

INTEGRATING WORLD CLASS MANUFACTURING PRINCIPLES INTO VE FOR THE PROCESS INDUSTRY

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ABSTRACT

To help their manufacturing clients, VE must identify and evaluate process design alternatives that not only satisfy the functions related to "Make Product", but when implemented result in a competitive world class manufacturing process. This paper describes for Value Engineers the key functions of world class manufacturing and the metrics used to quantify world class performance, along with a strategy for their integration into the VE Job Plan.

- increase their flexibility in responding to market needs for existing and new products
- reduce their operating cost and total investment
- become profitable at any production volume.

In terms of the Value equation, WCM Value equals Performance divided by Cost, where Performance is a function of Response Time, Quality, and Flexibility, and where cost is a function of Operating, Investment and Inventory Costs.

Therefore, to provide value to the customer, manufacturers must excel by both improving performance and reducing cost. They must conceive, design, build, and operate plants that have world class performance, and yet are cost-competitive from an investment, operating, maintenance, and environmental standpoint. If they focus solely on the traditional approach of identifying the lowest cost plant design to satisfy the functions related to "make product", they can get an inexpensive plant; however, it might not be competitive from a world class performance level. A well-balanced emphasis must be placed on both cost and performance in the determination of value.

INTRODUCTION

To become a leader in World Class Manufacturing (WCM), a company must be able to anticipate the acceleration of change in the marketplace, and meet customer needs before--and more cost effectively--than the competition. Strategies based on economies of scale are no longer sufficient to insure profitability. Manufacturing companies must design world class performance into their plants so that they can:

- succeed at managing a complex product line with exacting quality standards

For VE Consultants to properly satisfy their manufacturing clients, they must improve their

knowledge and skills in applying WCM concepts and principles. They must also help generate and evaluate alternatives which will enable the attainment of WCM behavior. Such capability will help VE Consultants understand the needs, goals, and language of manufacturing so that they will better relate to--and satisfy--their manufacturing clients.

WCM DEFINITION AND METRICS

WCM is a set of techniques and concepts for improving quality, cost, response time and flexibility.' There are several key functions or principles that a VE team can apply during project concept definition which will help result in a world-class facility. These are:

- Eliminate or reduce activities and investment that do not add value from the customer's perspective, and simplify those that do add value.
- Build the "right factory", not just a copy of an existing factory. Old designs may not yield facilities that are competitive today.
- Strive to reduce the manufacturing cycle time from receipt of raw materials to production and storage of finished products.
- Reduce the impact (e.g., time and quality) of transitioning between different products.
- Eliminate variations in product flow paths. Don't pursue flexibility for its own sake. Learn to group families of products on certain production lines. And don't allow flexibility to cover up potential equipment failures--use predictive/preventive maintenance techniques.
- Reduce variations in the process. Provide better process control schemes so that products are made correctly the first time.
- Produce only enough to satisfy demand. Inventory can be an enemy because it incurs costs for storage, tracking, capital, etc. The alternative to inventory is better forecasting and the ability to make products just-in-time.
- Eliminate all waste. Waste includes capital, process waste, energy, environmental waste, and time spent working on things that should not be worked on.

Six measurement standards, known as the WCM

Metrics, can be used to measure the degree to which a manufacturing process adheres to these principles. A company can thus use these WCM Metrics to benchmark its performance:

- Manufacturing Cycle Time: The time a product is in the process, beginning when material is introduced to the first process step, and ending when the finished product leaves the process.
- Process Capability: The ability of the process to make product on aim and within customer specifications.
- First-Pass, First-Quality Yield: Percent of raw material that ends up as first quality product without blending, recycling, or rework.
- Uptime: The equivalent amount of time a process can operate at its demonstrated capacity while making first-quality product.
- Capacity Impact of Type Transitions: The additional percentage of first quality product that could be made if all product transition losses could be eliminated.
- Process Efficiency: Percentage of Manufacturing Cycle Time that a process is adding value.

WCM METRIC	TYPICAL TODAY	WCM TARGET
Manufacturing Cycle Time	31 days	1 day
Process Capability	1.00	2.00
First-Pass First-Quality Yield	80%	95%
Uptime	75%	95%
Capacity Impact of Type Transitions	15%	1%
Process Efficiency	1%	20%

Figure 1: WCM Metrics and their numeric values

Numeric values of these metrics for typical processes today and for WCM targets are shown in Figure 1.

