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Multivariate Analysis: Enabling the Next Killer Apps

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Summary

There are numerous applications and solutions available to manufacturing companies that help improve efficiency, lower costs, improve quality, and increase profitability. Of all the possible choices, one technology – Multivariate Analysis – is emerging that has the potential to dramatically augment the way companies operate by providing increased understanding and insight to manufacturing operations. Multivariate Analysis finds use as a continuous improvement tool, as an offline advisory decision support system, and as an online monitoring and prediction solution. In all cases, the benefits are undeniable. The technology is complementary to other techniques and solutions employed by most users, including advanced process control. This document provides a brief overview of the manufacturing operations space as related to Multivariate Analysis.

The pressure to improve manufacturing performance is intense. Manufacturers are finding it difficult to improve product quality and provide early detection of process upsets and shutdowns. Enhancing asset performance with the aid of a real-time process monitoring system can result in significant cost savings by providing early warning and diagnostic of process excursions and upsets as well as defining optimal operating regions.

Manufacturers Control Complex Processes and Make Complex Decisions Daily

Manufacturers use complex processes to make their products. As such, they must make complex decisions regarding which processes to use, how to best use them, and how to best control them in an ever changing world where satisfying demand requires balancing conflicting requirements of agility and efficiency. Some decisions, such as designing quality into the process, occur with low frequency and others, such as adjusting operating parameters, occur at high frequencies over short time intervals. Despite the

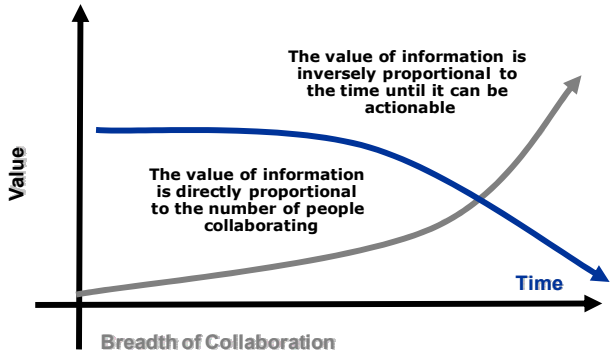
frequency, however, all of these decisions have a significant effect on profitability and require a thorough understanding among the relationship of many interacting variables to ensure an optimal outcome.

To facilitate the decision making process, manufacturers automate processes and rely upon a host of solutions and applications. In fact, a typical plant may have more than two-hundred applications. Some of these applications help organizations plan their activities while others help to execute those plans. Still others are used for assessing performance, providing insight and greater understanding, and making improvements. Despite all the applications and solutions employed by operations, most companies still struggle with making optimal decisions about how to best operate and control their processes – especially in real-time.

Multivariate Analysis is particularly well suited to address the growing need to extract meaningful information from complex data in an offline or online fashion. Multivariable Analysis can easily determine the magnitude of each contributing factor. It can also be used to determine the significant relationships that exist between variables, thus providing the insight and understanding companies need to improve their operations.

The Need for Speed, Agility, and Tight Process Control

Recent advances in technology are creating a new global playing field where information, knowledge, and resources are connected without regards to geographic boarders or political boundaries. Improvements in supply chain planning, management, and execution along with the Internet continue to make it easier to make, sell, and support products globally. Competition on a global basis presents new market opportunities, but also presents greater challenges. Customers demand greater product variety, improved responsiveness, along with products that satisfy local specifications and comply with regulatory requirements. Competing in this new arena requires lowering costs and improving operational efficiency, agility, responsiveness, and quality. Many companies are already using Multivariate Analysis successfully by monitoring processes to ensure products are made to tight quality specifications and to



