balancing the two.

Industrializing and depersonalizing a service undermines key facets of the service operation. Similarly, unnecessarily high goals of service quality incurs high costs without guaranteed appreciation or willingness to pay by the customer.

Pure service does not exist. Most services have an element of product transformation operations integrated with the delivery of the service. Often methods useful in designing, implementing and evaluating product operations are relevant in service contexts. Indeed production managers have a lot to learn from the service ethic. Yet service operations managers face problems that may be insignificant to production managers who would meet such situations far less or not at all. The primary difference is a matter of focus rather than a fundamental difference between service and manufacturing operations.

A comparison of service with manufacturing operations demonstrates differences in design emphasis.

Design Emphasis Function Manufacturing Service Customer participation Low High Using the customer as labor Moderate High Maintaining inventory High Moderate Managing variability in demand High High The intangible aspects of a service Low High Process efficiency High Moderate Product / Service quality High High

Service Design, Quality and Intangibles

Quality (as measured by customer satisfaction) often depends on the intangibles in the service package. Thus designs that seek to limit, shape and control to improve efficiencies and reduce costs may adversely affect the quality of the customer experience.

This is demonstrated by the satellite company that offers different groups of channels in packages A, B and C. You cannot have a few elements of A, two from B and one from C - it's a take or leave it situation. While this simplifies tasks for the provider by equalizing, standardizing, simplifying the range of services it dramatically degrades the product quality for the customer with special needs. You may find yourself addressing the customer that insists on a custom solution. How your service delivery is structured will determine your ability to respond to the customer's needs. Ideally you can avoid the following response:

"Fine - but it will cost you a premium - and even then we may not be able to guarantee that you will maintain the same set of channels from month to month."

Be aware that simplification and standardization may get in the way of some customer's enjoyment and interpretation of the experience.

Quality Costs

The service level - as agreed or as specified - has to be delivered, and there are costs of failure. If we can identify the levels of service quality and service components that customers value, we can assign these a cost and evaluate both their contribution and how much customers will pay for them. In designing the service we can ensure that the design elements target the right service systems, transactions and experiences which command staff attention, skills, expenditure and other resources.

Inspiring and maintaining customer confidence

The threat of a union strike at an airline directly affects the confidence of potential customers and their perceptions of service quality. When the service prompts uncertainty, the customer is uncertain about what to do.

Will the plane arrive on time or not? Will I be able to get to my meeting?

The customer may receive contradictory or too little information. The client's confidence may be undermined by the service provider's own displays of uncertainty or difficulty in coordinating parts of the service.

Ensuring that a service has internal consistency is important. It maximizes confidence.

The staff providing the service should speak as one and not be seen to contradict each other. They must focus on the customer's problem, not the difficulties that they feel other departments have created. They need to work with each other and sort out internal communications difficulties - away from the customer's view. Interdepartmental wrangling should not be part of the customer's experience.

Elements in the service package must be consistent and service personnel and managers must agree on what customer needs are and how (methods/practices) their "satisfactions" can be achieved. If these are not shared there will be disjointed views on how to deliver the service. Customer uncertainty will result.

Operations Management and Product Design

Design phases

1. Basic research and development
2. Define market needs in various situations: Is it market demand that is pushing change or is emerging new technology (lower costs, better products) pushing change, i.e. internal development and upgrading
3. Create the "design"

Concurrent Engineering Begins at this point

4. Evaluate alternative designs and agree which to prototype
5. Prototyping, evaluate (design and process of implementation)
6. Finalize the design and transfer it to operations to produce

The scope for involvement of operations managers at each of these stages (concurrent engineering)

Evaluate alternative designs and agree which to prototype

Design for manufacturability and assembly (DFM)

DFM focuses on

design simplification
component reduction, standardization and sharing subassemblies between designs

process improvements

Value Engineering

Value engineering involves disassembly and reappraisal of service and repair costs, methods and times, with an eye to improving design and production methods and adding value to the company and customers. Questioning the design can improve assembly processes (e.g. use new epoxy glues rather than screws to affix a display filter.) We can review energy usage, disposal and recycling issues, technical obsolescence and waste.

Variety vs. Standardization

Some products are designed so they can be made into hundreds even thousands of models just by changing a few components. Often in these cases the design can be modified to allow for a standardized process. This is an area which should be closely examined if the product volume is consists of small quantities of a large variety of products. By using standard processes for all product variations, you can achieve the benefit of high volume production while retaining the ability to produce short runs of a variety of product models.

The design should also be evaluated for the setup time. Setup time is the time and effort needed to begin producing a product. Examples include:

The time it takes for an oven to reach operating temperature.
The time it takes to change the ink color in a printing press.
The time it take to set up an end mill for machining.

Inventory

The use of standard "off the shelf" components reduces the demands on purchasing and inventory. Standard components are frequently stocked by suppliers. This allows your company to respond quickly to changes in product demand while keeping inventory levels low.

Special order components increase component cost and increase lead time, especially if the order quantities are low.

Custom built components give you the maximum control over quality and delivery. The downside of custom components is that they require additional resources from engineering and purchasing.

Creative vs. Standardized Design

Ideally, new designs and product upgrades use existing components and processes. But the creative freedom of designers is inhibited by such standardization. Suboptimal designs result. Good designers push forward the boundaries in exploiting new materials and applications. They search constantly for new, innovative components, materials and processes. It is the designer's role to be up-to-date on emergent materials, components and methods. This means scanning supplier catalogues and reading trade journals.

They also need to know which components and processes are already approved and available within the company.

The operational temptation is to go for something that is known and available. Technological obsolescence, however, is a considerable problem. You may find that achieving a balance in this area is one of your most difficult tasks.

Quality and Reliability

Adoption of new technologies and raw materials requires rigorous inspection and testing to ensure high-quality, reliable output. Safety critical products - hardware, software and human systems are particularly vulnerable.

Building the Prototype

Initial production volumes may be small. Experience is acquired through “hand-crafting”. As sales take off the design and the production methods may allow additional cost savings.

For small-scale electronic assemblies, standard components on a circuit board may do the job for the prototype, but as volume increases these may be integrated into custom or semi-custom components. This will reduce the components and increase the reliability at a lower cost (for higher volumes.) The change may now enable the product to be offered with a smaller power supply unit. The product’s casing may be changed and the assembly skills required to produce it may be reduced.

Construction of the Prototype

Traditional process alternatives

- unit
- batch
- repetitive, continuous (assembly line)
- repetitive, batch (different models on one assembly line)
- continuous (true ‘process’ — as in oil refining)

Produce for Stock vs. Produce to Order
This decision must be made in conjunction with marketing, so that the organization’s general approach to meeting customer demand is satisfied.

Several design reviews are normal during the prototype process. The design review process allows for test marketing and performance improvements. The product design can be altered during this phase to be more compatible with existing facilities, making it easier to develop manufacturing procedures and establish the equipment and routings for the new product.

The Prototype phase allows the operation function to determine how the product will be built.

- There may be many ways to perform a given task. Processes should be evaluated and selected.
- Process selection is strongly influenced by the magnitude of the potential market .
- Build quantities may make the purchase of specific equipment impractical at this stage, but knowledge of equipment alternatives is necessary.

- Special purpose or general tools / machinery decisions should be made at this time
- Facility layout should be formalized.
- Make-or-buy decision should be made at this time.

Finalize the Design and Begin Production

A finalized design is characterized by

Complete documentation of all raw materials, sub-assemblies and final assemblies.
Vendor selection and qualification.
Complete documentation of the manufacturing process.

At final design, the product should be in its finished form. Often it is formalized into a design review process where all parties sign off on the design.

If this step is hurried, it may result in releasing a product to the market which is still in need of revision. Sellers and customers will report the product's shortcomings, and the product will be returned to engineering for changes.

While engineering changes are a normal part of manufacturing and of the product life cycle, there are certain costs of engineering changes which are to be avoided.

- parts made obsolete by the design change which can't be used in assembling the revised product.
- added costs to rush the newly required parts.
- loss of utilization as departments are slowed down by the changes. (waiting for parts, revised assembly layout, worker retraining)
- data processing maintenance: new bill of materials, specifications, engineering prints and routings
- potential loss of sales, customer dissatisfaction

If the design process is done properly the first time, the only added costs are those of the design process itself, mostly engineering time.

Inventory

All Organizations Keep Inventories

All organizations keep inventories - some trivial, some highly significant. Even the trivial can take on a degree of importance if it holds up a major order. What is trivial to one organization is important to the next, e.g. cleaning materials - trivial in a factory but essential to a supplier of cleaning materials. Spare parts, office supplies, consumables are inventory common to all organizations.

Inventory Management and Control

An inventory is the stocking of an item or resource used by an organization. Good inventory management is important to all organizations, whether manufacturing or service.

The largest reason for controlling inventory is money. For many organizations a substantial percentage of their sales is tied up in inventory. Inventories affect virtually every aspect of daily operations. A poorly managed inventory can lead to serious cash flow problems, can affect job scheduling, shipments, may even shut down company operations. But an inventory can also be a major competitive weapon, for the company which has stock when a competitor does not.

Basic inventory decisions involve:
How much to order (replenishment quantities)
When to order (timing)
How to control the stock system security (issues, safety levels, issues from stock, etc.)

Inventory incurs costs, ties up working capital, consumes space and must be managed. Stock can deteriorate or get stolen. In most operations, capacity planning and scheduling depend on inventory. Stock serves to smooth out timing gaps in the rates of supply and demand.

Challenges of Inventory Management

The two major objectives of inventory control are maximizing the level of customer service, and minimizing the cost. Higher levels of inventory are often associated with a high level of customer service. With a higher level of inventory, a company can ship from stock, providing good customer service. But higher levels of stock are more costly to the organization.

Many discussions about inventory seek to strike a balance between the level of service and the level of cost.

Inventory Costs

Elements of Inventory Costs

There are several costs which affect the inventory decision.

Holding Cost -
This is the cost to hold inventory in storage. This may be a fixed sum per unit per time period, or it may be a fixed percent of value per time period. In more complex models it may consist of more than one element. That is, holding costs may consist of both physical storage and capital costs (missed earnings). Holding costs can sometimes be expressed as a % of stock value and may be 15-30 % per annum.

Storage costs can include warehouse space, equipment and staff to track (and guard) the inventory. This is often 5-10 % of stock value per annum.

Stock losses/wastage (legitimate or otherwise). Stock obsolescence, damage, theft (burglars and employees), reduced item life, spoilage, accidental damage, and stock exceeding its shelf-life. How much depends upon the goods (perishables, rust, aging designs) but the write-off level will usually be greater than zero.

Miscellaneous costs may be insurance, security and taxes.

There may be a cost of capital — the cost of funds borrowed to purchase inventory, the interest saved if that money were use to retire debt, or the interest that could have been earned on external or capital investments. The cost of capital tied up in inventory is the lost opportunity cost of the money which could be invested elsewhere.

Shortage Cost -
The costs of managing shortages or backorders. An organization which runs out of a product may initiate a special order. In retail, rain checks are an additional cost, used to satisfy the customer. For a manufacturing company, a special order to rush an item will usually incur an extra charge.

Acquisition/ordering costs-
Costs arise from ordering/acquiring goods regardless of the actual value of the goods. In both making to stock and making to order operations, stock acquisition costs are incurred. In the simplest models this is treated as fixed regardless of the size or amount of the order. In more complex models it may be composed of a header cost plus a line cost for each item being ordered.

The purchasing order processing costs include receiving the goods, delivery for large or small orders, and invoice processing. The precise cost per ordered unit is often difficult to determine, but the cost of staff and overhead is significant.

Ad-hoc purchasing vs. long-term contracts must be compared, especially if the long-term contracts include some supplier flexibility.

There are costs in researching and negotiating the supply contract. A whole team may be involved, with associated travel and hotel costs. Each part consignment may require special processing costs, such as packaging, bill of lading, insurance, special shipping, etc. These costs are generally higher for custom built parts and lower for standard “off the shelf components”.

Maximize Customer Service

A buffer of inventory stock maintains the independence of operations and allows two stages in the manufacturing process to operate at different speeds (decoupling). This type of inventory serves to smooth supply and demand. Operations can maintain a uniform manufacturing rate in spite of variations in the demand for the product.

Inventory can also be used to compensate for peaks in customer demand. If this can be done, capacity can be set at average demand, rather than at peak levels. Capacity is covered in a later section.

Avoiding Out of Stock Situations
Operations mostly depend on maintaining the proper levels of stock. This can be as simple as setting safety stock levels high enough so that out of stock situations are avoided. This may increase your inventory costs beyond acceptable limits. In these cases a more sophisticated system of controlling inventory is needed.

Material Requirements Planning (MRP) Software can be used if there are multiple jobs requiring the same part and you are facing an out-of-stock situation. The software can allow you to allocate parts to specific jobs based on need rather than first come first serve.

A raw materials shortage in manufacturing means halting production and rescheduling to make a different product or taking quick action to secure an alternative supply.
Example: A personal computer assembly line that runs out of memory chips must stop production.

If the finished goods are out of stock, or a raw materials or consumables shortage affects the customer, then the customers may cancel orders and go elsewhere. This loss of goodwill means that competitors develop a relationship with your customer. This is an out-of-stock situation. All out-of-stock situations involve costs.

Anticipation Inventories
Anticipation inventories are specific planned changes in inventory position when anticipating infrequent events, such as strikes, shipment delays, vacations, special sales and promotions, etc. A special type of anticipation inventory is the hedge inventory, which occurs in anticipation of a price change. Anticipation inventories may be increases or decreases. An organization might increase its inventory in anticipation of a supplier's price increase, but decrease its inventory in anticipation of a price decrease.

Service Inventories
There are few if any uses of inventory management in a pure service operation; services cannot be "stored". A doctor cannot perform surgery in advance and store the service until such time as a patient demands it. The doctor does, however, depend on a variety of supplies which must be available before surgery can begin.

Although service can't be stocked, there must be an inventory of support items which are components of service transactions. Electronic repair or auto repair requires basic parts and shop supplies. In a central heating installation and service company, technicians maintain a supply of standard components.

Challenges of Inventory Management

An improperly managed inventory can put the organization at financial risk. It is not unusual for upper management to set cost objectives for inventory management.

The organization's Inventory Management System must carry out the objectives set by upper management. It must perform in such a way to enhance rather than detract from the organization's profit or performance.

The objectives set by management will frequently fall into either of two categories: (1) customer service objectives, and (2) inventory investment objectives. The first category includes such concepts as service level and the out-of-stock rate; the second, such items as the number of inventory turnovers per time period.