APPLYING WCM PRINCIPLES

By helping manufacturing clients understand the needs of their customers, VE Consultants can assist manufacturers to identify which of their actions add value to their products. WCM focuses on identifying only those things that add value and on the importance of doing those things right every time. This frees our manufacturing clients of the waste, operating cost, investment, delay, inventory, and hazards of doing things that don't need to be done,

while still allowing them to satisfying their customers with their products. In short, VE must improve the value of the manufacturing process and facility under design by increasing the expected performance of the process while decreasing the anticipated investment and operating costs.

In particular, during execution of the VE Job Plan, the VE Consultant must focus on several issues, including: Value-adding activities vs. nonvalue-adding activities; "Straight-through" processing; and Process flexibility. These considerations help to identify and rank areas of the process needing improvement.

Value-Adding Activities

Definition: A manufacturing activity or function adds value to a product if its end result is an attribute for which the customer is willing to pay the manufacturer.

The idea behind this is that a manufacturing company does many things in the course of producing their products, but only some of these activities actually add value to the products from the customer's perspective. To test an activity against this definition, ask these questions:

- 1 If the manufacturer made (and sold) their product without doing this activity, would their customer expect to pay less for it?
 - 2 Would the customer pay to have this activity done if each preceding activity were correctly understood, controlled, and operated?
- If the answer is "no" to either question, then that activity is nonvalue-adding.

The activities performed in a typical chemical process are depicted in Figure 2, including blending, recycling, rework, installed spares, material handling, inspection, and inventory. *It's not the equipment that adds value: it's the activity or function performed by the equipment.*

However, only some of the activities actually add value to the product; i.e., the shaded ones being receiving materials, running the reaction, drying the product, compounding it, and delivering it. These activities are all value-adding because the manufacturer is paid by their customer to perform them. In fact, if the manufacturing company didn't perform one of these jobs, the customer would not pay them as much for the product, because the customer would have to do that job themselves, or pay someone else to do it. All of the other activities are classic examples of nonvalue-adding activities; they are performed because of the limitations of the manufacturer's systems and processes to make the right product, when they want to make it, the first time they try.

Other classic examples of nonvalue-adding activities are any tasks which are done and then undone, such as: dissolving then drying; packaging then re-opening; storing then retrieving; or solidifying then liquefying. Keep in mind a big trap: just because an activity is sophisticated, or artfully-performed, or even poorly understood, doesn't mean it adds value.

This thinking applies to all types of processes: discrete, batch, and continuous. The value-adding steps are only those that contribute directly to making product. All other steps are required because of inadequate understanding or control of the process. The ideal chemical/polymer process would react chemicals and then separate product from by-product. All other activities (such as hold-up, multiple separations, re-work, etc.) represent how the manufacturer deals with deviations from this ideal.

Although the customer may say "thank you" for performing the activity, or the manufacturer may feel good that they've done it, it doesn't necessarily represent value if the customer is not willing to pay for it. Likewise, just because the manufacturer has always done something a particular way doesn't mean they can't add equal value some other way. And finally--the biggest trap of all--just because an activity costs money to do doesn't mean that it adds value.

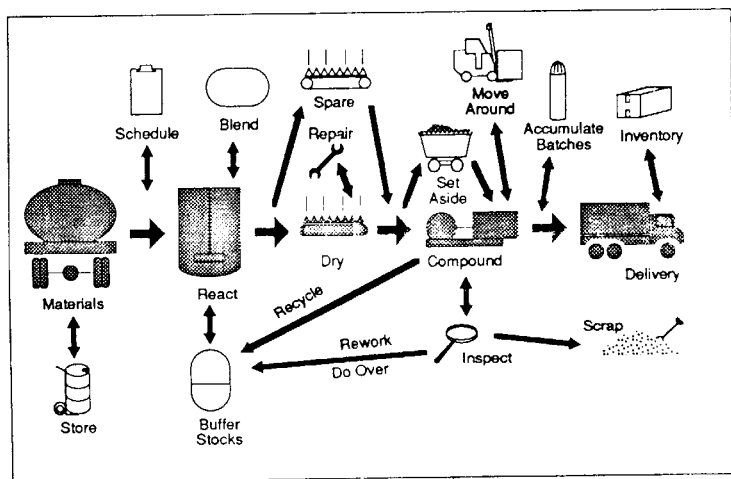


Figure 2: Value-adding and nonvalue-adding activities

Surely, understanding the function performed by an activity helps to identify and evaluate alternatives that cost less, i.e., which provide better value. Consider that the basic function of a pump between two tanks might be to "move liquid" through pipes from one tank to the other. It is possible to look for less expensive pumps and pipes. Another possibility is for one tank to be located above the other tank such that gravity could move the liquid between them. Another alternative would be to pressurize the first tank to force the liquid into the second tank. Yet another alternative would be triggered by identifying the "move liquid" function as a nonvalue-adding activity, and possibly reducing the manufacturing cycle time by eliminating the "move liquid" function altogether and searching for ways that the processing might be accomplished in one tank. This focus frees the VE team from concentrating on equipment type and allows them to look beyond the way things have always been done.