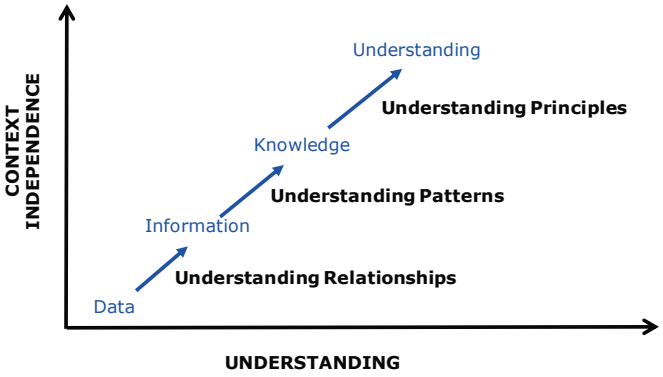
Value of Information

mitigate process upsets or faults. In addition, MVA provides the information necessary to make faster more knowledgeable decisions in a variety of areas that help improve efficiency and lower operating costs.

Too Much Data and Not Enough Information

Companies today continue to lose their most valuable asset – people – to retirement. The exodus of workers severely erodes a company's knowledge base and compromises their productivity if not duly compensated by other means.

Increasing competitive pressure is forcing enterprises to deploy their physical and human assets more effectively. The greater scrutiny of manufacturing operations leaves the smaller workforce with less time to collect data and make insightful analysis, and correspondingly good business decisions about operations. With less time for analysis, people must not only work harder, but also work smarter. Employees must have access to critical "on-demand" information to make better decisions to improve the bottom line.



Knowledge Is a Key Competitive Advantage

The key to success is not to generate and distribute more data, but to improve understanding of the data and distribute timely information that companies already have in numerous disparate applications scattered throughout their organization. It also means using embedded "intelligent" applications that interpret the data and take action. Solutions that provide manufacturing intelligence are a key element in the distribution and interpretation of information. Staying competitive means transforming all the data in the plant into information and making that information available in the proper context to all personnel involved in operations. It also means adopting methods to better monitor and control processes in real-time. People spend over half their time looking for and analyzing data to perform their jobs. This effort is wasteful and unproductive. In many cases, different people looking at the same multi-dimensional problem, will make the abstraction based upon their own biases and judgments and come up with different conclusions. Therefore, the abstraction

should be done automatically and explicitly. MVA is capable of greatly simplifying the analysis process while providing deeper insight and understanding of the data. In addition, real-time process monitoring using MVA has proven effective in prediction and dealing with critical conditions that lead to off-spec product or unscheduled downtime.

Disparate Plant Systems and Applications Hinder Performance

Most manufacturers acquire applications and solutions on an ad hoc project-by-project basis. This situation has left them with disparate systems and islands of information that make it difficult to get a real-time unified perspective on manufacturing operations.