Inventory Objectives

It is up to the operational manager to turn inventory objectives into quantifiable terms which can be measured. Some examples include:

- How often should inventory be rotated
- Holding costs
- Acceptable out of Stock rate
- Purchasing cost as % of a buy
- Inventory dollar value
- Facility Requirements

Generally, the achievement of higher levels of customer service is accomplished with larger amounts of inventory, but is subject to diminishing returns. The achievement of higher levels of the investment objectives is generally accomplished with smaller inventories. Thus we see the basic conflict of inventory management: some objectives call for economizing on inventory levels, while other objectives call for increasing inventories. These objectives may create conflict along departmental lines: finance wants smaller sums tied up in inventory, while marketing wants larger amounts so that customer orders can be filled quickly.

When evaluating inventory systems, it is desirable to put inventory objectives into quantifiable, measurable terms.

Basic Inventory Decisions Involve

Inventory systems can be rather complex and there are courses which deal with the subject in great detail. Since this course is an overview we will be dealing with the basic elements of inventory and how they are applied.

No matter how complex or how simple every inventory system must perform three basic functions:

Determine how much to order
Determine when to order
How to control the stock

In this sense, “order” may mean purchasing supplies, or it may mean building a product.

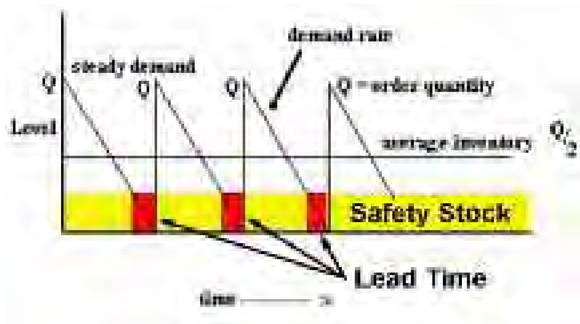
Examples of Inventory Decisions

- A manufacturer must determine the amount of raw materials to order.
- A manufacturer must determine the quantity of work-in-process (WIP) inventory to ‘ship’ to another stage of production. The processing speed at one department or workstation may differ from the speed of another. A work-in-process inventory will allow each station to operate at its own optimal rate. The inventory therefore decouples the two production rates.
- A distributor or manufacturer must determine the quantity of finished goods to ship to a customer. (Will the customer’s order be shipped as a single shipment or will it be divided into several smaller shipments?)
- A retailer or wholesaler must determine the quantity of goods to order for resale.
- An individual or a corporation must determine the quantity of funds to be held as inventory.
- A manufacturer may need to protect himself from supplier shortages or disruptions. A safety stock of raw materials can provide this protection. Likewise a retailer may need to keep safety stocks of products in order to manage uncertainty in the level of demand for those products.

The examples above indicate that inventory performs a variety of functions, most of which are related to the primary purpose of inventory, which is buffering or decoupling.

Safety Stock Inventory System

A safety stock system is probably the simplest system to implement and maintain. A safety stock is a specific quantity of parts. When the stock level falls below the safety level, a buy order is triggered. Safety stock serves two functions, it determines when to place an order and it protects against an out of stock situation.



Just because it is simple doesn't mean that it will not meet the needs of your organization. This type of system is best suited for situations where you need to keep the cost of maintaining an inventory system at a minimum.

This type of system can be run effectively without a computerized tracking system.

Setting Safety Stock Levels

Setting safety stock levels depends on two variables, lead time and demand

Lead time – the time between when an order is triggered and when parts are available from stock. It includes time to:
detect inventory level, then authorize replenishment
establish supplier contact and complete administrative paperwork
obtain, produce and have the goods delivered
perform receiving and quality assurance tasks

Demand – part usage per unit of time.

Safety Stock should be set to the lead time multiplied by the demand

Example:
Lead time is three weeks.
Demand is 100 items per week
Safety stock should be set to 300 (3 x 100)

If lead time and demand are constant this is all the analysis that is needed.

The purpose of safety stock is twofold: to make sure you don't run out of materials, and to notify purchasing when to place an order. To make this system work, the demand for each item must be tracked, and the lead

time must be known. This information can be as simple as a set of index cards. More complex systems might use a computer database.
The information for each item should include a vendor part number, phone number and a contact person – whatever information is needed to purchase the item. This helps avoid problems when adding new purchasing staff.

Variations in Lead Time and Demand

You should expect to see variations in demand and lead times. Lead times can vary due to holidays, weather, strikes and unusual demand for a particular part. Demand variations can be caused by changes in customer demand. It can also be influenced by production errors or excessive scrap rates.

If you keep a history of lead times and time between orders you can enter this data into statistical program or an engineering calculator.

You will end up with two numbers mean and standard deviation. The mean is point were 50% of the population is higher and 50% is lower. If the distribution is normal
(a bell curve) mean and average are the same. Standard deviation is an expression of how much variation you can expect. Plus or minus 1 standard deviation represents approximately 63% of the population in a normal distribution. This means that 63% of the time lead time should be within this window. Plus or minus 3 standard deviations represents approximately 99% of the population in a normal distribution. You can use this information to adjust your safety stock levels to reduce the probability of out of stock situations.

Let's say that the mean lead time is 4 weeks with a standard deviation of 1 week.
The mean demand is 100 parts per week with a standard deviation of 20 parts per week.

Assuming a normal distribution this means that lead time can vary from 1 to 7 weeks.
Demand can vary from 40 to 160 parts per week.

If we had set our safety stock to the mean 400 (4 x 100) it is reasonable to expect stock outages from time to time.

If we use the extreme case and wanted to insure there would be little chance of a stock outage we would have to raise safety stock to 1120 (7 x 160). This would cover the situation with the longest lead time coupled with the greatest demand. Fortunately, while this is possible, it is also unlikely. If you are willing to tolerate the occasional stock outage, you can use 1 standard deviation for your calculations. 600 (5 x 120) This covers about half of the worst case conditions, and it saves the holding costs associated with a higher stock level.

Bin Replenishment System (Kan-Ban)
A variation of a safety stock system is bin replenishment. Imagine two equally sized bins (bays, pallets or similar) used for storage in the warehouse or at the workstation storage point. The reorder point can be seen visually. With the first bin empty, a new full bin is "called" to arrive before the second bin is exhausted. The call is rotated. With proper rotation, the system is efficient (little paperwork). In a computerized environment the bins/pallets themselves can be bar coded; their movement and the batch numbers of bin components can be traced.

A two bin system is suited to components issued in large quantities where the bin size and reorder points can be easily checked. With many stock items this is inappropriate.

Parts that need to be allocated to specific jobs.
Parts that take up a lot of space.
Parts that are easily stolen.

These problems can often be overcome by using a series of smaller bins. As the bins are emptied they are brought to a central location. When the number of bins meets or exceeds a preset level an order is placed.

Computer Driven Reorder Point System -
A computerized system is indicated if detailed control over issues is needed. A computer program functions as a stock record system showing issues and balance.
Computerized systems enable replenishment orders to be initiated as soon as stock falls below a reorder level.

In a supermarket, the record for each stock item is decremented as each sale is logged at the checkout. With computer interconnectivity, the regional warehouse receives the store's replenishment needs and makes up a replenishment package for next day delivery.

Computer records require time to check stock against reorder levels.
Periodic stock checks to count the stock physically enable the store to feed in adjustment figures to reconcile physical against book stock. This allows a mechanism for entering stock losses into the system.

The advantage of a computerized system is that it assists with demand forecasting. Up-to-date demand figures can be used by marketing and to optimize reorder point and order quantity calculations.

Setting Order Quantities

How much to order? A few very large orders? Many very small orders? With a few very large orders, the cost of ordering costs is lessened, but the cost of carrying inventory rises. In the second case, with many very small orders, the cost of carrying inventory is small, but the cost of ordering may be excessive.

Once the safety stock level is decided, the order quantity also needs to be decided. The two factors which help determine order quantity are acquisition costs and holding costs.

Acquisition costs consist of:

the cost of placing an order
set-up costs
shipping

The average cost of placing an order will be just an estimate, unless accurate time records are kept. An item produced in-house will have set-up costs – kitting, parts, and machine set-up time. With bulky or heavy items, the cost of shipping may be a factor. These relatively fixed costs must be added to the cost of the parts themselves.

Due to the economies of scale, the greater the quantity of parts, the less the cost per item when considering acquisition costs. This, however, must be weighed against the cost of holding the inventory.

Economic Order Quantity
Purchasing inventory by economic order quantity (a.k.a. economic batch quantity, economic lot size or EOQ) seeks to reconcile ordering and holding costs to obtain an optimum order size.

Economic Order Quantity (EOQ) models answer the question of how much to order. All variations of the EOQ models specify an optimal order quantity, which minimizes annual costs associated with maintaining inventories. These models clearly demonstrate the tradeoffs required in inventory management.

The holding cost per unit (Ch) is the average total inventory value multiplied by the cost of carrying the item. Holding costs are typically 15 to 30 % of the item's value. This cost includes the average value of total inventory over the period of a year, the annual cost of interest payments, maintaining stock records, handling issues and receipts, the staff needed to control the stock, and facility costs. Unlike order costs, which decrease with quantity, holding costs increase with quantity.

The order cost (Co) is the cost per item plus the order/acquisition cost (or set-up cost for a produced in-house situation.) Order cost should also include any discounts received for purchasing in quantity.

As the order quantity increases, the average level of stock inventory for the item increases. This is a linear relationship and assumes that demand is relatively constant. As the average inventory increases so do the holding costs. The formula is

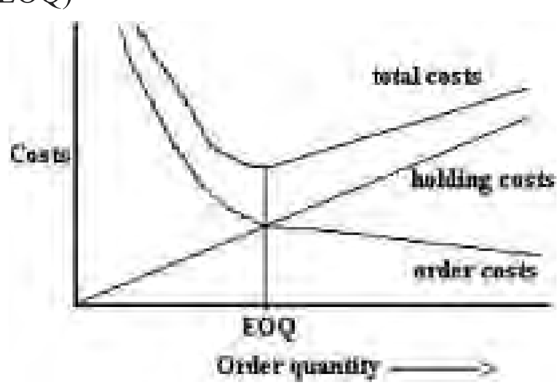
Ch = (Order Quantity / 2) x Holding Cost

The inverse is true for order cost. As order quantities increase the number of orders decrease, lowering the order cost. The formula is

Co = (Annual Demand / Order Quantity) x Order Cost

Therefore **Total cost** = Ch + Co

The relationship between total costs, holding costs and order costs can be seen in the graphic representation of Economic Order Quantity (EOQ)



The EOQ is found at the lowest point on the total cost curve. Here the order size is optimized for a balance between the holding costs and order costs.

To calculate EOQ you need to know
D = Annual Demand
H = Holding Cost (item cost x holding cost percentage)
O = Order cost (The cost to place an order)

The formula is
EOQ = square root of (D x O) / (.5 x H)

As an example:

In company A, order cost is estimated at $10, the holding cost is 25% of item value, and annual demand is 1000 units at a supply price of $36. If we substitute these figures in the EOQ formula then the EOQ is 48 units.

EOQ Evaluation and Assumptions of Simple EOQ

- Demand is known and steady so average inventory can be estimated
- The effect of price breaks need to be taken into account.

Inventory Rotation

If you are dealing with items where shelf life is a concern you may need to monitor inventory turns and / or coverage. Using coverage you can determine if you need to modify or delay ordering items so they don't go bad in stock. This information is also useful for measuring service or cost objectives, and may be used as a performance measure by upper management.

Inventory Turn (annual usage / average stockholding)
Example:
Annual usage 5,000
Average stock quantity 1,000
5,000 / 1,000 = 5 This means that inventory is turned over 5 times per year.

Inventory turn is especially important if stock loses value or function over time.

Coverage (stockholding x 52 weeks / annual usage).
Example:
Annual usage 5,000
Current stock quantity 1,000
(1,000 * 52) / 5,000 = 10.4 This means that there is 10.4 weeks of inventory.

This is important to consider if ordering lead times are long.

Retailers are interested in a high inventory turn (a small, continuously replenished stock of fast moving items). A inventory turn of 13 means that the total inventory is replaced every four weeks. If $100,000 is tied up in stock, roughly, this means an annual sales (not profit) of $1.3 million.

Inventory turns may be a measure of the quality of the buying decisions - possibly the purchase of slow moving items and the need to reduce inventory. For an auto dealership an inventory turn of 6 means that the average stock on the auto lot changes every 2 months.

Safety Stock Inventory Control

Safety stock inventory control can be as simple as parts on a shelf with the safety stock stored in a special package. When the package is opened, it triggers a reorder. The advantage of this type of system is simplicity, low personnel costs and low facility cost.

A safety stock system can also be computerized. If this option is selected the stockroom must be controlled and good records must be maintained.

You need to balance the benefits of better control against the increase in cost. Computerized inventory does not always mean better or more cost effective operations. Unless you write your own software you may find that the software package will determine your inventory and purchasing practices.

Demands on Inventory: Independent Demand Items and Dependent Demand Items

Independent demand items
are shipped as end items to customers. They are used directly from stock and are not used to build another product. Items may be finished goods or spare/repair parts. The demand is market-based, and is independent of the demand for other items. Demand for this type of part is easy to calculate – how often is the part requested?

If your inventory consists of Independent demand items, you may be able to use software programs like Quicken or Peachtree to control your accounting, inventory and purchasing functions.

Dependent demand items
are used in the production of a finished product. Such items may be raw materials, component parts or subassemblies. Demand is based on the number needed in each higher-level (parent) item where the part is used. These items add a great deal of complexity to an inventory system. Unless an organization has only one or two simple products, dependent demand items are usually managed by a Material Requirements Planning (MRP) software package.

Independent Demand Inventory Models
The models described below concern independent demand inventory — products whose demand is independent of the demand for other items sold or used by the organization. Dependent demand models are more complex and will be discussed later.

Some of the important independent demand models are as follows:

1. Basic Economic Order Quantity
There are no shortages, no quantity discounts. Carrying and ordering costs are constant. Arrival of supplies is instantaneous.

2. Quantity discounts
There are two models: A percent discount, or a schedule of price breaks. Normally, the larger the quantity, the lower the unit price. Is it cheaper to order larger amounts in order to take advantage of such price breaks?