The idea to be promoted here is that a nonvalue-adding activity is not to be condemned or indicted or "ripped out of the process"; rather it should be a trigger during the VE Information/Function Phase for identifying alternatives to improve the manufacturing process.

Straight-Through Processing

During the Information/Function Phase, a process can also be analyzed to determine how much rework, recycling and in-process holdup affects the "cycle time" of the product--or how long it takes for the raw materials to be transformed into the final product ready for shipping.

to a longer cycle time for the product, and many of them represent a "hidden plant" of latent process capacity. A "straight-through" process would eliminate blending, rework, recycle, and in-process inventory to minimize cycle time and maximize the productivity of a manufacturing plant.

Process Flexibility

A process can also be analyzed for flexibility, e.g., the ability to switch from one product to another with minimal yield loss from transitions and start-ups. When many different products are being manufactured, a plant based on several very small lines can have the same effective capacity as a large single-line plant at a reduced life-cycle cost. This contradicts traditional notions of economies of scale. With multiple small lines, products having similar characteristics can be grouped together into families,

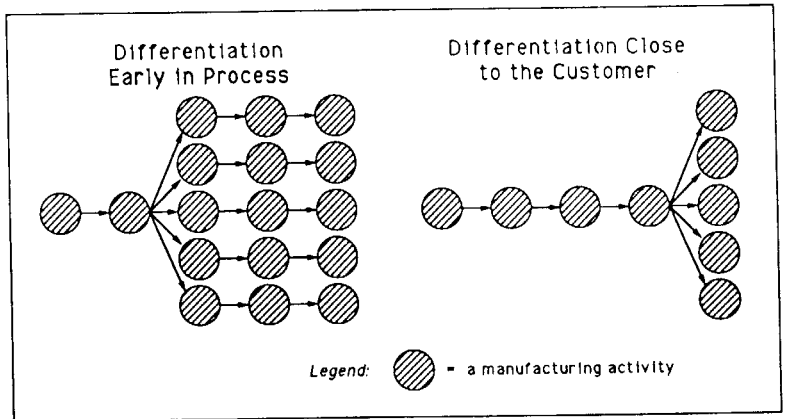


Figure 4: Product Differentiation and Product Flexibility to be manufactured separately on each line. This use of "group technology" reduces the impact of transitioning between products. Moreover, the multiple-line plant enables continued production even if one of the lines shuts down. With a single-line plant, nothing is produced during a shutdown.

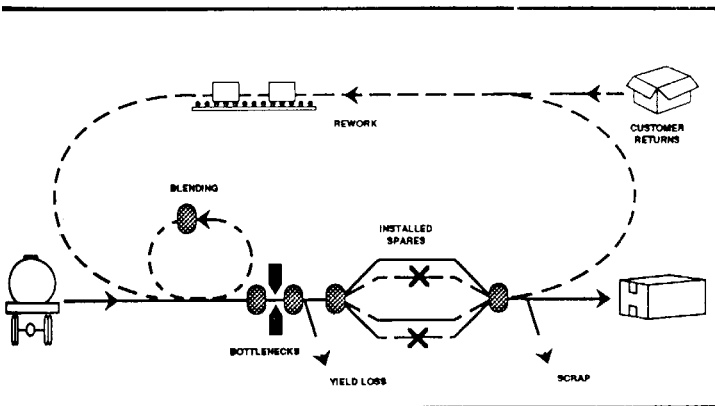


Figure 3: Unsimplified process and the "hidden plant"

Figure 3 shows a process that includes blending, rework, and attendant bottlenecks. All of these functions lead to in-process holdup, which contributes

An important key to process flexibility is differentiating the product as close as possible to the customer. That is, the manufacturing process should be shared on the same minimal set of equipment for all product varieties until the last possible step. This concept, illustrated in Figure 4, minimizes investment and reduces product variability. An example would be the manufacture of paint. Making a base paint of white and then adding color at the last possible moment (e.g., at the hardware store) permits a single manufacturing process to be used for making white paint. The undesirable alternative would be to have multiple production lines, each making a different color paint, with the colorant added early in the

paint. The undesirable alternative would be to have multiple production lines, each making a different color paint, with the colorant added early in the process (which is the way paint used to be manufactured).

