VITAL SIGNS OF MANUFACTURING COMPETIVENESS

12 Alternative Indicators of Performance Excellence

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SOS CONSULTING, LLC
Transforming Small-to-Medium Manufacturers to COMPETE in the Global Marketplace

VITAL SIGNS OF MANUFACTURING COMPETITIVENESS: 12 ADDITIONAL INDICATORS OF PERFORMANCE EXCELLENCE

Six Essentials

In the companion paper, “ Vital Signs of Manufacturing Competitiveness: 10 Indicators of Performance Excellence,” we introduced six essential elements to manufacturing competitiveness that leaders of small-to-medium manufacturers can use:

1) Cohesive leadership,
2) Strategic clarity
3) Communication
4) Process thinking
5) statistical thinking, and
6) Relationships.

We also introduced 10 indicators or “vital signs” of performance excellence that capture the essence of each essential and can be easily segregated by groups within the organization, products/services/value streams or customers to identify root cause(s) for taking action to improve productivity and profitability. An additional 12 indicators may be useful to identify the root cause(s) of poor performance and/or be more readily available, depending on the organization, its products/services, and industry.

The six essentials are depicted as a house and just like building a house requires all the right pieces to come together at the right time and place, the essentials are interdependent. See Figure 1 for a depiction:

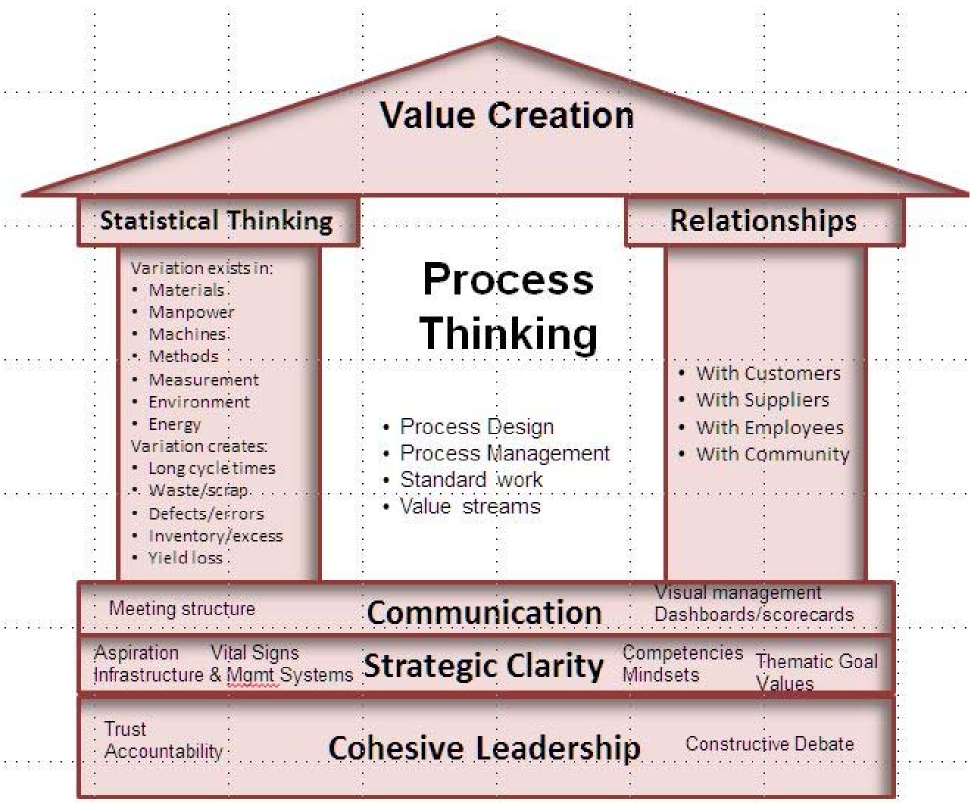

Figure1: Six Essentials Depicted as a House

Objective of the Essentials

What makes an organization successful for the long-term? Beyond profit, what drives longevity? Let's agree that a successful organization is one that provides **value** to its customers/ clients/ volunteers/ members/community. A manufacturing organization that provides value to its customers through its products and/or services will provide good living wages to its employees and shared value to the community over time. A hospital that heals and prevents disease (value) will transform the health of the local community through its care for community members. This is our objective, what we are aiming for; **value creation forms the roof our house.**

Why Vital Signs?