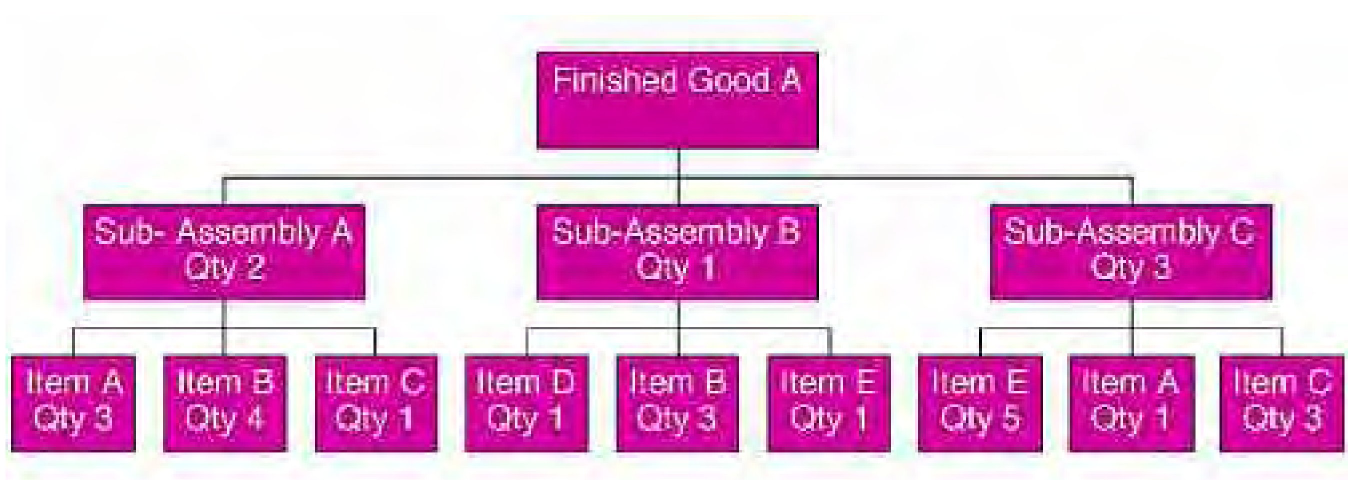
The rationale for this model is that the discount offered may be large enough that the savings on the cost of the item more than offsets the increased inventory costs.

3. Blanket Orders
A blanket order takes advantage of pricing discounts but does not take delivery all at once. A delivery schedule is part of the purchase agreement. Payments are spread over the life of the order and stocking decisions are pushed back to the supplier. Often suppliers will allow changes in the delivery schedule, which allows the organization to respond to changing inventory needs. The benefit to the supplier is a guarantee of sales over a period of time.

4. Deterministic Shortages
When costs of handling backorders or shortages are known, the organization may have an optimal amount of backorders in each cycle. Here, too, some items ordered never reach inventory — they are used to satisfy backorders instead. Demand may be discrete or continuous.

The rationale for this model is that, if shortage costs are low enough, or carrying costs high enough, it may be cheaper to deliberately incur shortages than to keep inventory. This is especially true for perishable items, and for high value custom items such as recreational vehicles and Harley Davidson motorcycles.

Dependent Inventory



A bill of material (BOM) is a listing of all the parts needed to build a product.

In this example, Finished Good A requires:
Qty 2 of Subassembly A
Qty 1 of Subassembly B
Qty 3 of Subassembly C

Each of these subassemblies also has a bill of materials listing the raw materials used in its construction.

Production of this one product, Finished Good A, may not require a computerized Material Requirements Planning package. Let's assume that there are two more products, Finished Good B and C. Finished Good B uses 5 of Subassembly C, 3 of Item C and 6 of Item E. Finished Good C uses 4 of Subassembly A, 2 of Subassembly B and 9 of Item C. Now assume that Finished Good A, B and C all need to be produced at a different rate. A paper system may still work, but it becomes a daunting task.

Levels of Inventory

There are four accounting categories, or types, of inventories:

- Raw materials
- Subassemblies
- Work-in-process (WIP)
- Finished goods

Systems that have dependent items require tracking of several levels of inventory

Raw materials are the individual components. Subassemblies are assemblies which are not the end product, but are used to build a finished product. A car engine is a subassembly used to build a car.

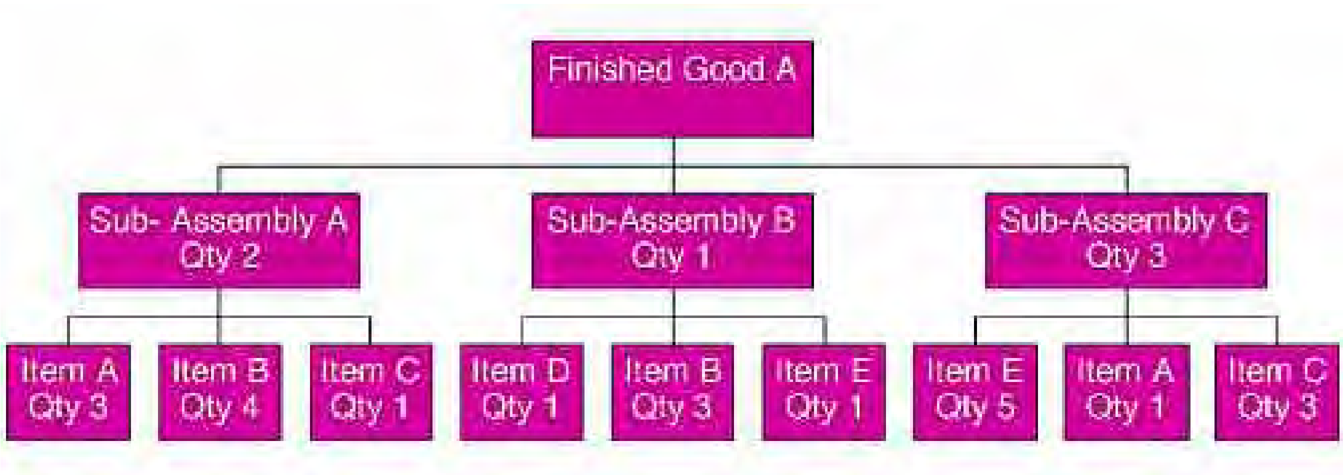
A retail shop exemplifies a single stage inventory system consisting of only finished goods. Supplier deliveries are taken into stock and sold.

A washing machine manufacturer will transform raw material stock into subassemblies which are held in stock. Inventory that is in the process of becoming a final or subassembly is considered work-in-process (WIP). Subassemblies and additional raw materials are used to build the final product. The final product may be shipped or may be held in stock.

Work in process (WIP), the inventory in the process of production can be a substantial part of your inventory. While not physically in the stockroom, they are still considered inventory, and as such, need to be tracked.

For accounting purposes, the value of subassemblies and finished goods is determined by parts plus labor.

Dependent Inventory



This is a very simple product structure which illustrates how difficult it is to calculate demand for dependent inventory items.

A customer calls and wants to buy 50 of Finished Good A

How much inventory is needed for:

Item A = (50 x 2 x 3) + (50 x 3 x 1) = 450
Item B = (50 x 2 x 4) + (50 x 1 x 3) = 550
Item C = (50 x 2 x 1) + (50 x 3 x 3) = 550
Item D = (50 x 1 x 1) = 50
Item E = (50 x 1 x 1) + (50 x 3 x 3) = 500

If you have 20 of Subassembly A, 10 of B, and 30 of C, how does this change the demand for ordering raw materials? If you don't have stock on some of these items, how long will it take you to fill the customer's order?

The calculations are simple, but there are many involved. A computer and software will simplify the task.

Materials Requirements Planning (MRP)

Each Materials Requirements Planning software is different., but generally carries out the following inventory functions:

Uses sales forecasts or sales orders of finished goods to calculate the demand for subassemblies and raw materials
Allows for entry of lead times
Generates a report to purchasing
Schedules jobs for the production area
Keeps track of inventory levels

MRP software is a significant problem for small and start-up companies. There is not much offered between a Quicken or Peachtree type program and the larger company programs such as SAP, Peoplesoft and J.D. Edwards.

Selecting, obtaining and setting up the software is a time consuming and expensive undertaking, and once the software is in place, it will need to be maintained and modified.

Before selecting a package, develop a detailed list of what the software should do. Consider how to evaluate the software for ease of use. If possible, visit companies that have already installed and are using the software. Be aware that if the software does not quite do what you want, you will have to adapt the software to your use (often expensive) or you will have to adapt to the software (often inefficient.)

A computerized MRP system is not a substitute for good production planning and forecasting. Promising a customer a ship date in four weeks is not sensible if some of the raw materials will take eight weeks to arrive on your dock.

Controlling Inventory Costs

Not all of the hundreds or thousands of parts in inventory deserve equal attention. Attention should be focused on the few parts which have the greatest impact on inventory. These parts are generally:
Items that represent the bulk of the dollar volume
Items that can affect customer service or scheduling

Safety stock levels can be set on large numbers of items without a great deal of analysis, without fear of much impact on cost or on level of service.

The smaller number of items which deserve greater attention can be identified by a Pareto analysis, initially based on dollar volume, followed by the impact on the level of service.

Pareto (ABC) Analysis

ABC ANALYSIS: follows the guidance of Vilfredo Pareto, that a relatively small number of products (the critical few) has very important impact on total inventory costs. Therefore, management should focus the most attention on controlling those items. In practice, less than 20 percent of all the inventory items represents over 80 percent of inventory investment. These are the A items, which are typically high-price, high-volume items worthy of management's scarce decision-making time. On the opposite end are the C items, which are typically low-value and low volume. They may comprise 80 percent of total items but only a small fraction of inventory investment. In between are the B items.

The typical ABC analysis uses a Data Base Manager or a Spreadsheet to rank all inventory items by annual dollar volume. Management then searches for natural dividing points for the three classes of items. Often, about 10 percent of all items will be classified A, 30 percent as B, and 60 percent as C.

- "A" Items are tightly controlled, have accurate records, and receive regular review by major decision makers.
- "B" Items are less controlled, have good records and regular review.
- "C" Items have minimal records, periodic review, simple controls.

Dollar volume analysis points the way to where control efforts are best directed. Judgment is needed on critical inventory items or security matters that dollar volume analysis does not reveal.

Additions to the A list should include items that

- Have long lead times
- Have a high cost per item
- Are custom parts
- Are only available from a single supplier.

(A special order o-ring made of a proprietary material.)

Subtractions from the A list should include items that

- Have short lead times
- Are low cost
- Are standard components available from many suppliers.

The Process

This section will focus on the details of how a product is made or how a service is delivered. It answers, in a detailed way, how inputs get turned into outputs. For most, this detailed analysis may be viewed as inconsequential or trivial matter. A careful examination of your processes, however, can uncover areas for substantial improvements in the performance of your organization.

Just like custom parts ordered to your specification, processes should be well documented. Processes that reside in the mind of one or two people represent a substantial risk to your organization. What would happen if these people were injured or left for a better job? How long would it take you to recover and provide the level of performance you currently expect?

A well documented process is a valuable tool to train new employees and cross-train current employees. Lack of clear and accurate process documentation leads to training that suffers from generation loss as employees pass information to other employees from memory. While this oral tradition is a great way of preserving and shaping an organization's culture, it is a poor way of insuring the delivery of a consistent product or service. Each telling of the "story" is different from the last, details change, or are left out. In the end the process is subject to changes that can have a significant impact on how the process is performed. This may be good or it may be bad but it is certainly uncontrolled. This changes are generally hidden from view and are not evaluated in light of the overall objectives of the organization. The first management hears about them is when there is a major problem with a product or service.

Process documentation should cover what you are actually doing. Not:

- What you hope to do
- What you wish to do
- What you plan to do

Process documentation that:

- is not up to date
- is confusing
- is not relevant to the people who need to use it
- is not available when it is needed
- makes it difficult for users to get the information they need

is a waste of time, money and effort!

Good process documentation usually contains two or more of the following elements:

Background information
Safety precautions
A step-by-step description of what needs to be done.
What needs to be considered to make a good decision – Decision Flow
Critical Parameters

Background Information

Background information provides the operator information that puts their task into context. If the operator is doing one step in a multi-step process it is desirable to give the operator an overview of the entire process and how their step fits in. It is not wise to view people as automatons. If people know what comes before their process and what comes after they can be alert to problems which may not affect their process but will impact on the overall outcome. You want employees that have enough knowledge of the overall process so they can alert management of problems early on when they are easier to correct.

It is also a good idea to include a description of a quality outcome for the process. This is why it is so important to define what the organization is trying to accomplish. Again people are not automatons. If they know what the goals are they are more likely to make better decisions and suggest better ways to do things. Keep in mind that your process operators are the experts on how to get things done in your organization. This is a valuable resource that you should not ignore.

Some processes must be done in a specific order in a specific way. You should include an explanation of why strict adherence to the procedure is needed. The emphasis of this type of background information should explain the consequences of not following the procedure.

For example, a body repair shop may have a procedure for mixing up paint. As part of this process you should tell the operator to check the viscosity before you pour the paint into the paint gun. Then you should tell the operator why this is important. If the viscosity is too high the paint will have a tendency to run when it is applied to the car. If the viscosity is too low the paint will tend to sputter out of the gun causing “globs” in the paint.

Put yourself in the shoes of the paint mixer. Knowing about the importance of the viscosity how likely are you to skip the step if you are under a time crunch? How likely are you to just dump the paint in if you are unable to get the right viscosity?

Safety Precautions

Safety precautions include what the operator needs to know to perform their job safely. This covers a wide variety of subject areas depending on the industry. Some examples include:

- Avoiding Repetitive Stress Injury
- Right to Know - Chemical Safety Training
- Dealing with dangerous customers

The objective here is to make sure your employees know how to perform their job safely. In some cases, such as Employee Right to Know, this information needs to be provided as part of regulatory compliance. In other cases you may need to provide information so that employees can recognize and avoid dangerous situations. If at all possible safety precautions should be designed into an employee's normal routine.

A Step-By-Step Procedure

The step-by-step procedure is the heart of any operational process. It is a description of exactly how your organization turns inputs into outputs. While turning inputs into outputs is the primary function of an operations manager, procedures are often given a very low priority. This may be acceptable if your procedures are very simple and are easily communicated. However, if your operational processes are numerous and complex, formal documentation is most likely a necessity.

You also may be required to develop formal process documentation if you are producing a product regulated by the Food and Drug Administration or you organization is seeking ISO certification. Just having such documentation does not mean that it is suited for your needs or that it is effective. Remember everything in your operation should be geared toward achieving the goal of a quality output. It is quite possible to spend a lot of time and money on process documentation that is ineffective.