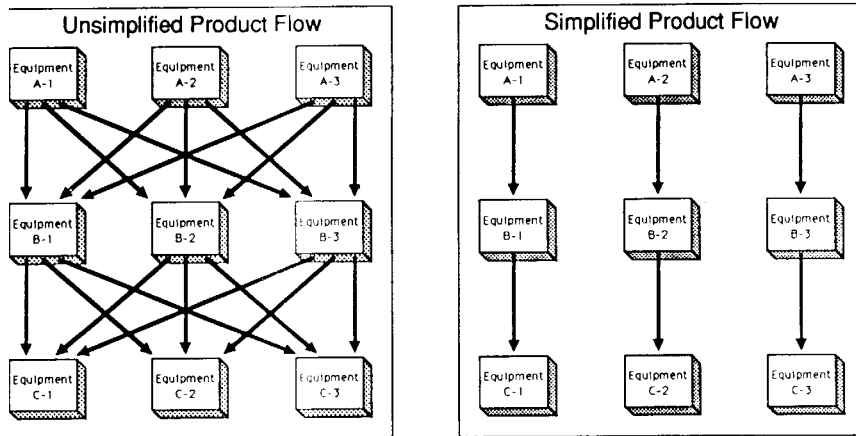


Figure 5: Product flow before and after simplification

Another flexibility issue concerns variations in product flow paths. Having too much flexibility in the process (e.g., multiple pipe-header or conveyor systems) complicates scheduling, maintenance, and control operations, and can require added investment. By using "group technology", machines and products can be grouped into families for consistent manufacturing and reduced product variability. This concept is illustrated in Figure 5. In addition, a maintenance excellence focus on uptime helps to keep the simplified product flow a reliable system.

BENEFITS OF INCORPORATING WCM PRINCIPLES INTO VE

So what exactly are the benefits of integrating WCM Principles into VE? These benefits include, but are not limited to:

- An Improved Focus to VE: It's not enough to look for the lowest cost alternative to perform the function. The VE Consultant should help the team search for the lowest cost alternative that also provides the best performance for the manufacturer to be competitive versus WCM standards.
- Improved Project Value: A WCM focus during VE tries to find the best value for a project or venture, i.e., the highest performance for the expected process at the lowest investment and operating cost.

- Reduced Permanent Investment: Equipment that is identified as inherently nonvalue-adding, such as blenders and material handling equipment, or equipment that adds value in an inefficient way, can be eliminated or reduced. Very often, a sizeable amount of stores, supplies, and spares back up a piece of installed equipment, and can be eliminated if the equipment is removed, resulting in a secondary benefit. Even where elimination is not an option, a WCM focus may make it possible to squeeze more product out of an investment. For example, additional investment may not be necessary for expansion of a simplified, more flexible operation because the extra equipment can be used to make more product. The equipment formerly needed to recycle off-spec product in a process that was not "straight-through" can be used to set up a second line or additional lines to handle small orders.

- Reduced Inventory (Working Capital): One of the most common benefits of a simplified manufacturing scheme such as a JIT/pull system is a substantial reduction in significant working capital items. These include raw material, semi-finished and finished product inventories as a result of reducing lot size, lead time, and process hold-up, and from installing multiple lines.

- Increased Yield: Overall yield from a process increases as losses are prevented by: eliminating nonvalue-adding steps such as blending, multiple passes, extra handling, and storage; and basing facility design and production scheduling on simulation modeling that maximizes flexibility and minimizes transition losses.

- Cost Savings: In addition to those already listed, cost savings can be expected: the cost of designing an inefficient or capital intensive process and facility; the cost of poor quality; the cost of multiple passes (recycle, rework, etc.); the cost of performing extra steps in the process (nonvalue-adding steps); the cost of owning and maintaining extra equipment; the cost of operating extra equipment when the same amount of product can be made with less equipment through improved efficiency; the cost of technical and other support groups reduced as a result of a simpler process with fewer steps; and other costs of supporting people or investment.

- Increased Productivity: Through simplification, VE can identify activities and equipment that are not needed by our manufacturing clients to make their products. Consequently, our clients can apply their resources to more profitable pursuits.

- Incremental Capacity: When market forecasts indicate a need for an incremental capacity increase, simplification frequently identifies an attractive alternative to new investment. The value adding perspective helps pinpoint latent processing capacity and human resources. In essence, simplification reveals the existence of a "hidden plant" that can be used for substantial incremental capacity.