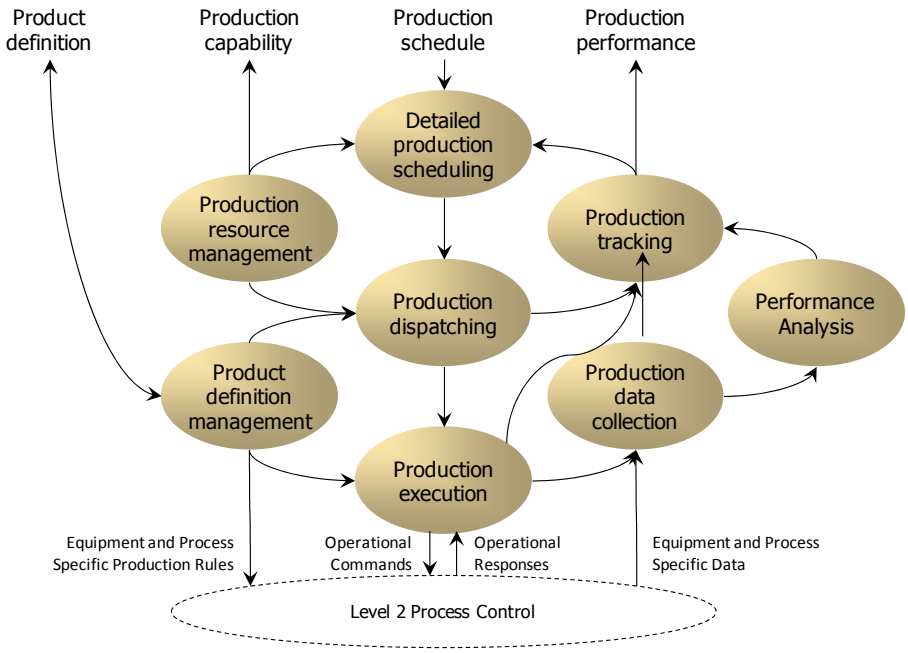
With the aging workforce and the loss of knowledge and production know-how, companies are looking for ways to simplify their manufacturing environments by reducing the number of applications it needs to support and by standardizing on applications across their enterprise. They also need to make a smaller workforce more productive. One of the stated top priorities for manufacturers is to increase manufacturing performance visibility. This is more difficult than it appears as the many non-integrated applications and systems hinder performance visibility. Consequently, users are focusing their efforts on solutions that automate production control and assist in making knowledgeable production decisions through improved performance visibility and manufacturing intelligence. Many companies today are focusing on aggregating and disseminating production data. This effort provides significant benefit, but it does not go far enough. Analytical methods, such as MVA are required to bring an additional level of intelligence to the data.

Making Sense out of the Manufacturing Application MES

As stated earlier, manufacturing operations use complex processes and make complex production decisions. They use a host of manufacturing or production applications that cover a broad range of functionality. There are many ways to classify these applications. One method is to use the ISA-95 standard, which categorizes information flows and major activities within the production environment. The major production activities include:

- Detailed Production Scheduling
- Production Resource Management

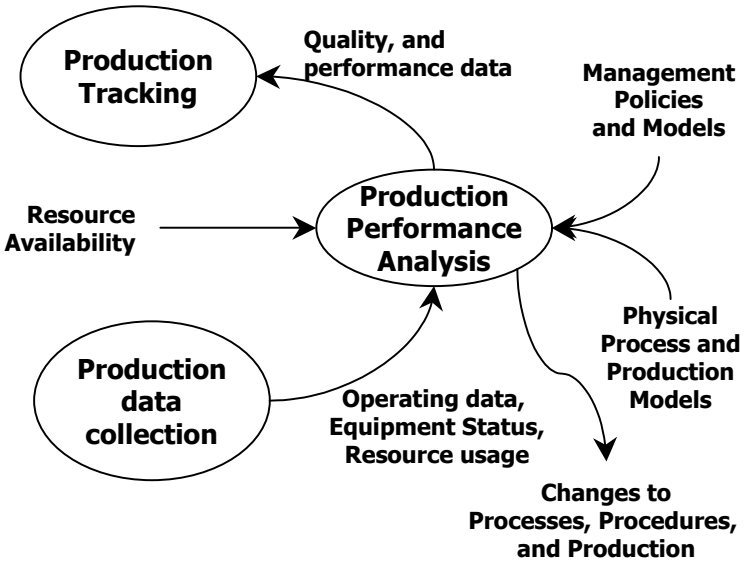
- Production Dispatching
- Product Definition Management
- Production Execution
- Production Data Collection
- Production Tracking
- Production Performance Analysis
- Maintenance Operations
- Quality Assurance Operations
- Inventory Operations
- Inventory Operations/Transfer Tracking
- Management of Security
- Management of Configuration
- Management of Documents
- Management of Regulatory Compliance