Ineffective process documentation can be identified by following symptoms:

- New operators make a lot of mistakes.
- The operators never use the documentation.
- There is a wide variation in time to perform an operation from employee to employee.
- Certain problems re-occur every 3 to 9 months. (You keep solving the same problems over and over.)
- The documentation does not match the actual process.

If you really want to know how things are done in your organization, interview your most experienced operators. They are the ones who know what can be done out of sequence, what needs to be done in a specific order, and where to kick a machine to get it to work. Take a small tape recorder and ask the operator to show you how a process is done. Ask them to explain it as if you were a new employee. In about 2 to 4 hours you will have almost all the information you need to document the process.

If you follow this suggestion, you will note that there is a substantial difference from person to person in the ability to train a new person from memory. Often you will find that you will have to play the tape several times over before you gain a clear idea of what needs to be done.

When writing a process it is best to avoid a paragraph style.

For example:

1. Click on the new part icon then enter the part number from the job jacket. Load the parts on the pickup tray making sure rounded edge is toward the front and the stack is straight then press the start button.

Could be converted to;

1. Press the esc key until the main menu appears on the monitor.
   (Define what the operator should see at the start of the process.)

2. Click on the new part icon.
   (Use simple sentence structure. This makes it easier for employees with limited reading skills.)

3. Enter the part number.
   (Try to match your numbered steps to the steps the operator must perform. This makes it easier for a new operator to perform the operation. Read a step then do.)

   3.1 Refer to the job jacket for the part number.
   (If the operator needs some information tell them where it can be found.)

4. Load the parts on the pickup tray.

   4.1 The parts should have the rounded corner to the front of the tray.

   4.2 The parts should be stacked as straight a possible.
   (Define the things an operator must look for to make sure they are doing the operation correctly.)

5. Press the Start button to begin the loading process.

If you take the time to begin to write out the process you will notice that what originally appeared to be a single operation is in reality a series of short subprocesses. This is how your process documentation should be broken down. Generally speaking these subprocesses are less than 12 steps long.

Breaking process instructions into subprocesses has the following advantages;

- You can train a new hire to do a few tasks and have them be productive almost immediately.
- It is easier to access information on processes that an operator doesn't do on a regular basis.
- It provides a structure for an experienced operator to train a new person.

Critical Parameters

Once someone knows how to operate a piece of equipment or how to perform a particular process they do not need to refer to the step-by-step procedure. A properly trained an operator needs only a few bits of information to do their job. These bits of information are what I term critical parameters.

For example, a product enters a painting process. The operator already knows how to prepare the paint and apply it correctly. All they need to know is what color this product should be painted. Or an operator knows how to develop a roll of film but needs to know the print size and if this order requires double prints.

It is desirable to keep critical parameters separate from your process documentation. Because these parameters change frequently, you want your operators to have easy access to them. If an operator must hunt through several pages of a process document to find the one bit of information they need, it is likely you will find operators using “cheat sheets” which may or may not be accurate.

Keeping critical parameters separate from the process procedures also helps keep your process documentation costs down. Developing and maintaining the process procedures generally caries the greatest cost. If you can reduce the need to make revisions this can reduce the documentation work load. Because critical parameters are usually quite volatile keeping them out the process procedures reduces the need for revising the process procedure.

Critical parameters answer the question. “After the operator knows how to perform the process, what information do they need to complete a specific job?” Generally this information is contained on a sheet that comes with the job or is posted at the work site.

Decision Flow

Some processes can be broken down into step-by-step procedures which rarely change. Other processes cannot be documented in this manner because the actual steps vary according to the situation. This is often the case in service operations. The lack of a standard set of steps does not make process documentation impossible. It, in fact, increases the need for good documentation.

The question we need to answer is, “What do we want the employee to do?” This has to be more specific than “Give the customer good service.” To accomplish this it is helpful to look at the mechanics of what I will call a decision flow process.

Situation 1:

A customer comes into a hardware store and is met by a salesperson who asks, “Can I help you?” The customer responds, “Yes I am looking for a new drill.” Salesperson “Do you want one that is cordless or one that plugs into the wall?” Customer, “A cordless model”

Situation 2

A customer comes into a hardware store and is met by a salesperson who asks, “Can I help you?” The customer responds, “Yes I want to return this drill.” Salesperson “Do you want a replacement or credit?” Customer, “A replacement”

Let’s breakdown both of these situations and look at what’s happening.

	Situation 1	Situation 2
Assessment	There is a customer that needs help.	There is a customer that needs help.
Response	Confirm that the customer needs help	Confirm that the customer needs help
Assessment	Customer wants a new drill	Customer wants to return a product.
Response	Determine what kind of drill the customer is interested in.	Determine what kind of return is requested
Assessment	The customer wants to be shown the cordless drills.	The customer's drill is probably defective.
Response	Show the customer the cordless drills and talk about the various features	Determine the nature of the defect and get the customer a new drill.

Decision Flow processes concentrate on

- The sequence of decisions.
- The knowledge needed by the operator to make good decisions.

While the example above may appear to so obvious that it is not worth documenting, consider how many times it doesn’t happen in a retail setting. Remember, people aren’t born with these skills. Not everyone has experience in retail sales.

This type of process analysis is also useful because it highlights other areas where documentation and training is needed.

- Knowledge of cord and cordless drills.
- How to handle returns for replacement.
- How to handle returns for credit.

Documenting Processes or a Product or Service

Unless your organization produces only one or two products or services you probably have fewer processes than products. It is not unusual for products with different functions to share the same processes. Examples include scheduling jobs, inventory functions, one or more manufacturing processes and shipping.

Documenting your process rather than individual products or services hold the following advantages:

- Reduction in the number of processes to document and maintain.
- Simplification of operator certification for ISO requirements.
- Reduction in the effort needed to bring new products to market.

Reducing the Cost of Process Documentation

In an industrial setting process documentation is typically the responsibility of the engineering group. Be aware that when a person goes to school to become an engineer they usually don't see themselves writing process procedures. In fact is it probably the least desirable of the tasks assigned to an engineer. In addition, most engineers are not trained in how to write useable process documents. Considering an organization's engineers are among the highest paid of the technical staff it makes sense to assign process documentation to a technical writer. Then, the role of the engineer is reduced to reviewing the document before it is finalized. This frees up the engineering staff to focus on research and development and the improvement of existing products.

Organizations which have a just a few or very stable processes may want to outsource process document development. Permanent staff could be reduced to a minimum if they are just required to keep process documents current.

Using Process Documentation as a Planning Tool

Breaking processes into subprocesses makes the task of time studies much easier. This is especially true if you have a wide variety of products each of which require a different mix of sub-processes. Time studies will be discussed further in the capacity section.

By having clear and accurate process information it is much easier to:

- Determine the education requirements for the job. (Math - Reading - technical skills)
- Specify and evaluate new capital equipment.
- Identify potential process bottlenecks.
- Determine the division of labor and staffing requirements
- Document operator certification.

Process Capability

Just because you are able to build one or two products it doesn't automatically mean that you can build hundreds or thousands without defects. The same is true of services. Just because you can change the oil in your car doesn't mean that you are ready to run an oil changing service. To be successful, your organization needs to be able to reliably replicate a product or service. Process capability is a way to evaluate your organization's ability to produce a product or service on a consistent and reliable basis.

Process capability focuses attention on the ability of your processes to consistently achieve the desired results. Process capability is essentially a three step process.

- Identify the factors which can affect the outcome.
- Determine the amount of acceptable variation for each factor.
- Devise a system which maintains each factor within acceptable limits.

Identifying Process Factors

In order to perform this task a person needs to have a background in the theory of the process. Process theory is an explanation of why things work they way they do. A strong background in the theory of a particular process is useful in making a preliminary list of factors which need to be controlled to ensure the process is repeatable.

As a general guideline the following areas should be evaluated for important process factors.

- Raw Materials
- Machine Settings - (Temperatures, Flow rates, Light intensity etc.)
- Environment - (Humidity, Cleanliness, Lighting)
- Employee Training
- Process technique

Determining What Variation is Acceptable

Once the critical factors of a process have been identified we need to determine what level of variation is acceptable. If the factor is mechanical or electrical an engineering tolerance analysis may be all that is required. If this type of analysis is not possible, a controlled experiment is the next logical choice. A controlled experiment varies one or more factors as part of a controlled run. Data is collected and analyzed.

A well designed experiment should reveal the following information.

- Which process factors are more important than others.
- If the equipment you are using is capable of meeting the process requirements.
- The interaction between process factors.
- Process limits for each factor.

Some processes depend on operator technique and don't lend themselves to analysis by experimentation. This does not mean that they cannot be evaluated with an eye toward establishing process limits. If the process involves human interaction you can use role playing to determine what situations can cause the process to break down. If the process depends heavily on technique you may want a variety of people to perform the task to determine how easily the task is learned or if you need people with special skills to perform the operation.

Controlling Process Parameters

After the critical process factors have been identified and their limits established, the final step is to develop a control mechanism. A control mechanism consists of two components monitor and adjust. For process parameters which are quantifiable developing a control mechanism is often easy. Temperature, pressure, timing can all be maintained by incorporating a sensor and a programmable logic device to regulate the device you wish to control.

Situations where parameters are quantifiable lend themselves to automation. In fact automation is preferred to human interaction. For example, it is not reasonable or effective to expect a person to constantly monitor a temperature gauge. Assigning these types of tasks to your employees may be easier than installing a new piece of equipment but you shouldn't expect consistent results.

Situations where the parameters are subjective or require interpretation are suitable tasks for your employees. It is very difficult to automate a task that involves an evaluation based on appearance. One example is solder connections. A visual evaluation based on physical characteristics is the most reliable way to determine if a solder connection is good or bad.

Case Study - Injection Molding

Overview of the Injection Molding Process

A two part metal mold is made in the shape of the desired part. This mold is mounted onto a press which allows the mold to be opened and closed. In the closed position the mold is clamped together with 10 to 100 tons of pressure. The mold is designed to allow molten plastic to flow into the cavity of the mold. Once the cavity is filled the plastic is allowed to cool and solidify. When the plastic is cool enough the mold opens and the part is ejected.

The Production Cycle

Plastic pellets are held in a drying hopper over the injection molding press. The pellets are gravity fed into a tube and screw mechanism. As the pellets travel along the tube they are heated by a series of heaters which bring the plastic to the melting point. The melted plastic is then forced under pressure into the mold. The pressure used to force the plastic into the mold determines how fast the mold fills and how hard the plastic is packed into the mold. The machine can also be adjusted to control how much plastic is injected into the mold.

Process Capability

This process is interesting because determining if the process can produce an acceptable outcome (i.e. a good part) can be broken down into two components. The most obvious area of inquiry is the capability of the machine. A less obvious component to study is the mold used to make the part. Because the same machine can be used with several molds it is not a given that if the machine is capable to make good parts with one mold it can make good parts with any mold. For this reason we will look at each component separately.

Process Capability - Injection Molding Machine

Study the process - Are there some defining characteristics which can be used as an indicator for the entire process? In this case, yes, all dimensions grow or shrink in roughly the same proportions. An easily obtained measurement of a dimension is an indication of the start of all other dimensions in the part.

Define the Critical Parameters

Moisture Content
Heater Profile
Injection Rate - Profile]
Injection Pressure
Cooling

Define which of these are have the most affect on the process - rank them.

Establish control methods for each critical parameter. Determine the repeatability of these control methods.

Develop process limits for each critical parameter.

Process Capability - Mold

There is a direct relationship to the dimensions of the mold and the dimensions of the finished part.

Is the mold the correct dimension?
Does it take into account shrinkage?
Does it have enough draft to eject the part repeatably without distorting the part?

A capability study of each mold is needed to verify that all the dimensions are correct and that there is a correlation between all dimensions. There may be dimensions where this relationship does not exist. This may be due to the location of the filling point (the gate) or uneven cooling of the mold. If these situations are identified it may require modification of the mold or changes to the process limits established for the machine.

It may be that each individual mold will require a unique set of critical process parameters.

Fishing License

This process involves:
Taking out a form
Having the applicant fill out the necessary information.
Fill out any additional information.
Collect the money and dispense the license.

While this process may be well established for residents consider happens if a non-resident wants a license.

The process is essentially the same but it requires a different form. Selecting the correct form in this case is the critical parameter. If the person selling the license can't find the form or doesn't know which form to use the process is out of control. A transaction which should take 3 minutes now takes 20.

Loss of customer satisfaction.

Loss of potential sales - a customer who was about to make an impulse buy of a new rod and reel waited in line so long that he decided that it wasn't worth it.

Capacity

Capacity is often defined as "the maximum rate of output for a facility." While this definition is simple and straight-forward, it is not operational. Capacity is too complex an issue to be handled by this over-simplified definition.

There are many definitions of capacity. No single definition will suffice for the variety of industries and service organizations. Whatever definition is used, it must be in terms of the objectives of the organization. Capacity is a measurement of one or more elements of the organization's operational process. Some of these elements include:

- Inputs or Outputs
- Units of Measure
- Stock Levels
- Time Element
- Average or Peak
- Labor
- Equipment Utilization

It is advisable to determine capacity with respect to normal or sustainable conditions. Actual output can be increased well beyond 'capacity' (war effort) by reducing or deferring maintenance, adding temporary labor, and the use of overtime or outsourcing.

What Capacity is NOT!

Capacity cannot be defined as the actual rate of output. Actual output can be wildly different—higher or lower—from capacity. Capacity cannot be directly affected by changes in demand. An increase in demand does not make a plant capable of manufacturing more units in response.

It should be noted that demand can indirectly influence capacity. Increases or decreases in demand can cause changes in operating parameters which impact capacity.

Choosing the Appropriate Units to Measure Capacity

Using dollar measures is not advisable because they are ambiguous. Generally speaking, capacity is an upper limit to the rate of output. It may be unwise to measure capacity in dollar terms, because the value of the dollar is not constant. Capacity does not rise just because the product sells for a higher price.

Also, the value of the dollar is not the same from place to place. A McDonald's in New York City is not 'bigger' than one in Minot, North Dakota simply because the former does a larger dollar volume. Higher prices in New York make the dollar value non-comparable.

Note however that capacity can be affected by changes in the relative product price—as a product is higher priced and more profitable the firm may alter resources and schedules and find greater capacity to respond to the increased profitability.