In medicine, the four vital signs of temperature, blood pressure, pulse, and respiratory rate are used to measure the body's basic functions to help assess the general health of a person.[1] Likewise, vital signs of the six essentials can be used to assess the general performance and profitability of a manufacturing organization.

We measure so that we can monitor, control, and improve performance of the essentials over time in order to achieve and sustain competitiveness. Without measurement, leaders have no basis for:

- Communicating performance expectations to the workforce;
- Identifying gaps in performance and prioritizing corrective action;
- Providing feedback to individuals and teams in the organization, including recognition; or
- Making decisions regarding resources, policies, schedules and infrastructure.[2]

Sound measures are indicators of the critical dimensions of the essential and answer the question "What indicator will tell us how well this essential is in place and contributing to our performance and profitability?" There are several indicators/metrics that could be used for each essential. We have selected one for each that captures the essence of the essential and can be easily segregated by groups within the organization, products/services/value streams or customers to identify root cause(s) of poor performance. Three vital signs are identified for Relationships. One for each critical relationship: customers, employees and community These 10 vital signs by essential are depicted in Table 1 and described in the companion paper, "Vital Signs of Manufacturing Competitiveness: 10 Indicators of Performance Excellence" (available by request. Good data (valid and reliable) may not be available for all of these vital signs, or too time consuming, or may be too costly or expensive to obtain. Twelve alternative indicators may provide insights into the performance/health of the essentials; these indicators are described in this paper; see Table 1.

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[1] Vital Signs (Body Temperature, Pulse Rate, Respiration Rate, Blood Pressure), hopkinsmedicine.org, accessed 12/20/2016

[2] Rummler, Geary and Alan Brache. Improving Performance: How to Manage the White Space on the Organization Chart. San Fransico, CA: Jossey-Bass Publishers, 1990.

Table 1: Vital Signs for Six Essentials of Manufacturing Competitiveness

Essential	Vital Sign(s)	Alternative Vital Sign(s)
1) Cohesive Leadership	Team Diagnostic	-none-
2) Strategic Clarity	Alignment Diagnostic	Operational Discipline Assessment
3) Communication	Employee Survey	Digital Response Rates,
4) Process Thinking	On-Time-Delivery	Equipment Availability, Equipment Performance, and Inventory
5) Statistical Thinking	First-Pass-First-Quality Yield (FPFQY)	Capability & Performance Indices; Cost of Quality
Process AND Statistical Thinking	Overall Equipment Effectiveness (OEE)	Manufacturing Performance Index; and Asset Productivity
6) Relationships a. Customer b. Employees c. Suppliers d. Community	 Net Promoter Score; Days Away/Restricted or Job Transfer Rate (DART); Net Partner Score; Process Safety Incident Index	 Customer Satisfaction Survey Attendance Community Outreach Environmental Incident Rate

Essential 1: Team Diagnostic

Peter Lencioni in his book, *Overcoming the Five Dysfunctions of a Team: A Field Guide,* provides a simple ***team* diagnostic** tool in Section 4 that asks each leader on the leadership team to rate fifteen statements on a 1-3 scale (1=rarely; 2 = sometimes; 3 = usually) that once scored can be used to calculate a score for each of the five behaviors. See Appendix A. A score of 8 or 9 indicates that the behavior is probably not a problem for the team; a score of 6 or 7 indicates that the behavior could be a problem; and a score of 3 to 5 indicates that the behavior needs to be worked on. In our experience this simple assessment is sufficient to determine the cohesiveness of the leadership team; we have found no alternative to this vital sign. *Interviews with each leader and employee surveys may be used to understand the lack of cohesiveness and identify actions to improve.*