ISA 95.03 Manufacturing Operations Functions

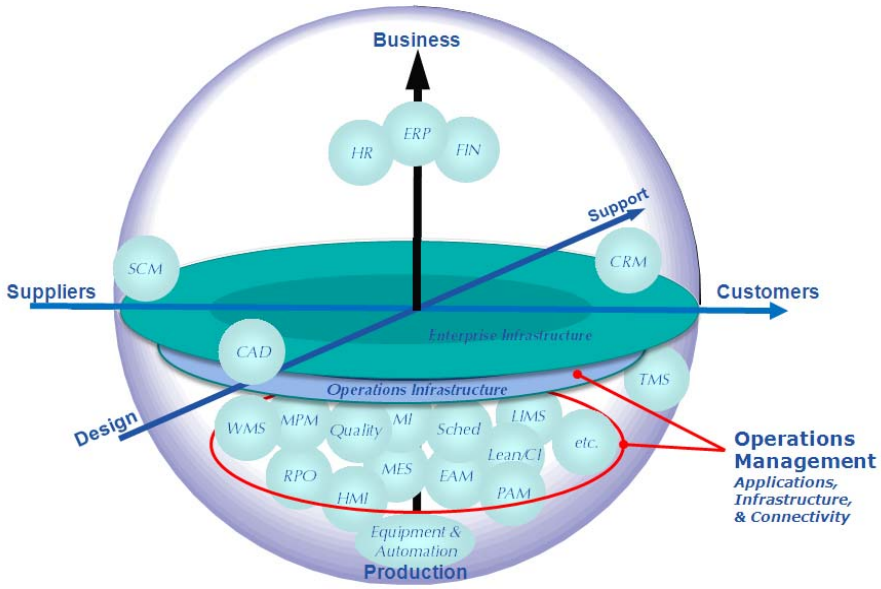
Many of these activities can be broken down further. For instance, Production Performance Analysis covers production unit cycle times, resource utilization, equipment utilization, procedure efficiencies, and production variability. The information is normally fed to other systems and used to optimize production and resources. Production performance analysis is a continuous process that requires reexamining policies as raw materials, equipment, process configurations, and business objectives change. Similarly, Production Execution can be broken down into several elements that include advanced monitoring and advanced process control.

ARC closely follows the production management application environment used by manufacturing operations. ARC expands upon the ISA- 95 standard by incorporating other functions and activities and by grouping similar functions in order to obtain greater insight into the production operations environment. ARC has created the Collaborative Manufacturing Management Model to help users extract greater value from their production assets. The model promotes greater collaboration and information sharing between people, organizations as well as applications.



Activity Model for Production Performance Analysis

The applications based upon Multivariate techniques fall into several categories within the Collaborative Manufacturing Management model. For instance, MVA, DOE (Design of Experiments), PAT (Process Analytical Technology), and online monitoring have are important components of Real-time Process Optimization ((RPO) and includes Advanced Process Control (APC)), Human Machine Interface (HMI), Plant Asset Management (PAM), Quality Control, Manufacturing Intelligence (MI), Manufacturing Execution Systems (MES), Continuous Improvement (CI), etc. MVA works with many other applications in this collaborative environment to provide valuable real-time monitoring capabilities and an additional level of understanding to many domains within the operations management space.



CMM Model Depicting the Relationship of OM and Other Applications

Benefits of Multivariate Analysis

Manufacturers in the process and hybrid industries are facing a major challenge to improve product quality and provide early detection of process deviations, excursions, and potential breakdowns. Preventable anomalous or atypical process conditions account for losses approaching 3% to 5% of a plant's total capacity each year. This translates into hundreds of thousands if not millions of dollars in lost revenue each year per plant. Losses accrue not only from reduced throughput from unplanned shutdowns, but also from off-spec production, equipment damage, reduction in asset availability, disruptions to schedules, safety hazards, and environmental remediation. Offline data analysis can help define optimal operating conditions. In addition, real-time process performance monitoring systems capable of predicting and preempting process excursions help to ensure safe and reliable operations while maintaining quality and profitability.

At the execution level, a real-time process performance monitoring system provides a standardized approach for performance feedback and control. For a process performance monitoring system to be effective, it must provide current performance information and analyses in a time frame that is consistent with the production cycle so that corrective actions can be taken to improve product quality, avoid process excursions, and enhance plant performance.