It may be difficult to measure capacity in units. This is especially true if an organization produces a variety of products or services. This is a standard problem of apples versus oranges. Here it may be possible to define a ‘standard unit’, where products other than the standard may count as fractions or multiples of the standard. Thus a ‘full-size’ pickup truck might count as 1.2 standard units, where the standard unit is a ‘down-sized’ truck (with otherwise comparable equipment and option lists).

A unit of measure for capacity should include two elements, the amount of resources required and a unit of time.

For example a bank teller can have a wide range of capacities. Over a single day the teller could process 500 customer deposits. The same teller could also process 150 registered checks over the same period of time. In addition processing a registered check requires more equipment than a simple customer deposit. The resource elements of capacity generally include equipment as well as labor.

The time element of capacity is usually days, weeks or months. Time, however is not automatically based on a 24 hour day. In the example of our bank teller, if the bank is only open for 8 hours the unit of time per day with respect to capacity is 8 hours. Even with an automated teller you must take into account the time the machine is out of service due to gathering deposits and restocking and periodic maintenance.

One possible way of defining capacity is by process. The chart on the following page demonstrates how this could be done.

				Labor	
Process Type	Qty	Hrs per Day	Per Operation	Total	Qty per Day
1	50	8	0.25	12.5	1.56
2	75	8	0.1	7.5	0.94
3	15	8	1.5	22.5	2.81
4	75	22	0	0	0.00
5	1	22	1	1	0.05
			Available Resources		6
			% Capacity		89%

		Machine #1	
Process Type	Per Operation	Total	Qty per Day
1	0.05	2.5	0.31
2	0.5	37.5	4.69
3	0.25	3.75	0.47
4	0	0	0.00
5	0	0	0.00
	Available Resources		3
	% Capacity		182%

		Machine #2	
Process Type	Per Operation	Total	Qty per Day
1	0.15	7.5	0.94
2	0	0	0.00
3	1	15	1.88
4	0	0	0.00
5	0	0	0.00
	Available Resources		5
	% Capacity		56%

		Machine #3	
Process Type	Per Operation	Total	Qty per Day
1	0	0	0.00
2	0	0	0.00
3	1	15	1.88
4	0.15	11.25	0.51
5	1	1	0.05
	Available Resources		10
	% Capacity		24%

Sustainable Rate

Any measure of capacity should be with reference to some *sustainable* rate of output—not the maximum that could be achieved in some brief time period, but which cannot be repeated.

Peak vs. Average

Capacity can refer to the maximum availability of resources to meet demand. But capacity can also be used to refer to minimum or average availability to meet demand.

For example, average demand on an electric utility has little meaning to the firm, which must prepare to meet the peak demand (some hot August afternoon?) placed on it.

In contrast, a make-to-stock manufacturer, which forecasts an annual demand of 120,000 units currently needs capacity to produce 10,000 units per month, perhaps regardless of how the demand for those 120,000 units is distributed over the year.

Stock vs. Flow

In a later section, you will see inventory decisions of two basic types: those that require both timing and quantity decisions, and those that require only quantity decisions. There is an analogy between these inventory models and capacity.

Ordinarily, capacity will be treated as a flow through an organization or through some part of an organization. But if the time element is not a necessary part of the problem, then capacity ceases to be a flow variable and becomes a stock variable. This is a convoluted way of saying that capacity for a stadium, a classroom, a fuel tank, or an airliner is handled quite differently than capacity for a factory or hospital. In the four cases cited, capacity is related to a single instance of use, not use over a span of time. And in these cases, capacity becomes a stock variable.

Stadium capacity may be properly stated as 72,432 (if that is the number of seats that can be used for an event) without any time dimension.

Using Inputs as a Measure of Capacity

Inputs are not generally a useful measure of capacity, since they ignore the processes necessary to achieve the desired outputs. However, it may be convenient to refer to a restaurant's seating capacity. Indeed, in many service operations, the lack of a common denominator for output may result in greater use of inputs as capacity yardsticks.

Realistic Evaluation of Capacity

Effective capacity reflects the manner in which the labor and equipment is actually used. Capacity should reflect good planning—that is capacity evaluation makes allowances for work breaks that are part of the collective bargaining agreement, or are part of the standard work rules. It makes allowance for preventive maintenance of equipment. It makes allowances for machine breakdowns—recognizing that all equipment will need maintenance and will experience failure at some time

The Bureau of Economic Analysis (also the Federal Reserve Board and the Wall Street Journal) defines maximum practical capacity as “that output attained within the normal operating schedule of shifts per day and days per week while bringing in high cost inefficient facilities.”

Linking Capacity to Demand Management

Since the most expensive units to produce are those which utilize resources at the peak capacity, it may pay the organization to practice demand management—to manipulate demand to reduce the need for a high peak capacity.

Electric utilities do this with time-of-day pricing; so do long-distance telephone service providers. Some restaurants perform demand management with reservations, most doctors’ and dentists’ offices do the same with appointments.

Many other types of organizations, including retailers, have little ability to manipulate the flow of customers or clients. They must therefore have capacity to meet peak demand, or risk losing demand that occurs in excess of available capacity.

Capacity Planning

Capacity planning methods vary according to industry or service but many of the principles are similar. Capacity planning can be broken down into three areas of study: long term, medium term and short term.

Long Term

This view may cover months to years. An operations strategy/policy is needed covering overall organizational capacity (production sites, hotels, hospital wings, warehouses, production lines/machinery, computer upgrades and investment in new facilities, etc.

Medium Term

Forecasting demand then scheduling available capacity to best meet that demand. This typically involves machine scheduling, staffing levels and materials requirements planning.

Short Term

Day-to-day adjustments are typical of capacity management. Unforeseen contingencies occur by the hour, day or week. Operational staff need the expertise, discretion and some “slack” for flexibility to make locally identified adjustments - without upsetting the objectives of the organization

Long Term Capacity Planning

Long term capacity planning is concerned mainly with facilities and capital equipment. Long term capacity planning is normally a strategic, semi-structured decision.

Long Term Capacity as a Strategic Decision

Determining long term capacity is usually done only periodically or infrequently, often only once in the lifetime of a company. For most organizations, the capacity issue is clearly a strategic decision.

- It involves the commitment of large amounts of resources for long periods of time.
- It influences the operating costs of the plant; it affects the ability of the plant to meet product demand.
- The decision is an important one because mistakes can be very costly, and can be very difficult and time-consuming to correct.
- The wrong capacity, whether too large or too small, will put the firm at a competitive disadvantage, and may result in the failure of the enterprise.

Setting capacity goals are not the responsibility of an operations manager. Because it is a strategic decision, it is made at higher levels within the organization, certainly with input from the operations manager and the operations planning staff. The function of operations management is to take a strategic vision and turn it into a functional reality.

Long Term Capacity as a Tactical Decision

For some firms, capacity decisions are made often enough that they become regular (Wal-Mart, McDonald's). This may tend to demote the decision from strategic to tactical. Certainly the decision has become more highly structured. For some firms, the capacity decision may be embedded in their mission; hence capacity is a positioning decision for them.

Question: under what circumstances would capacity NOT be strategic?

- Where there is no "right size."
- Where capacity can be added or deleted with little delay or expense.
- Where operations are "scalable."

"Key Questions"

- How should we measure capacity?
- What is the maximum reasonable size for our facility?
- How much capacity cushion is best for our processes?
- Should we follow an expansionist or a wait-and-see strategy?
- How should we link capacity to competitive priorities?

Long Term Capacity and Operations Management

The question of how much and what kind of capacity is harder to do properly than it may appear. Long term capacity can be difficult to define if it is not stated in quantitative terms. For example, it is useless to say we want to increase the capacity of our hospital to respond to the aging of the baby boom generation. What does this mean? Does this mean you need to increase the number of beds? Does it refer to ability to treat specific conditions?

It is quite possible that operations management will not get a quantitative statement from upper management. If this is the case, turning a strategic vision into quantitative statement should be one of your first tasks. A quantitative statement is one that is as specific as possible.

It is recommended that women over 50 get regular mammograms. Based on the demographics of the baby boom generation, we will need to increase the capacity of mammogram screening by 10% each year for the next 7 years.

Medium Term Capacity Planning

Medium term capacity planning includes number of days worked per week, number of shifts worked per day and staffing levels. It may also involve equipment purchases and rearrangement of the work area.

Medium term capacity planning allows adjustments to the type of products and services provided. Seasonal adjustments to production fall into this category. An oil refinery increases its capacity for heating oil while decreasing gas production in the fall reversing these changes in the spring.

These types of changes typically represent a shift in emphasis rather than a change in overall capacity. This is not always the case. A retail store needs to increase its capacity during the Christmas season and decrease it after the first of the year.

Managing Demand Variations

Operations managers seek to manage demand in relation to capacity. We can have variation in demand between products which, if total demand remains roughly constant, can be managed by use of scheduling systems. If there is a variation in total demand we may try to smooth demand by

- marketing to even-out seasonal effects
- finding complementary products (greetings cards for all occasions).
- differential pricing of services (off-peak tariffs).

These strategies help, but the operations manager may still face problems and can try one or a mixture of the following:

Working to a Level Capacity

Working to a level capacity can be an effective strategy. In a service organization, customers must be willing to wait during times of peak demand. In production or retail, stock can be used to buffer variations in demand. In order to function properly, products must have a long shelf-life.

In a working to a level capacity model attention to demand variations is minimal. Total system capacity is set to the average demand plus a small contingency surplus. Work scheduling maintains steady output of products. Products are made for stock during the off-peak periods and sold from stock at peak.

The key to make-for and sell-from stock in peak periods lies with efficient use of operations resources which results in low costs. This strategy can be enhanced by promoting or discounting products during off peak periods.

The cost savings of maintaining a relatively consistent level of production must offset the additional inventory cost plus the cost of promotion and discounting.

Matching Capacity to Demand

Matching capacity to demand is an attractive option if operational costs are directly related to capacity. Products or services which are labor intensive tend to fall into this category. Using this model, capacity is varied quickly in response to changes in demand.

Capital-intensive operations largely have a fixed capacity. In the short term it is difficult to vary capacity. These types of operations do not lend themselves to quick changes in capacity unless a substantial portion of overall capacity is carried out by contract suppliers.

Managing capacity by controlling labor is not without expense. Increasing the full-time staff incurs recruitment and training costs. Lay-offs are expensive, add to staff unrest and generally result in the loss of knowledge specific to the organization. These costs can be reduced by the following strategies.

Overtime working

Five hours overtime on a basic 40-hour week gives a 12% increase in output without employing extra staff. Overtime premiums must be paid but we get better capital utilization. This is generally effective for short periods of time (3 to 4 weeks)

Flexible and Part Time Labor

With a front-shop and back-office service, back-room staff can be assigned to boost front-shop capacity. Back room work can be put on hold. In a department store, non-selling staff may work on the shop floor as sales assistants for the first, busy days of the sales. This strategy can also be used in a production area where operators are cross-trained on a number of operations.

Larger short-term variations such as a Christmas rush or a large new order may require the addition of part-time staff rather than overtime. Service operations typically rely on staff working up to eighteen hours weekly. In a hotel, part-time staffing enables split shifts to manage demand which varies hourly and extends beyond a single 8 hour shift.

Resorts with their seasonal demand variations depend upon seasonal casuals - of which there is usually a reliable supply of students who want summer work.

Sub-contracting

Buying in components that are normally made in-house is an option provided the source can offer the right quality and delivery. The make-or-buy decision thus focuses on capacity as well as price. Bought-in components may cost more than those made in-house. There is an additional problem of dependency and the reliability of a supplier.

As a general rule you should keep the following operations in-house:

- Operations which are proprietary or involve trade secrets.
- Operations which your organization has particular expertise.
- Operations where the timing of delivery is critical.

As a general rule you should out-source the following operations

- Operations where a contractor has more expertise than you.
- Operations which require large capital expenses which are not justified by your production volume.
- Operations that contractors supply to a number of other organizations.

Civil engineering subcontracts in very efficient ways. A main contractor will be the project co-ordinator who hires subcontractors , workers and plants as required. In clothing manufacture, out-workers (self-employed, home-working, subcontractors) may be used. The sub-contractor has the premises, expertise and equipment. A window installation company may vary its order fulfilling capacity quickly with fewer cost penalties by using its list of reliable subcontractors .

Hybrid Strategies

At the end of the day a company may use stock, overtime, part-timers and demand/marketing management and still not have maximum utilization. Services rely on queues or appointment systems at peak times and have off-peak, unused capacity. The balance between demand and capacity is a target which operations managers strive towards - recognizing inevitable compromises on the way.

Shelf Life

Shelf life refers to products or services whose value is related to time. Food products are an example. After being produced the item holds its value for a specific length of time. Products which have a short shelf life require special attention to their production and inventory. The shorter the shelf life the greater the problem.

Sample Problem: Product Shelf Life

A bakery produces donuts for $2 per dozen, and sells them for $4.

Leftover donuts have no value.

Demand varies from 6 to 9 dozen per day, with no seasonal or day-of-week influences.

The payoff table is shown below

	Demand 6	Demand 7	Demand 8	Demand 9
Produce 6	$12	12	12	12
Produce 7	$10	14	14	14
Produce 8	$8	12	16	16
Produce 9	$6	10	14	18

Each cell is computed by subtracting total cost from total revenue.
For example, the cell "Produce 9, Demand 7" has
Revenues 7 x $4 = $28
Costs 9 x $2 = $18,
Profit $28 - $18 = $10.

Demand distribution at this shop is as follows:

6 dozen, 10 percent
7 dozen, 20 percent
8 dozen, 50 percent
9 dozen, 20 percent

Question: If you were running this shop how many donuts would you produce?

Why?

Assuming a consistent demand distribution, are there any changes you could make that could increase your profit margin and / or customer satisfaction?

Setup and Shutdown

Setup and shutdown are two important subsets of the time it takes to produce a product or service. Setup represents the costs associated before a product or service can be produced. Examples of set up costs are:

- Travel time for a repair technician to a customer's site.
- The cost of preparing the raw materials. (Mix paint, kit parts, chop lettuce etc.)
- The time it takes to prepare a machine to run. (Changing tools, heating ovens, loading programs etc.)