Essential 2: Operational Discipline

Operational Discipline is a measure of the deeply rooted dedication and commitment by every member of an organization to carry out each task, the right way, each time; it reflects the strength of an organization's culture in maintaining effective systems and providing tangible results. Without strategic clarity, people in the organization do not know the right way for each task. Therefore, operational discipline can provide insights into state of strategic clarity within an organization. Operational discipline is most often associated with safety. Diagnostic tools exist for safety that can be used to assess operational discipline.[3] The safety operational discipline tool we have found useful is presented in Appendix A. Three to five statements for each of four categories (leadership focus, employee involvement, practice consistent with procedures, and housekeeping as depicted in the Appendix) are rated on a 1 to 5 scale (not being done to excellent performance) and represented in a radar chart in which the higher scores are on the outside The higher the score for each element, the better. The balance in the scores for the four categories shows consistency in systems, but balance is not as important as in the Alignment Diagnostic. Figure 2 shows Operational Discipline scores for three manufacturing facilities within a packaging graphics business. Note one of the three facilities is lower on all four categories than the other two. This information is useful in identifying the dis-connects in the plant's management systems. In this case, the root cause was found to be conflicting messages between four employee unions and plant management.

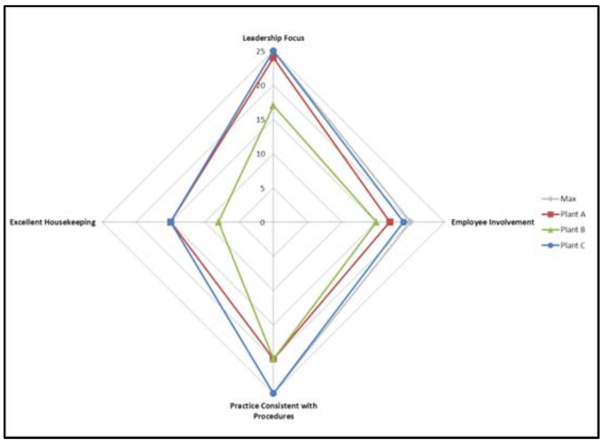

Figure 2: Sample Operational Discipline Radar Graph

Vital Sign for Communication: Digital Response Rates

Some approaches to measuring communication using digital communications technology include:

1) Employee awareness – use technology tools at your disposal to measure reach in different communication channels. For instance, how many employees open email communications, how many employees subscribe to the company blog, how many employees use the intranet site to search for company information/resources on a strategic initiative?
2) Employee engagement – if using a social collaboration tool, what is the total number of connections between people; If not using a social collaboration tool, how many likes, shares and comments are made to messages or blog posts?[4]

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[3] Klein, James A. and Bruce K. Vaughen, "A Revised Program for Operational Discipline," *Process Safety Progress*, Vol. 27, No. 1, March 2008.

[4] Mazour, Veronika, "How to Measure your internal Communications' Effectiveness? Exoplatform.com, December 16, 2015.

Essential 4, Process Thinking: Availability and Performance

As discussed in the companion paper, a manufacturing organization executing with process thinking, will have a flow of materials from suppliers to customers with little wasted time or materials as value is created. In order for this to consistently occur, equipment availability and performance must be high, Equipment availability (often known simply as Availability) is the percent of time the equipment is actually operating and creating value. Equipment performance (often known simply as Performance) is the percent of time the equipment is running at full speed. Equipment availability and performance calculations are shown below[5]:

$$\text{Availability} = \frac{(loading\ time - downtime)}{loading\ time} \text{x } 100$$

$$\text{Performance} = \frac{(theoretical\ cycle\ time - actual\ cycle\ time)}{operating\ time} \text{x } 100$$

Loading time = available time/day

Availability will identity and prioritize opportunities to improve flow and reduce waste caused by downtime (both unplanned and planned), set-up/adjustments, exchange of tooling, and administrative activities (morning planning meeting, paperwork). Performance will identify and prioritize opportunities to improve equipment maintenance and stability of the flow of the process; it is also useful information to identify improvements in product and process design.
Ideal conditions are:

- Availability greater than 90%
- Performance greater than 95%

The 2014 *Industry Week* best plants averaged 95.9% Availability as a percent of scheduled uptime.[6]

Essential 5, Statistical Thinking: Cost of Quality and Capability & Performance Indices

Cost of Quality (COQ) is the sum of all costs associated with internal and external failure costs as well as prevention and appraisal activities to prevent or ensure conformance of product to standards/requirements See Figure 3 for examples of each of these costs:

Theoretically, as prevention and appraisal costs increase, failure costs decrease. The minimum level of total quality costs is when quality of conformance is 100% (no defects). Many companies find that they are far from this optimum cost point. Prevention costs are often too low and both internal and external failure costs are too high. Larger investments in prevention costs drive savings in appraisal and failure costs. When confronted with mounting numbers of failures, organizations typically react by throwing more and more resources into inspection. But inspection is never completely effective, so appraisal costs stay high as long as the failure costs stay high. The only way out of the predicament is to establish the "right" amount of prevention. The “right” amount of prevention requires identifying and understanding

5 Nakajima, Seiichi. *TPM: Introduction to Total Productive Maintenance*. Cambridge, MA: Productivity Press, 1988.
6 *The Industry Week Best Plants 2014 Statistical Profile*, Industry Week, 2015

sources of variation in materials, equipment, methods and/or measurement and taking preventive action in design and planning to reduce, if not eliminate these sources of variation.

Prevention Costs:	Appraisal Costs:
• New product qualification • Quality planning • Supplier quality evaluation • Quality improvement projects (meetings, testing, etc.) • Quality education & training	• Incoming inspection/testing • In-process product testing • Final product testing • Product, process or service audits • Calibration of measuring equipment • Testing supplies and materials
Internal Failure Costs: • Scrap • Rework • Re-inspection • Material review • Downgrading product	**External Failure Costs:** • Responding to customer complaints • Customer returns • Warranty claims • Product recalls

Figure 3: Examples of Cost of Quality by Category

Quality costs vary widely depending on the complexity of the products and processes used in manufacturing the product(s). COQ can be as high as 15-25% of sales. Typical ratios for US companies are:

- Prevention Costs 0 – 5% of total costs
- Appraisal Costs 10-50% of total
- Internal Failure Costs 20-40% of total
- External Failure Costs 20-40% of total[7]

Costs outside these ranges indicate a need to reduce variation in design, materials, equipment, methods, and/or measurement and to examine prevention practices to accomplish the reduction. The 2014 *Industry Week* Best Plants had average warranty costs (external failure cost) of 0.23% of sales and scrap/rework costs (internal failure costs) of 0.2% of sales.[8]

Capability & Performance Indices[9]

To excel in today's business environment making product simply inside specifications is not good enough. Suppliers of consistent products/services with low variation that meet customer need are product leaders. When a manufacturing organization achieves product consistency (low variation) in all parts of their business, they are more productive.

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[7] *Certified Manager of Quality/Organizational Excellence Primer,7th Edition*, Quality Council of Indiana, 2013, p. VI-72.

[8] *The Industry Week Best Plants 2014 Statistical Profile*, Industry Week, 2015.

[9] Herman, John T., John E. Miler, and Susan O. Schall. *Measures for Continuous Quality Improvement Part I: Understanding Process Capability Indices and Related Measures*. DuPont Quality Management & Technology Center Accession Report #H-33295, Nov, 1991.

The process **capability index, C_p**, describes consistency of the product/service relative to customer's requirements for a particular product characteristic/feature.. C_p is the ratio of two ranges, calculated as:

$$C_p = \frac{Upper\ Specification\ Limit - Lower\ Specification\ Limit}{(6 * capabiliy\ standard\ deviation)} = \text{tolerance}/(6*\sigma_{ST})$$

Product specifications quantitatively define the customer's requirements. They include upper and lower specification limits which define the acceptable range. They may also include a target value, that is or is not in the middle of the specification range. Specifications are independent of the variation in the product/process. Voice of the customer (VOC) tools can be used to elicit and quantify the customer's needs if not specified directly by the customer.

The capability standard deviation is an efficient measure of the variability of a process in a "state-of-statistical-control." A process in a "state-of-statistical-control" results from using standard operating procedures, conditions, equipment and raw materials; there are no apparent "special" or assignable causes of variation that give rise to shift, trends, cycles, or changes in variation during the period of time observed. Alternatively, the capability standard deviation is calculated as the 'short-term" variability, where "short-term" is defined as within a subgroup or small sample of consecutively produced product.