Plant automation and information systems collect, process, and store thousands of real-time measurements that provide the basis for real-time process performance monitoring. It is possible to use this data to determine a region of optimal performance and to maintain operations within this region through diligent process monitoring and control.

Multivariate Analysis provides many benefits to users in all industries. The pharmaceutical industry is already embracing Multivariate Analysis as a means to help achieve its Process Analytical Technologies (PAT) initiatives. PAT is a major component of the risk-based manufacturing approach promulgated by the FDA in order to encourage pharmaceutical companies to adopt the latest manufacturing techniques and practices. Multivariate Analysis is well suited for designing quality into the process using DOE and monitoring the process by making timely measurements of critical quality parameters during processing to assure acceptable end product quality at the completion of the process.

Other industries have achieved significant benefits using both offline and online Multivariate Analysis techniques. Still, the adoption level is not at the level commensurate with the benefits. One of the biggest misconceptions is that multivariate analysis is superfluous because many manufacturers already use APC. The two technologies are not mutually exclusive. While it is true that APC improves process stability and throughput, it does not have early fault detection capability or the ability to aid in root cause analysis and continuous process improvements.

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Multivariate Data Analysis (MVA) techniques, such as Principle Component Analysis (PCA) and Partial Least Squares (PLS), are better suited to provide early indications of conditions that lead to impending faults and to determine the root cause of problems. In manufacturing operations, there are typically many variables that together determine the final product results. In most situation, these variables are not independent of each other. Since the manufacturing process is not driven by the number of arbitrarily measured variables, but by the underlying process itself, the relationship between each variable must be taken into account using Multivariable Data Analysis. A key feature of PCA is its ability to model a process or a quality data set with a smaller, simplified set of

variables. Using available process data, a control region can be created representing the optimal run conditions. Real-time data is compared to this optimal control region to detect and predict potential faults. In addition, the decomposition of the PCA model is useful for providing process insight and determining the cause of a process upsets.

Multivariate Analysis tools are well beneficial for a wide range of plant personnel including operators. The value of Multivariate Analysis tools for operators cannot be understated. These front line workers are responsible for sustaining performance in the face of changing requirements, process disturbances, and equipment degradation. The fact that monitoring normal process data with traditional techniques provides little early warning of potential problems and the underlying causes, seriously threatens operational and business performance of manufacturing companies. These threats often go unnoticed while the process quietly progresses towards a critical condition because the cause is hidden by the relationship among a large number of variables.

Multivariate Analysis is not only a powerful tool for operators, but also for engineers and maintenance personnel. It provides engineers with a structured methodology to define normal operating ranges, perform detailed analysis of process faults, and establish a better understanding and interaction of complex process variables. Multivariate Analysis is also helping operations and maintenance personnel monitor the condition of important pieces of equipment that are difficult to interrogate by ordinary asset management techniques.

Conclusions

From ARC's perspective, process manufacturers' current challenge lies in improving Return on Assets. There is a large amount of unrealized performance remaining in manufacturing assets. Offline Multivariate Analysis tools and real-time process performance monitoring applications can help improve product quality, reduce costs, and increase productivity while helping to maintain the process in a safe state.

- Companies need to develop a strategic plan for the adoption and pervasive use of Multivariate Analysis tools. Organizations must consider using Multivariate Analysis applications where major process upsets have a detrimental effect on asset availability, schedules, and cost.

- Companies need to also identify which processes can benefit from having a more rigorous methodology for monitoring, controlling, and troubleshooting processes, both in advanced of upsets and afterwards to diagnose the problems.

- Organizations should consider using real-time measures of performance to make decisions about the process and provide the necessary tools down to the operational level where products are made and processes are adjusted.

This paper was written by ARC Advisory Group on behalf of Umetrics. The opinions and observations stated in the paper are ARC's. For further information or to provide feedback on this paper, please contact the author.