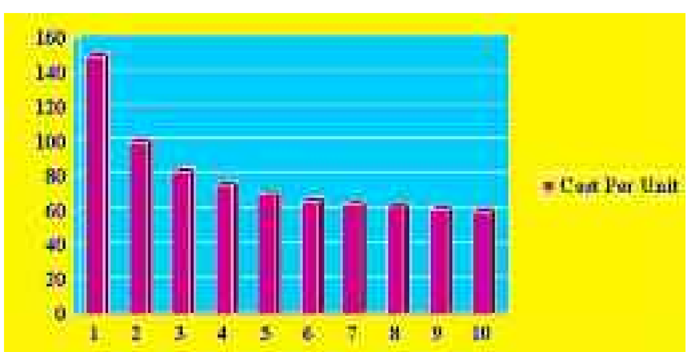
Shut down costs are similar to setup costs.

- Recording repair time and parts used for a repair.
- Clean up of equipment
- Allow the equipment to cool or shut down in a controlled manner.

In general, setup and shutdown costs are not dependant on the number of products or services provided. For example a copier service technician must travel the same distance to a customer's site to service one or any number of machines. The number of machines serviced at each site does have an impact on your overall cost of operation. The cost of travel time is spread out over the number of machines serviced. This principle applies to any product or service as shown in the table below.

Setup Cost: $100
Cost per unit $50

Qty	Total Cost per Unit
1	$150
2.	$100
3	$83
4	$75
5	$70
6	$66
7	$64
8	$62
9	$61
10	$60



Reduction in Output Due to Setup and Shut Down

Changes in product mix can dramatically reduce your capacity. A good example of this occurs is when an organization increases the number of items in a product line. There must now be more start-ups, changes in the cycle time of production, more time spent between production runs—cleaning, adjusting machines, etc. This reduces time available for production, and results in lower capacity.

If your productivity seems to be decreasing for no apparent reason you may want to investigate how much time is spent on setup and shut down activities.

Reducing Setup and Shut Down Costs

The quickest way to alleviate start up and shutdown problems is to increase the build quantity per session. This is really only a stop gap solution. As build quantities increase the ability to respond to demand for a product you are not building is reduced. To compensate you may have to raise stock levels, incurring the costs associated with such a move. If you are supplying custom products or services increasing the build quantity per session is not a viable solution.

Effective reduction of costs associated with setup and shutdown involves a careful analysis of each situation. For this discussion it should be noted that cost includes time, labor and wasted raw materials.

Begin by identifying the primary cause of each setup cost. The question here is what triggers a setup or shutdown? Some possible causes might include:

- Inherent to process being used (The oven needs to heat up)
- A change in model type
- Replenishing raw materials
- Machine maintenance or breakdowns

It is likely that you will uncover multiple causes which trigger a setup or a shutdown cost. Perform a Pareto analysis to identify the causes which have the greatest impact on your costs. The next step is to explore ways to reduce the number of trigger events. Some of these might include:

- Changes in the design of a product or service
- Use of dedicated instead of multi-functional equipment
- Scheduling preventive maintenance during off peak hours

Once you have reduced the number of trigger events you should begin to explore ways to reduce the cost of each event. This may involve:

- The redesign of work stations.
- Structuring the work flow to take advantage of similarities between models or services.
- The use of customized fixturing.
- Changes in product design to allow for standardization.

Analyzing and Minimizing the Risk of Equipment Failure

We don't give much thought to a car battery until the car won't start, you're stuck in the middle of nowhere and it's 40 below zero. The situation improves, however, if you have a cell phone and it could have been avoided altogether with some attention to preventative maintenance.

What is true of your car battery, a cell phone and preventive maintenance is true of the equipment used in your organization. Ideally you want to prevent equipment breakdowns. In cases when this is not possible, you want to take steps to reduce the impact of a breakdown if it does occur. Maintaining your equipment and reducing the impact of breakdowns are not all that difficult but they do require some planning.

Analyzing the risk of equipment failure involves asking, "What if?" For each piece of equipment determine the impact on your organization if the equipment were to fail. Your analysis of capacity may be of some help.

				Labor	
Process Type	Qty	Hrs per Day	Per Operation	Total	Qty per Day
1	50	8	0.25	12.5	1.56
2	75	8	0.1	7.5	0.94
3	15	8	1.5	22.5	2.81
4	75	22	0	0	0.00
5	1	22	1	1	0.05
			Available Resources		6
			% Capacity		89%

		Machine #1	
Process Type	Per Operation	Total	Qty per Day
1	0.05	2.5	0.31
2	0.5	37.5	4.69
3	0.25	3.75	0.47
4	0	0	0.00
5	0	0	0.00
	Available Resources		3
	% Capacity		182%

		Machine #2	
Process Type	Per Operation	Total	Qty per Day
1	0.15	7.5	0.94
2	0	0	0.00
3	1	15	1.88
4	0	0	0.00
5	0	0	0.00
	Available Resources		5
	% Capacity		56%

		Machine #3	
Process Type	Per Operation	Total	Qty per Day
1	0	0	0.00
2	0	0	0.00
3	1	15	1.88
4	0.15	11.25	0.51
5	1	1	0.05
	Available Resources		10
	% Capacity		24%

Let's say for instance that machine #3 is a computer terminal. If any one terminal should fail the impact on the organization is minimal because there is more than enough reserve capacity. If, however, all of these terminals depend on a central server for data, a functioning server becomes very important.

Assuming the server fails, all 10 terminals become unusable. Since these terminals are used in processes 3, 4, and 5 the organization will be unable to provide these products or services. Processes 3, 4, and 5 account for just over 40% of the total organizational output (91 out of 216 operations).

The capacity analysis also shows that you are well over 100% capacity for processes that use machine #1. You may be compensating with overtime or by adding a second shift. The success of this strategy depends on all three machines remaining operational. Considering the importance of processes 1, 2, and 3 to the organization the failure of even one machine will have a serious impact on the organization. The danger in this situation is compounded because the machines are operated almost twice as long as they would in normal conditions, increasing the possibility of failure.

The actual impact to the organization depends on the actual product or service being provided. An inability to provide a product or service for a day to a week may not amount to more than an mere inconvenience. On the other hand it can have a severe impact. Just like taking your cell phone, you should take steps to lessen the impact of equipment failures.

Some of the steps you can take include:

- Redundancy
- Service Contracts
- A preventative maintenance schedule
- Maintaining an inventory of spare parts.
- Access to a loaner machine as part of a service contract.

Technology

Unlike a consumer, an operations manager cannot afford to be a gadget hound or a technophobe. Technology needs to evaluated and implemented in a way that will serve the interest of the organization. Since operations management is concerned with the process of turning inputs into outputs it is prudent to look at technology with respect to doing things better, faster and cheaper.

Better

One of the ways you can improve the operations function of your organization is to revisit some of your process capability studies. Process capability studies can be used two ways. The first way is discussed in the process capability section where we set limits based on the needs of the product or service. The second looks at the maximum control we have over the process.

For example we may find that a mill can hold a tolerance of ± .002 inches on a machined part. This may be fine if the desired outcome needs to be ± .005. This limitation, however, keeps us from accepting jobs where the tolerance is less than ± .002 or if we do accept such a job our costs will increase due to the production of scrap and the costs of sorting good from bad.

Here is a case were it would be wise to begin looking for equipment that will allow you to gain a greater share of the potential market in a cost effective manner. If you are already performing tasks that are beyond your process capability, the search for new technology should move toward the top of the agenda. You may be able to recover your investment in new technology just from the cost savings of improved capability.

There is another benefit to improving your process capability — your reputation in the marketplace. When people think about your products or services do they say “Company X - they are OK for the simple stuff but they can’t handle the difficult or newest designs.”
Company Y - “We use them for our most difficult jobs. They are the only place in town that can meet our requirements.”

Having the capability to do things that your competitors cannot makes you an industry leader rather than a follower. If you can be competitive with the simple, less high tech jobs also, you can become a one stop supplier. In effect your increased capability may bring in additional conventional business. Keep in mind there is no reason you cannot be competitive if your processes are streamlined and under control.

If you have processes that depend on the technique of the operator, you know that this can be a constant source of headaches. Maintaining a consistent result requires constant training and oversight. Removing technique from a process is generally not accomplished by small incremental improvements. It usually requires a radical re-thinking of how to accomplish the desired outcome.

Back in the 1950s and 1960s, in the days before hand held calculators, math problems were solved using a slide rule. The slide rule did a fine job of division and multiplication but it did take some learning and was unable to keep track of zeros. If you didn’t use it correctly you could easily be off by tens, hundreds or even thousands. In fact it was quite easy to come up with the wrong answer all together. People who were good at using a slide rule liked them and they worked well but their proper use depended on technique.

Back in the olden days there really wasn't much of an option. Computers were huge and expensive. If you ever tour the first launch pads at Cape Canaveral you can see a very large computer that was performing one or two calculations and which couldn't do anything else.

With the advent of the integrated circuit, the hand held calculator became economically viable. They were not susceptible to the technique errors common to slide rule use. A wider number of people could learn to use them correctly. Even though at their introduction the calculators were 10 to 20 times the cost of a slide rule, the cost could easily be offset by the reduced number of errors.

From the perspective of today the debate between slide rule vs calculators seems like a no-brainer. At the time, however, there was considerable resistance. Being skilled at a particular technique that not everyone can do carries a level of prestige. The introduction of a radical new method represents a loss of prestige along with uncertainty of a person's value to the organization. The introduction of a new process always involves problems which need to be worked out. These two conditions provide a fertile ground for opposition to the adoption of a new way of doing things. You should expect this opposition and be sensitive to its root causes.

Not all applications of technology will be met with opposition. Changes that automate mundane or difficult tasks are often greeted warmly. In this category are finding ways to automate controls. This type of technology frees your employees to do tasks suited to human talents, letting technology keep track of the mundane details. Find ways to let technology tell you when something goes wrong. This allows employees to focus on what needs to be done to correct the problem.

Faster

As we have discussed earlier, time and money associated with set up and shut down can raise havoc with inventory and the ability to respond to changes in demand. There are three potential areas to examine to reduce your costs in this area.

The first is to investigate if your present equipment can be modified to reduce set up time. Even if your equipment is recent there many have been changes which can be retrofitted to suit your needs.

For purposes of illustration, let's use a hand-held drill. During the course of a day, your operation requires the drilling of many different sized holes. Each time you need to change the hole size you have to take a key and remove one drill bit and replace it with another. This operation takes about 20 seconds. While this doesn't seem like much if it is done 75 times a day this represents 25 minutes per day, or 2 hours per week. The change takes time, and it may contribute to repetitive motion injuries.

A newer drill does not require the use of a key to secure the bit. Retro fitting the drill to this newer style saves 10 seconds per change over. Incorporating this change results in cutting your setup costs in half. Better yet, consider having multiple drills — one for each different size bit. A drill is inexpensive enough to consider it for duplicate purchases.

When a new technology becomes available it is at its most expensive. As time goes on more features are added and the cost of acquisition goes down. If your organization is an industry leader you may be an early adopter. While this may be good strategy for capturing a market you need to be on guard against your competitors benefiting from the maturation of a new technology. On the other hand, if you are late to a market opportunity you can use this maturation to your benefit.

Originally the technology may have been so expensive that you had to purchase a multi function unit. This means that the equipment was required to perform a number of different operations. Given the level of business combined with the cost of the equipment, it was necessary to tolerate the set up costs when switching operations. The technology, however, many have progressed to the point where you can afford several smaller dedicated pieces for the price of or near the price of the large multi-function unit.

The application of this change in technology has a two fold benefit. First you can have dedicated work stations which can virtually eliminate your setup cost. The second is that you have probably gained additional flexibility and capacity. If there are long term shifts in demand, some of the work stations can be changed to allow for an increase in capacity.

The third area to explore is production on demand. Here we are looking for technologies that can eliminate the need to carry inventory. The area of printing is a good example of this concept.

In the past the only way to get high quality color printing was to have it run by a printer on a four color press. This would involve several hundred dollars in setup costs and was economical only in runs of 1,000 or more. If changes were needed in the copy, these costs would reoccur.

With the advent of the color laser printer you can print 10 sheets for the same cost as 100. You could even print one at time if needed. Since the setup and production time is very short there is no need to hold inventory. Printing can be done as needed.

The same concept has been applied to product labels. Take a look at the model label on a product that has been manufactured recently and compare it with a product that is about 10 to 15 years old. You will notice that the newer product has a computer generated label. For a company that makes a wide variety of products this can reduce inventory and purchasing cost by thousands of dollars a year. Plus, the company reaps the benefit of minimal lead time and low setup costs.

Cheaper

Cheaper is possibly not such a good word because of its association with items of poor quality. In the context of applying technology it means finding ways to reduce costs while maintaining or increasing the level of quality. A better description might be adding value to your product or service. The utilization of technology in this manner tends to fall into three categories, new material, processes or products.

Let’s talk about products first using a DJ service as an example. Not too many years ago music was only available on records. To put on a show, the DJ had to lug turntables and records to each event. Between each song a record had to be selected and cued for play. This involved a lot of hunting and searching especially if special requests were made. The size and weight of the records placed a limitation on the selection of music available. With all that moving and usage a certain percentage of records needed to be replaced on a regular basis.

With the advent of CDs the problem of weight and bulk was minimized. In addition the level of audio quality was improved. Yet the issue of finding and cueing songs and potential damage to the CDs remained. Both of these problems could be eliminated using a CD juke box capable of holding 100 or more CDs.

In comparing records to a CD juke box we see a reduction in the cost of maintaining a music library, and the elimination of a storage and retrieval system for individual records or CDs. Use of the CD juke box also frees the DJ to concentrate less on the mechanics of the job and more on entertaining the client. In this case costs are reduced and the level of service is increased.

It is difficult to consider recycled plastic as a high tech development but it is a relatively new material which has the potential for cost reduction. One of the big environmental problems with plastic is that it doesn't degrade like paper or wood. While this characteristic is undesirable in a landfill, it is a benefit if the plastic is used as a substitute for wood. The specific application I will illustrate is picnic tables and benches.

If you have ever owned a wooden picnic table you know that it requires periodic maintenance or it will begin to deteriorate. If you only have one picnic table this may not be much of a bother but if you are running a facility which has many tables, this can represent a significant cost in terms of labor and materials. The use of recycled plastics, in this case, can reduce your costs without affecting the quality of service.

Advances in technology often create opportunities for improvements in processes. An example of this is the assembly of electronic circuits using leadless components. (Surface Mount Technology) While this assembly process has been around for 20 years it only became practical about 10 years ago when the components could be placed robotically.

Many of the components used for this type of assembly are very small — less than 1/32". This makes it difficult to manually place the component on a circuit board with any degree of accuracy. In addition, because of their small size it is difficult to identify the value of the component. These two factors combined to make hand assembly too time consuming and too prone to errors. Surface mount circuit boards were only done when the savings of size and weight of the final assembly was worth the extra cost of assembly.