Observations of product characteristic/feature values can be described in a frequency distribution or histogram in which the property value is on the horizontal axis and the corresponding frequency of values is on the vertical axis. Figure 4 shows a Normal distribution of product characteristic/feature values for a process in a "state-of-statistical-control." The average is the location of the center of the distribution and the standard deviation is the variability or spread of the distribution. The average and standard deviation are estimated values calculated based on a representative sample of the product.

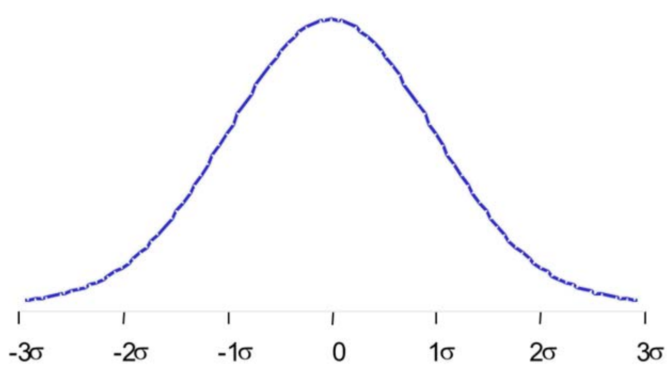

Figure4: Normal Distribution of Product Characteristic/Feature Values

Process capability is the range of three standard deviations on either side of the process average. For a Normal distribution, +/- 3 standard deviations around the average accounts for 99.73% of the distribution, making it a good representation of the total range of variation a customer can expect to see in the product characteristic/feature.

C_p can be thought of as the multiple of the process capability required to match the specification range. The larger the multiple, the better the capability of the process to produce product within the specification range, assuming no "long-term" variation. A process with C_p = 2.0 generates 3.4 defects (units outside specifications) per million units. This is commonly recognized as a "six sigma process."

Cp does not, however, take into account the process average; it assumes the process is running in the middle of the specification range. This can be far from reality; many processes operate closer to one specification limit than the other due to operational boundaries, cost, ease of equipment set-up or employee fear of producing product outside the limits. A second capability index, C_{pk}, considers how close the process average is to the center of the specification range. C_{pk} is defined as:

$$C_{pk} = \min \; \frac{Upper\ Specification\ Limit - Process\ Average}{(3 * capabiliy\ standard\ deviation)}; \frac{Process\ Average - Lower\ Specification\ Limit}{(3 * capability\ standard\ deviation)}$$

When the average is in the middle of the specification range, C_p will equal C_{pk}.

Process performance indices, Pp and Ppk are similarly defined. There is no requirement the process be in a "state-of-statistical -control." The total standard deviation or "long-term" standard deviation is used in place of the capability standard deviation. 6* total standard deviation defines total process performance. Process performance indices should be used whenever the process is not in a "state-of-statistical-control" or does not follow a Normal distribution.

The relationship between the indices is: $P_{pk} \leq P_p$; $C_{pk} \leq C_p$; $P_{pk} \leq C_p$.

Limitations of the indices include:

- Process must be in a "state-of-statistical-control" in order to calculate C_p and C_{pk} or estimate the capability standard deviation using "short-term" variability.
- The distribution of characteristic/feature values must be normally distributed in order to calculate C_p and C_{pk}.
- Measurement variability must be negligible. Otherwise, the capability standard deviation is inflated and incorrect conclusions may be made.
- ONLY specifications that reflect true customer requirements must be used.

The indices may be used for the following purposes:

- To assess capability to meet specifications.
- Compare performance to capability. Low performance indices may indicate special cause problems that need to be addressed.
- Monitor quality improvement over time. Upward trends in capability and performance indicate decreasing variability whereas downward trends indicate increasing variability.
- Guide quality improvement by identifying which product characteristics/features need improvement. As such, they can be used to prioritize improvement opportunities.