- Reduced Waste: This added perspective to VE will help eliminate: waste of people's time and talents; waste of materials (and the attendant costs of handling and disposal); waste of our client's capital; waste of process opportunity; waste of lost business and client's credibility.

STRATEGY FOR INTEGRATING WCM INTO THE VE JOB PLAN

Timing

The principles of WCM should be applied throughout the life cycle of the capital project. To facilitate the integration of these principles, VE should be conducted at least twice during the project. Its first use should be timed to coincide with the early stages of the project concept definition, when engineering rework can be minimized because VE will help to get the concept right from the start. It is at this point, when the design is less than 5% complete, that VE can help to improve the preliminary process diagrams. Early application of VE maximizes the potential savings in capital investment. Delaying this first use of VE until the process design is more articulated gives rise to time and emotional barriers which hinder re-engineering the process concept.

After VE is used the first time to help define "what" is the right process, VE should be applied a second time--usually around 25% design complete--to examine in more detail the equipment, hardware, materials of construction, facility layout, equipment arrangement, product flow and material handling, information flows, and life cycle costs.

Team Membership

To incorporate WCM principles, the typical VE

Team would include--but not be limited to--some mix of the following people: conceptual engineers; scientists; technology specialists; production operators; maintenance personnel; marketing person; logistics person with knowledge of scheduling, ordering, shipping; R&D person; first-line supervisor; quality resource; cycle time specialist; and supplier/user organization representative.

Structure

The focus on WCM should occur through much of the VE Job Plan; however, it's strongest presence should be structured during the Information/Function and Speculation phases. And the Information/Function phase can be expanded to include several analyses which broaden the understanding of the performance aspects of the manufacturing process under review. Listed below are these analyses and what occurs in each:

- Metrics Analysis - Examine the WCM values versus their targets thus providing a snapshot of overall manufacturing performance and an indication of how much change is possible.

- Value-Adding Analysis - Identify the value-adding parts of a process.

- Transition/Flexibility Analysis - Explore whether a process can make a given mix of products and the impact of product transitions.

- Quality and Yield Analysis - Examine how well the process can make the right products correctly, the first time it tries.

- Inventory Analysis - Surface problems for which inventory is a symptom.

- Facility Analysis - Examine the competitive facility design and layout strategies.

- Equipment Analysis - Examine the suitability and reliability of process hardware.

- Environmental/Energy/Emissions Analysis - Examine issues around minimizing emissions and waste.

- Turndown Analysis - Explore whether the manufacturer can produce first-quality product at reduced rates during slack periods without shutdowns and startups.

- Cost/Time Analysis - Examine the rate at which cost is added to the process, which helps to prioritize the targets to simplify.

- Process Control Analysis - Examine the speed of process corrections from feedback control points.

Remember, the purpose of conducting these additional analyses is to broaden the VE team's understanding of the manufacturing process and thus make the Information/Function Phase more robust, and to help trigger ideas in the Speculation phase.

As for the Speculation phase, the VE Team aims to create process scenarios that yield the aspects of flexibility, response time, and quality as described earlier in this paper, and improve the process performance as identified by conducting the above analyses. A key activity which aids Speculation is Visioning, where the VE Team develops a plant concept of what's possible without any constraints; that is, a description of a future-state, "ideal", fully simplified, all value-adding manufacturing process. This Vision is used to help brainstorm alternatives. Interestingly, all alternatives generated during Speculation can be judged during the Evaluation Phase versus their ability to achieve the Vision (and improve the WCM metric values).

SUMMARY

The basis of VE is an understanding of "worth", where worth is the "minimum cost to perform the function". A focus on WCM helps to make more

robust the understanding not only of "function" but of "performance of function" with respect to the manufacturing industry. Thus, a well-balanced emphasis can be placed on both cost and performance in the determination of value. Simply put, a factory can be built very inexpensively and still "make product", but it won't be competitive from a world class performance level.

VE must increase its penetration of use within the manufacturing industry. Application of the concepts and principles presented in this paper will help VE Consultants improve their knowledge and skills so that they can successfully broaden VE's application base in that arena. It will also help them understand the needs, goals, and language of manufacturers so that they will better relate to potential manufacturing clients, from top management to workers on the factory floor. VE Consultants must understand how to generate and evaluate concepts which will enable the definition of WCM processes. This knowledge is useful in applying VE both: to capital projects for new factories; and to continuously improve the performance of existing manufacturing processes. Thus VE can help manufacturing companies reach their competitive goals.

REFERENCES

1 Schoenberger, Richard (1986) *WORLD CLASS MANUFACTURING*, New York: The Free Press