A robotic assembler solved the problems associated with hand assembly. It could, with accuracy and repeatability, place components in the correct location. It also had the benefit of being many times faster than the hand assembly method.

Use of this process also presented a reduction in inventory costs. The small components could be stored on the machine. The machine was then programmed to pick the component and place it on the board. This eliminated the need for stockroom personnel to find and kit the parts for each assembly. As each part was assembled inventory could be automatically adjusted, eliminating the need for a manual data entry.

Keeping Your Organization Current

Hopefully, some of the examples I provided have illustrated how important it is to keep track of developments in technology. At the least you need to keep track of trends in *your* industry. Trade publications are a good source of this information. Don't read them cover to cover, just scan them for articles of interest. Being a member of a trade or professional organization is another good way to keep on top of industry trends.

You also may want to develop a list of problem areas in your operation. What would it take to make the problem go away. “If only we didn’t have to do X or If we could only eliminate Y the problem would not be an issue.” This will help you keep things in the back of your mind. There may be a product designed for another market that can be modified to meet your needs. Keep your eyes open — you may be surprised at what you stumble across.

Guarding Against Technical Obsolescence

Let’s return to the DJ example and examine two responses to the introduction of CDs.

Situation 1 (Introduction of CDs)

The owner of the DJ company is unsure that the CD will catch on. They are more expensive than records and the CD players are a lot more expensive. In addition not all songs are available on CD, so we would need twice the equipment for each event. The company has already made an investment in records and turntables and the owner is unwilling to risk money in this new technology.

At this point in time this really is a logical argument. Buying new equipment probably would have little impact on service being provided. It is a risk and would reduce the company’s profits.

Situation 2 (Introduction of CDs)

The owner of the DJ company has heard of CDs and evaluated the technology. The sound is clearly better and the owner feels it would improve the quality of the service. The owner makes an investment in a player and some CDs that are popular with clients. The owner is not sure what kind of impact CDs will have on the DJ business but is willing to make the necessary investment.

The owner is taking a financial risk with no clear return on investment in sight. The company is healthy, however, and if the investment falls flat it will have little effect on the company.

Situation 1 (3 Years after CDs are introduced)

The owner of the DJ company still sees no need to switch from records to CDs. They are still more expensive than records. There are still some songs that are not available on CD. Clients aren’t asking if the company uses CDs when they hire the company’s services. The decision is made to continue with records.

You might argue with the owner that he has his head in the sand. CD are catching on and they sound better. But at this point you could not prove that the decision to stick with records will have detrimental effect on the company.

Situation 2 (3 Years after CDs are introduced)

The owner has gotten a favorable response from clients who require the improvement in sound quality. The DJ company has even landed some jobs because the customer found out the company used CDs and the customer preferred the sound quality of CDs. The DJs like them because it is easier to cue up the music. The company plans to purchase multi-disk players and has developed a plan to phase out records over the next year.

The small initial investment was useful in determining the potential of the new technology. The company has developed a plan to eliminate the need for maintaining the equipment for both records and CD. It has made a commitment to this technology and seeks to cuts its costs by dropping records.

Situation 1 (7 Years after CDs are introduced)

Records are no longer being made. Business has dropped off. It is obvious that the company must invest in new equipment. This is now difficult because sales are down and there is not much money to buy new equipment.

This is a painful situation. The business will have to shut down or it will need to borrow money to make the necessary investment in equipment and CDs.

Situation 2 (7 Years after CDs are introduced)

The company continues to do a good level of business. Profits are up because the company has found that CDs don't need to be replaced as often as records. An investment in CD jute boxes has reduced setup and shut down costs and allowed the DJs to concentrate on entertaining the clients.

Customer demand has shifted to the point where CDs are the industry standard. The company has fully adopted this standard and needs to only make incremental improvements to keep current.

While this is just a fictitious example, you can see how seemingly good business decisions can lead to technological obsolesce. While it is easy to see the trend when looking at a seven year history on paper, it is much more difficult to discern while you are living through it. This is especially true for operations managers who, by necessity, need to keep track of the day to day details of the organization. It is advisable to take time to sit back and determine the direction and speed of your industry.

Determining when a Technology is Ripe. - Case Study

The Feasibility of Interactive Multimedia in an Industrial Setting

In this paper I hope to explore the feasibility of using interactive multimedia technology to train production workers. To some this may seem like a non-issue that would cause the reader to check the date that this paper was written. After all, there are thousands of interactive multimedia titles currently out in the market. The technology exists and it seems logical, at least at first glance, that interactive multimedia training should be adapted to the needs of industry. On the other hand, the mere existence of a technology does not guarantee that it will be feasible for all applications.

In an area such as interactive multimedia, where the technology is relatively new and is changing rapidly, it is prudent to clarify just what we are talking about. Multimedia can be characterized by the communication of information using most, if not all, of the following: text, sound, animation, still photographs and video. Generally all of these communication forms are stored and displayed on a computerized system. Interactive can be characterized by the ability of the user to control the display and sequence of the multimedia presentation and to receive feedback to determine if the message being presented is being understood. The key words describing interactive are control and feedback.

Defining interactive multimedia, however, is not enough. We must also know what it must accomplish. The goals of interactive multimedia can be quite varied. Consider the following example. You are responsible for overseeing the technical training for the production area of International Widget. The vice-president of manufacturing has just entered your office and demands to know why the productivity per employee has dropped significantly in the Widget sub-assembly area. You explain to the vice-president that human resources has just doubled the number of people in that area, using a temporary employment agency. The people we received have no prior experience building widgets and it would be a matter of a couple of weeks of on the job training before productivity figures returned to normal. The vice-president responds by pounding his fist on the table and demanding that an interactive multimedia training program be developed so that any idiot off the street can come in and build widgets.

In this scenario, one of the main reasons for creating interactive multimedia training is to keep your job. Another might be to demonstrate to your customers that your company is on the leading edge of technology. In this case the reason is primarily based on projecting an image to the market. I am a realist and will acknowledge that both of these are valid reasons to proceed with the development of interactive multimedia as technical training methodology. But these reasons aside, what are objectives of any technical training program for the manufacturing area and how well does interactive multimedia meet those objectives?

To answer this question, it is valuable to look at industrial training prior to the industrial revolution. A romantic might refer to this period as manufacturing by artists; a shoemaker would make shoes, a watchmaker would make watches. These were one or two person manufacturing facilities. One person would be responsible for all aspects of the operation: sales, marketing, design, manufacturing, finance and customer service. For purposes of this paper, it is relevant to define pre-industrial manufacturing by professionals (artists) in terms usually associated with post-industrial manufacturing. It is useful because it highlights the many and widely varied skills a person had to learn before becoming an full fledged professional.

If a person wanted to enter the profession of, say a shoemaker, they became an apprentice. During the time a person was an apprentice, they not only learned how to make shoes but also learned the business of shoemaking. The apprentice, who eventually became a journeyman, learned the business by observation, hands on experience and verbal instruction from the master craftsman. The instruction was one-on-one, was primarily verbal and involved every aspect of the business. The process was lengthy, but at its conclusion, the apprentice turned craftsman knew the entire business and the interaction and interdependence of the manufacturing process. At the completion of this process, the craftsman possessed both technical and business skills, a combination that appears to be rare in this post-industrial era.

In the beginning of the industrial revolution, the creation and transmission of power was terribly inefficient. In addition, the cost of machine-based manufacturing was many times that which was required by the small artisan / entrepreneurs. In order to make a machine based manufacturing process profitable, it needed to produce its goods in large quantities. Production in large quantities, of course, is not an end in itself; the products must be sold. According to the economics of supply and demand the price of these goods had to be substantially lower than what was being charged by the artisan / entrepreneur.

More relevant to the question posed by this paper is the shift from the need for a well trained generalist to a specialist. Machine based production demanded attention in ways that were different from an entrepreneurial enterprise. For example, it took several workers just to keep the power plant running. For the skilled trades, the process of training which followed the apprenticeship, journeyman and craftsman carried forward to the early industrial period. This scope of this training, however, was narrowed significantly.

Another interesting result of machine based manufacturing is that it broke the link between management and production. There are two significant aspects to this break. The artisan as manufacturer knew that keeping his or her job depended on satisfying the customer. In contrast, the employee in a factory knows that keeping his or her job depends not on satisfying the customer, but on satisfying a supervisor. As a general rule a person who works in manufacturing will seek training to answer the question, “What do I need to know to keep my job?”. Training a new person about the whims and wishes of a boss is always verbal and one-on-one.

The second important aspect of the break between management and production is that production workers became to be viewed in Newtonian, that is, in mechanical terms. It is often asserted that machines dehumanized the worker by making them cogs in the machine. This is complete nonsense. It is like maintaining that cotton and tobacco caused slavery. It is more accurate to say that machines created the economic incentive to attempt to transform workers into machine cogs. Conversely, the economics of making a living created the incentive for workers to project the image of being a cog.

While there is a great deal of evidence that workers resented being treated as cogs there is little evidence that they actually became cogs. Yet to management the picture was different. They treated workers as cogs, the workers acted like cogs so it was concluded that machines had made men into cogs. This, unfortunately is a management perspective. The dynamic behind this perception is the same as it is for the fictitious vice president I mentioned earlier in the paper. In this instance the creation of multimedia training is directly related to whim of the boss. In effect what I have described is a typical training session conducted by the vice president of manufacturing.

In reviewing the antics of our vice president, we see a reflection of the cog mentality. Specifically, the demand that training be developed so that “any idiot off the street can come in and build widgets”. This is a reflection of E. L. Doctorow’s description of Henry Ford’s production line where the production process was broken down into its “simplest steps so that so that any fool could perform them”. Mr. Doctorow is far more polite in his assessment than almost every manager I know who likes to paraphrase this statement. The tendency is to use the word “idiot” rather than “fool.”

The impact of breaking down the manufacturing process had the effect of further narrowing the scope to the technical training required for each position on the assembly line. It also facilitated the interchangeability of workers. With the work broken down so that “any idiot could do it” workers become a commodity. A company could specify the type of workers they needed much like the type of steel or screws. This development allows the development of formalized education in the trades. Here we begin to see broad use of text-based learning specifically for industry. Text based training was expanded considerably by the influence of the military during and after World War II.

The military established step by step procedures for almost everything imaginable. This style of procedure writing fit nicely into the industrial concept of workers as cogs and a division of processes into their simplest components. Until the decade of the 1980’s, industrial training primarily consisted of the following: Trade schools, which had replaced the apprentice / journeyman one-on-one training with a mixture of text-based and hands-on experience. Written process procedures, which were modeled after the style developed by the military. Verbal communication, which between workers and observation, informed the employee what was needed to maintain their employment.

In the decade of the 1980's and continuing today the disconnection between management and production and the metaphor of worker as a cog no longer serves industry as it did in the 30's, 40's and 50's. Global competitors who provided products of lower cost and higher quality forced industries to re-examine their operations and make changes or face extinction.

During the course of this re-examination, we can see what was going on by looking at popular management gurus. For brevity, I will mention only one to make my point. Tom Peters went looking for organizations that he deemed were excellent. His hope was to find a magic bullet for success. What he did uncover was the problem associated with the disconnection between production and management. In excellent organizations, production was in sync with the needs of the customer as opposed to the needs of their manager. In addition to knowing the mechanical aspects of their job, workers now needed to possess an understanding of the consumer. For the first time since the beginning of the industrial revolution, it became important that worker receive training so they could focus on the needs of their customer. The objective of this type of training stressed that customer could mean either the end consumer or the next manufacturing process.

A second realization of this forced re-examination was reformulating the role of quality control. To this point the function of Quality Control was basically to identify and remove defects from the assembly line. Here again, industry adopted the military's concept of Acceptable Quality Levels. AQLs, as they are called, take a statistical sample from a production lot. Based on the number of defects found in the sample you can determine the percentage of defects in the lot. The effective limit of this system of quality control delivers products with up to approximately 1% defects. In contrast, when we talk about a high quality product, it can generally be translated to a level of at least 100 to 200 defects per million. To put this in perspective, using AQL methodology, the best quality level you can reliably guarantee is 10,000 defects per million. As you can see, this is a substantial gap.

One might assume this dismal performance could be improved by substituting a 100% inspection of all products for the AQL sample. Unfortunately, if the inspection is done by humans the result is often equal to or worse than using an AQL sample. Even if the product lent itself to automated inspection to eliminate human errors, there is a significant cost attached to 100% inspection. You also have to factor in the cost of scrapping or reworking the defects that you find. Each scrapped product is directly subtracted from the company's bottom line, or passed on to the consumer. The market pressures, however, were demanding both high quality and low cost. This dictated a fundamental shift from inspecting for defects to process control.

Focusing on controlling the process attacked both the quality and cost problems by concentrating quality efforts toward preventing defects. Controlling the manufacturing process involves identifying the critical factors which determine if a product will be good or bad and controlling those factors so that only good parts are produced. A number of things become apparent as an engineer begins to take on this task. In my experience, the first thing found is that the machinery used in any problematic process is simply not capable of always producing a good product. It had been long assumed that machines were repeatable and accurate, therefore, any variation in product quality was due to the highly variable human component of the process. It was difficult for most managers to accept that this is not true. It can, however, be easily proven by performing an process capability study. Second, I found that assembly workers completely disregarded the military style written process instructions. When these process procedures were rigidly enforced the result was opposite of what you would expect. The number of defects increased and productivity decreased.

These two findings cast significant doubt on the concept of production worker as cogs in a machine. What emerges is a picture of production workers who possessed a great deal of practical knowledge about the process they were performing. They used this knowledge to modify the uses of the machinery in unique and personalized ways. These unique modifications were, not surprisingly, in sync with the verbal training they received which communicated "What do you need to do to keep your job". This is a far cry from the idea that machines turn workers into cogs.

I assert that it is more likely that management had a strong economic incentive to treat workers like cogs; in essence making workers a commodity. The goal was to increase the number of qualified applicants for any given position in a effort to control wages — simple supply and demand economics. Employees in turn faced economic pressure to play along and act the role of the cog. While it is true that workers were, and still are in some cases, treated like cogs and that they appear to act like cogs, I believe it foolhardy to believe that the illusion is real. Leaving the cog metaphor behind is critical to understanding what technical training in an industrial environment requires.