Process AND Statistical Thinking: Manufacturing Performance Index; Asset Productivity

OEE, a primary vital sign of process and statistical thinking, is not directly related to a manufacturer's profitability and can it be used to measure the performance of a factory consisting of multiple production lines. Rather, it is widely regarded as a problem-solving enabler for individual production lines. An easy to understand metric that defines factory performance as a ratio of actual production to the maximum production of the factory is the **Manufacturing Performance Index (MPI)**, calculated as:

$$\text{MPI} = \text{actual production/maximum production}$$

With knowledge of total manufacturing operating costs, actual annual production, cycle time per batch, number of scheduled shifts per day, number of hours per shift and number of scheduled working days per year, every percentage increase in MPI can be directly converted into profitability improvement. There are four potential sources of profitability improvement as MPI increases:

1. Lower unit cost of production - Increasing production while holding costs constant lowers the unit cost of production, resulting in more to the bottom line;
2. Reduce scrap - reductions in scrap caused by variability in machines, methods and materials will reduce costs and increase throughput;
3. Reduce overhead and labor costs - improved production allows the factory to better optimize the resources required for production;
4. Reduce planned capital investment - Increasing actual production allows a manufacturer to reconsider planned capital investment not only on a given production line, but the whole factory and manufacturing network[10]

MPI can easily be understood by all employees from the Boardroom to the shop floor and its correlation with profitability makes it easy to share with shareholders.

Another measure that incorporates both process and statistical thinking is **Asset Productivity.** Asset Productivity is a measure of a manufacturer's ability to productively use and manage resources to produce shareholder returns. It is often a criterion for determining if a manufacturer is a good investment (value creator). It is calculated as:

$$\text{Asset Productivity} = \frac{sales\ volume\ x\ selling\ price - expenses}{permanent\ investment + accounts\ receivable + invenories + prepaid\ expenses + other\ working\ capital}$$

Where: expenses = variable costs+ fixed costs + taxes

Sales volume is impacted by equipment performance, first pass yield, and on-time delivery; variable costs are impacted by first pass yield, and equipment availability; fixed costs are impacted by first pass yield; inventories are impacted by equipment availability and equipment performance – all vital signs associated with process and statistical thinking.

[10] Arni, Sudhir. "The Missing Link Between Manufacturing Data and Profitability, *Industry Week on-line*, March 31, 2017.

Relationships Vital Signs: Customer Satisfaction Survey, Attendance, Process Safety incident Index and Community Outreach

Once a customer problem has been reported, corrective action must begin immediately. To proactively understand customers' expectations and perceptions before a complaint, most manufacturers engage their customers to obtain feedback on products/services and the relationship. There are many instruments available to collect customer feedback. Surveys are the most common method; technology has made it relatively easy to ask customers questions about their experience with an organization's products/services. While research over the last two decades finds customer satisfaction surveys to be useless, information on customer expectations and perceptions can be gleaned from customer satisfaction surveys. Objectives of customer surveys vary; major themes include: define customer expectations, find out what competition is doing, identify factors that provide competitive edge, and identify product/service problems that require attention. The key is to use standardized questions so customer responses can be compared from one customer to another and over time. Another key is length. Long and complicated surveys yield low response rates and ambiguous results that are difficult to translate into operations improvements. 25-30 questions should be adequate to determine customer satisfaction, perceptions, and potential problems.

An indication of employee satisfaction is Attendance. An unhappy employee may find excuses not to go to work on all scheduled days and hours. An unhappy employee may also internalize the unhappiness which compromises their immune system and make them sick more frequently. An unsafe, poorly organized workplace, poor training, lack of opportunity/development or conflict with supervisor and/or peers may cause such unhappiness leading an employee to miss work frequently. Therefore, low attendance rates indicate low employee satisfaction. Segregation of attendance data by work area, team or supervisor, job type, shift and length of service combined with employee surveys and/or focus groups may unearth the causes(s) that can be removed or changed to improve employee satisfaction.

A manufacturer that seeks a good relationship with its community will do everything it can with the community to prevent safety & environmental incidents An environmental incident is a specific occurrence of pollution, contamination or degradation in the quality of the environment related to a specific event and of limited geographical scope. It does not cover general environmental risks unconnected with a specific event, such as climate change or atmospheric pollution. Incidents may be classified as minor, limited, serious, very serious or catastrophic.

$$\text{Environmental Incident Rate} = \frac{\textit{units of hazardous materials released to environment during specified period of time}}{\textit{total units of the material produced or handled for the same time period}}$$

Segmenting incident data by type, location, time of day, material, involved, employee work area and years of service may discover needed equipment, procedure, training and/or equipment improvements to prevent future incidents.