There are three main objectives for successful industrial technical training. One is along the lines of the old military style process procedures. This part of the training needs to provide instruction on the basic mechanics of the operation. How to turn things on and off, make adjustments, safety precautions and similar nuts and bolts information. The next two objectives utilize the adaptive process which occurs between human and machine. One objective consists of the process's theory of operation. This does not need to be communicated in highly technically terms but it does need to communicate the critical parameters and their effect on the process. The remaining objective communicates how to identify when the process is not running properly. This information is needed for the situations where all the indications show that the process is in control, but the result is not within specification. Overall, this type of training gives a production operator the tools they need to effectively operate and control the process they have been assigned.

The drive to achieve control over the manufacturing process and the high interest rates of the 1980s also had a impact on the type of machines that were installed on the manufacturing floor. Hopefully, I have established that the market forces which demanded higher quality and lower prices resulted in process capability studies. These studies identified the critical parameters which needed to be controlled in order to produce good product. Actually maintaining those parameters became somewhat of a problem. For example, let's say that process X has 4 critical parameters: two are temperature readings, one is conveyor speed and the fourth is air flow. All four of these parameters are displayed on a control panel. We assign the task of monitoring these parameters to a machine operator and find that we are still creating more defects than had been projected.

Further analysis shows that from time to time one or more of the critical parameters goes out of specification for a short period of time. This means that the machine operator is not constantly watching all of the indicators all of the time. This is to be expected, because a human is not particularly well suited to constantly monitor gauges over an extended period of time. On the other hand, it is a task that is particularly well suited to a machine. To address this problem, the task of monitoring gauges and tweaking knobs has been turned over to PLCs. (Programmable Logic Controllers - An industrial computer)

High interest rates created an economic incentive to reduce inventory in all areas of manufacturing. Of primary interest is the reduction of WIP (Work In Process). The biggest factor controlling WIP is the time between manufacturing operations. To reduce the time between operations, the layout of the plant floor was often changed so that work in process inventory was staged more efficiently, but more significantly, several operations were often merged into one machine. What emerged from this trend is the combination of previously separate operations. These combined operations are controlled by a PLC which monitors the critical parameters of the manufacturing process.

There are two other factors which I should mention briefly. The life of products in the marketplace has, in general, gotten shorter. This is probably most evident in the computer industry where new models have a life of less than one year. This means that the production line must be highly adaptive. There is also a demand in the market for individualized products. For example, you can purchase a computer from Gateway configured to your exact needs. In order to be competitive in this environment, the manufacturing operation must be able to produce one of a kind products as efficiently as it produces 100 or 1000. This can only be achieved if machine setup time between differing models is very short. This is achieved by a combination of product and manufacturing design.

What I am attempting to describe are the various forces which have reversed the concept of breaking down manufacturing into its simplest components. The role of the industrial computer is to take over the tasks of monitoring the process, a boring repetitive task that is not really suited to humans. I have outlined the market pressures to increase product quality, reduce inventory, lower product costs and economically build customized products.

The role of people in the manufacturing operation has shifted from being merely cogs in the machinery to highly adaptive troubleshooting, machine set up and maintenance. As a result, industrial training must give machine operators the information they need to perform these tasks. Specifically, training should include the following:

- The underlying principles of the manufacturing operation(s).
- How to identify when the process is not running correctly.
- How to correct for deviations in the process.
- How to configure the process to meet the needs of differing product models.
- How to setup, run and maintain the machinery.

Of these five requirements, only the last one is covered by the conventional process procedure. Identifying when the process was not running correctly was previously the job of quality control. Configuring the process for new production, and understanding the principles of operation was usually assigned to process engineering. By dropping the metaphor of the industrial worker as a cog in the machine, we see that it possible, even necessary, to combine operations and expand the scope of industrial training in order to remain competitive in today's marketplace.

Now I would like to turn my attention to how industrial training occurs. Again I would like to take a historical perspective of technology and implementation. As previously noted, a great deal of industrial training takes place on an informal one-to-one basis. Much of this training is not sanctioned or even understood by management. More formal training was originally created on the typewriter — simplified step-by-step procedures for each process. These procedures, unfortunately, were and are of minor consequence. This can be demonstrated by manufacturing operations that function effectively with no procedures at all. Even facilities that do have these type of procedures find that they gather dust in some corner of the shop floor.

A more effective use of the resources stated above, is to formalize the one-to-one training process. This is actually quite practical because it is most often the case that only one person, usually someone new to the area, needs training at any particular time. It can be assumed that any industrial training program must work effectively with just one student. What is needed, therefore, is a training manual with two functions. The first is to act as instructional guide for the trainer. It should contain all of the information that the trainee should know to properly carry out their job. Secondly, the training manual should act as a reference for trainee if they have questions or need to know some specific information.

The typewriter, copy correction fluid and a copier provided the basic means for generating and modifying these training manuals. It should be noted that these manuals need to be updated on a regular basis as manufacturing processes change or new products are introduced. This means that in order to maintain the effectiveness of the training manuals they must be easily created and updated. The introduction of stand alone word processors made this process easier to accomplish.

Using word processor technology created training manuals which were primarily text based. Illustrations, of course, were possible, if hand drawn, but they were not easy to produce or modify. This created significant errors in interpretation, especially in cases where information was basically visual in nature, or a technique. One example might be as follows:

"Apply a .150" bead of glue to the outside edge of the lens. You need to apply enough glue so the lens is held in place but not so much that it will ooze into the lens area."
In this example, it is really up to the trainer to demonstrate the proper technique for gluing in the lens. The trainee then performs the task and receives feedback from the trainer until the trainee is able to perform the task properly.

This particular example underscores the need to provide training for the trainer. The trainer must be able to present the material in the training manual in a way that is effective for the person being trained. Furthermore, they also need to have the skills to provide effective feedback to the trainee. This example also demonstrates the primary weakness of text-only training manuals particularly, when it comes to visual criteria. The problem is with interpretation of the instructions. Just how much glue is a bead of .150"? Must it be round or can it be flat? Also, how much ooze is too much ooze?

In 1984 Apple computer introduced the Macintosh computer along with the programs MacPaint and MacWrite. The combination of these three tools allowed the inclusion of illustrations into training manuals. It is important to understand what about these three products made this possible. First the equipment needed was affordable; the entire setup cost under $4,000. It allowed illustrations to be easily created and modified. Finally, it allowed those illustrations to be incorporated into a word-processing document. From this analysis we can begin to establish at what point a particular technology becomes feasible for industrial training. First, the equipment must be affordable. Second, the system must allow the quick creation and modification of the training medium. Third, it must be consistent with the five objectives for industrial training which I outlined earlier in this paper:

- The underlying principles of the manufacturing operation(s).
- How to identify when the process is not running correctly.

- How to correct for deviations in the process.
- How to configure the process to meet the needs of differing product models.
- How to setup, run and maintain the machinery.

When flatbed scanners and laser and inkjet printers became affordable, photographs could also be incorporated with illustrations and text. The inclusion of photographs and illustrations made it much easier to create a training document which was able to convey the principles of operation, identifying problems with the process as well as reducing the errors in interpretation common to text-only processes.

As good as these documents had become, training still depended upon the presentation of the trainer. As noted earlier, these people are (hopefully) given some type of “train the trainer” training. In an industrial setting, trainers are usually the most experienced process operators. Depending on the skill level of the trainer and time constraints due to production schedules, there is often a great deal of variation in length and depth of training from person to person. This variation can be reduced by creating a training check list. The check list operates as a mechanism to make sure that the trainer has covered all of the material and that trainee is able to perform the tasks required by the job. Yet it would be better if presentation of the training material could be standardized. At least in principal, multi-media could standardize the presentation process.

A standardized presentation makes sure that each trainee receives the same training. While this is desirable, it does have its drawbacks. In a one-on-one presentation, the trainer receives feedback from the trainee. If the trainer is sufficiently skilled, they use that feedback to modify the presentation to make sure that trainee understands the material.

If the goal of multimedia training is to replace the trainer, then we must include a mechanism to insure that the trainee understands the material. To replace the trainer, the multimedia presentation have both content and a feedback mechanism. If the goal of multimedia training is to replace or augment the paper based training manuals, then all we are concerned with is the effective delivery of content. Replace the trainer, or replace/augment the paper manual? Since this is an important distinction, I will evaluate each objective separately.

I have already established that the integration of text, illustrations, and photographs are technologically feasible for use in industrial training. The equipment needed for their use is available and relatively inexpensive. The combination of hardware and software makes training development reasonably easy to create and modify. The creation of training content accounts for the majority of the development time. In order to determine if training with multimedia technology is feasible, we need to evaluate the use of remaining multimedia components: audio, video, and animation.

The capability to inexpensively digitize audio has been available since about 1992 with the introduction of the Quadra 610 AV Macintosh. Currently, it is available on virtually all Apple computers and most PCs with a sound card. The hardware is generally capable of CD sound quality (16 bit 44.1 KHz sample rate). There are a number of editing programs available, the most popular being Sound Edit 16. Stock music is readily available in CD format. A second option is to generate your own music using a MIDI program and MIDI controller. Each of these components cost under $500 and are reasonably easy to use. The output is of good quality and modification is reasonably easy. It would seem that the audio component of multimedia is feasible for use in industrial training.

Unlike audio, video exists in a variety of formats both analog (video tape) and digital. Digital video standards are few and far between, and the visual quality varies greatly. At the risk of offending videophiles everywhere I will attempt to simplify the current state of digital technology as it relates to its industrial training application. Using a standard VHS tape as a quality standard, the video component of a multimedia presentation would have to be 200 to 250 lines of resolution on a television monitor or 640 by 480 pixels on a computer monitor. The frame rate should be 30 frames per second. This is often called full screen full motion video.

Full screen full motion video represents 600,000 bytes of information per frame. This translates to 18 Megabytes per second. At this rate, a 1 Gigabyte hard drive could only hold 55 seconds of video. This means that in order to digitize video economically, a method of compression must be used. Only one commercially available compression scheme is able to provide enough compression so that a useable amount of video can be stored on a DVD ROM; MPEG2.

Using commercially available equipment, this is what you would have to do to produce video into CD ROM multimedia. Shoot the video, typically storing the image in an analog (tape) format. Digitize the video in a JPEG format and edit the scenes as needed. Digitizing can be avoiding if the video is shot using a DV format. The digital footage is downloaded directly into the computer. Editing however is still needed and should not be minimized as a cost factor.

Once edited the finished video is run through an MPEG decoder. The currently the approximate minimum price for all this equipment is $30,000. Most of this cost is the MPEG encoder. Once the video is in the MPEG format it is nearly impossible to edit. In addition creating DVD ROM is full of arcane details". It would seem that the process of utilizing current MPEG 2 and DVD ROM technology to incorporate video into a multimedia presentation requires a substantial amount of development time. In addition, the final MPEG format does not allow for easy modification. As a result I would have to conclude that the use of MPEG 2 and current DVD ROM technology is not feasible at this time for industrial training.

Given the low cost of hard drives and the availbility of the DV format MPEG encoding and DVD may be eliminated altogether. This would be a substatial cost saving. An other cost saving option is a VHS player. The drawback, however, is that a typical VHS player does not allow for interaction. Interaction is possible, however, using a player with a low speed interface, the use of timecode and letting the computer queue up the appropriate video clip. The response time for this system would be slow. A second option would be to have each training system DV capable. This would be feasible as current off the shelf Apple computer have this capability built in.

It would seem that we can reasonably create, store and display video, audio, text, illustrations, photographs and simple animations. Then we are faced with the problem of how to present this material. This, by necessity, gets us into computer programming.

Multimedia programming is generally called authoring, yet I think for my purposes it is best to call it programming because the person who does the authoring needs to understand some basic programming concepts. These concepts include the use of logical statements, subroutines, and sequence of operations. The rest, and excuse me for being so simplistic, is just a matter of learning how to communicate what you want in a language that a computer can understand. There are three main types of authoring languages, card based, icon based and time based. Popular programs that represent these languages are Astound and Hypercard, IconAuthor and Authorware and Macromedia Director. Of these the card based tools, Astound and Hypercard card are the easiest to program. The time based Macromedia Director, by most accounts, is the most difficult. This is not meant to be a discussion of feature and pros and cons it is just an acknowledgment that suitable programming tools are currently available for use in creating interactive multimedia.

The more pressing question is one that I raised earlier; what should this technology accomplish? Do we want multimedia training to replace the trainer, or should multimedia training replace or augment the paper based training manuals that are an aid to a trainer? In effect, we must first decide what we want the program to do before we start the process of evaluating a tool. Further, it should be emphasized that unlike an academic setting, which assumes that a certain percentage will quit or fail, industrial training must result in the understanding of the material by all of the people who are to be trained. The end goal is to produce a quality product at low cost. To this end, industry cannot afford to have unqualified operators.

If the goal of multimedia training is to replace the trainer, then the program must be capable of determining if the trainee understands the material. If the program detects that the person being trained doesn't understand the material, it must be able to present the material in such a way that understanding is achieved. This is no small programming task, yet it is possible if the programmer has enough training experience to anticipate the areas where understanding maybe problematic and generate alternative presentation techniques.

A greater difficulty exists when we ask a program to evaluate the trainee's performance of specific tasks. Earlier, I used the example of gluing a lens as an example of a task which required a specific technique. To this, you could add common manufacturing processes like making a solder connection or performing a visual inspection. The common thread in all of these tasks is that the computer would have to interpret data that is difficult to digitize. To computerize the inspection of a solder connection, for example, you need to heat the solder with a laser then record the thermal decay profile and compare it to a known good reading. Given that ease of creation and modification are essential to making a technology feasible in an industrial setting, I would have to conclude that interactive multimedia is not feasible if the goal is to replace the trainer.

Turning our attention to multimedia as tool for the trainer to aid in the training process, we find that the goal of a multimedia presentation is essentially the same as it is for a paper based training manual. The multimedia presentation has the additional benefit of overcoming language and reading barriers. In situations where a trainee's reading ability or English language skills are poor, the audio capability of CD ROM based multimedia provides a superior solution. The interactive aspect of the presentation could be programmed so that specific information could be referenced easily, much like dividing information into chapters and subheadings. Given this capability, it is feasible to replace a paper based training manual with an interactive multimedia presentation.

Although it is feasible to utilize interactive multimedia in an industrial setting, the technology currently lacks the ability to incorporate video into the presentation. This is serious drawback in situations where the consistent demonstration of technique is important. In these cases, the use of a desktop video system a VCR and a television may prove to be a superior option. Further, unless there is a compelling need to incorporate audio into the presentation, the added expense of computer training stations compared to paper based manuals may not be justified.

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