Measures of the relationship a manufacturer has with its community are 1) the number of community outreach events in which the company has participated and 2) total number of participants in each event. Participants may include a local emergency planning committee, municipal fire departments, law enforcement officials, emergency medical serves personnel, and/or emergency management agency staff. Such meetings promote good will with members of the community and the use of common EH&S tools and procedures throughout the community. Both measures are a part of the American Chemistry Council (ACC) Responsible Care® program reported quarterly.[11]

Ensuring Good Measurement

The manufacturing vital signs, like human health vital signs, are best when used to make decisions to take action. Several of the vital signs of competitiveness require data collection (most notably Availability, Performance, Asset Productivity, Attendance, and Environmental Incident Rate); the remaining involve subjective analysis using survey tools. A Gage R&R study is not required for data collection and evaluation if good measurement system practices are followed. In all cases, good measurement system practices should be applied, such as operational definitions, unbiased sampling, and reproducibility of measurement between two or more data collectors. Good operational definitions are needed to ensure consistent measurement and evaluation over time. Survey tools should be piloted/tested prior to use. Deriving insights from the vital signs can be disastrous without good data: leaders take action when they should not and do not take action or the right action when they should, so it is very important to get good, trustworthy data using good measurement practices.

Summary

This white paper has described the essentials and additional vital signs that may be found in world-class manufacturing organizations. Vital signs of the six essentials of manufacturing performance excellence can be used to assess the general competitiveness of a manufacturing organization and used to take action to improve productivity and profitability. Good measures/vital signs allow leaders to:

- communicate performance expectations to the workforce;
- identify gaps in performance and prioritize corrective action;
- provide feedback to individuals and teams in the organization, including recognition;
- make decisions regarding resources, policies, schedules and infrastructure, and
- identify the root cause(s) of poor performance.

10 primary vital signs are described in the companion white paper, "*Vital Signs of Manufacturing Competitiveness: 10 Indicators of Performance Excellence.*" Good data may not be available for all of 10 vital signs, or too time consuming, too costly or too expensive to obtain. Twelve alternative indicators may provide insights into the performance/fitness of the essentials; these 12 indicators were described in this paper.

[11] The American Chemistry Council. "Performance Measures Guidance Document For Responsible Care ® Partner Companies", 2010

Appendix
Operational Discipline Assessment[12]

Operational Discipline General Assessment - Organizational	Score
Leadership Focus - Leaders model the behavior they expect from others.	
Leaders visibly demonstrate personal priority for core values in their decisions	
Leaders clearly document, maintain up-to-date, and communicate goals, standards, and systems	
Leaders monitor performance via metrics, audits and personal involvement to drive continuous improvement	
Leaders provide sufficient and capable resources to sustain performance.	
Leaders develop and support processes to facilitate employee involvement and effective teams	
Practice Consistent with Procedures – Work is completed as planned, following authorized and current procedures.	
Procedures are documented and readily available for all appropriate activities.	
Clear expectations exist for following procedures and for not taking shortcuts.	
Procedures are periodically reviewed and authorized to keep them current, including employee participation.	
All changes, tests, and deviations are reviewed and authorized before use.	
Training and field audits are conducted to ensure procedures are understood and followed.	
Employee Involvement – Employees are active and enthusiastic about participating in improvement activities	
Employees know and share the organization's core values and goals.	
Employees volunteer and are active in improvement activities and teams.	
Employees provide feedback and suggestions for improvement.	
Employees show pride in being part of the organization.	
Excellent Housekeeping – Employees are proud of their workplace and maintain consistently high levels of housekeeping.	
Clear expectations are established for maintaining good housekeeping	
Standards for equipment and area housekeeping are documented and clearly communicated.	
Audits are conducted to monitor and help improve housekeeping.	

Score: 1= Not being done; 2= significant gaps in performance; 3 = opportunities to improve; 4 = minor opportunities to improve; 5 = excellent performance

[12] Klein, James A. and Bruce K. Vaughen, "A Revised Program for Operational Discipline," *Process Safety Progress*, Vol. 27, No. 1, March 2008.

For more information, visit the SOS consulting website at www.compete2execute.com and join our bi-weekly blog, Essentials at: http://eepurl.com/cuCNgL.

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