Advanced Analytics Excellence In Discrete Manufacturing

ARC White Paper
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This white paper explains how advanced analytics helps discrete manufacturing achieve operational excellence, details what the potential benefits are, what capabilities the organization should have, and how the organization can be aligned with this approach. It discusses what can be done to improve Overall Equipment Effectiveness (OEE) in relation to productivity, asset availability, and quality. The paper suggests several factors as a starting point for analysis and optimization. It explains why the organization not only needs to implement technology, but also adopt adjustments in its business processes and develop competencies. A comprehensive methodology is provided.

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CONTENTS

Executive Overview

Organizational goals can be achieved with **advanced analytics**. Understanding what is going on inside your plant can enable you to achieve any number of benefits, from being able to drive quality excellence in a discrete manufacturing operation, to outsmarting cost and price volatility, to optimizing production while complying with diverse regulations and requirements.

This white paper explains not only how **advanced analytics** helps achieve these goals, but also how to realize additional business benefits, define the necessary capabilities for proper implementation and align the people side of the organization. It discusses what different disciplines can do to improve productivity, asset availability and quality. But in order to realize the full benefits of advanced analytics, an organization should do more than simply implement this technology – it should adjust its business processes and develop competencies and new levels of collaboration. This white paper delivers a robust analytics methodology that takes into account all aspects of optimal implementation and how to adjust ongoing business processes and strategy to achieve continuous improvement in your plant.

*What differentiates **advanced analytics**? Most frequently used analytics show trending of single variables. This provides useful information and can alert operations to abnormal deviations. Status information derived from trends is often represented as "traffic lights."*
To realize next-level improvement, it is necessary to take multiple variables into account. This helps identifying which parameters, in order of importance, influence the production outcome, and how those parameters interact. Using machine learning can help identify hidden, complex relationships. After a multi-parameter analysis, a multi-parameter optimization must be done to determine optimal operation and its outcome. These are non-trivial, advanced capabilities.

Vision and Rationale

In recent years, varying events have created major disruptions in material and energy prices and significant fluctuations in demand. While companies are on a roller coaster, regulations have become more stringent and more diverse in different countries, adding to the complexity of the decision-making process, requiring almost day-by-day adaptations.

Humans may not be able to look beyond this complexity to make optimal decisions. Only advanced analytics takes all relevant parameters simultaneously into account and can propose the optimal choices in ever-changing circumstances. With this set of tools, leaders can be aware of the consequences of making a particular choice and make an educated decision.

Analytics can be seen as part of digital transformation and can contribute to a key performance indicator (KPI) in this domain. The purpose of applying analytics in manufacturing is to benefit business outcomes. Advanced analytics can contribute to both the measuring of success and providing the insights to help leaders meet key performance indicators (KPIs), such as turnover, efficiency, productivity, quality, growth, safety and sustainability. By analyzing their data to help drive decisions, especially as part of a digital transformation, many companies succeed in applying analytics effectively to optimize their business outcomes.

Build Capability for Maximum Benefits

To create an organization that can build, operate, maintain and support these analytics successfully, companies need:

- An organization aligned with optimized business processes.
- Analytics software/ platforms rooted in data science.
- IT and OT capability that provides a reliable stream and reservoir of quality data from IT applications, both business and operational; from OT, embedded in production and lab equipment; and IoT, from add-on sensors.
- Manufacturing domain expertise in operations, asset management and quality management to make sense of operations data, discern correlating variables and interpret analytics results.

Aligning the organization with optimized business processes implies that a fact- and data-based culture needs to be created with digitally literate personnel who have access to easy-to-use tools – ones that are responsive because the underlying infrastructure is appropriate – and the data they need to make decisions is available. The people making decisions, whether high-level and global or smaller in scope and regional, must be able to choose the right algorithms, evaluate the accuracy of their results, and understand the difference between causality and correlation. They may need training and support by data scientists for this. Another set of experts in the IT domain must install, administer, operate, and maintain software components in the cloud, on premises, at the edge or via a combination of those, depending on

the goal at hand. Finally, the organization needs the input of the domain experts who know which parameters are relevant for line operation, equipment reliability, or high quality.

Overall Equipment Effectiveness *is composed of:*
- the availability rate (A), or the fraction of the time the equipment is available for production,
- the efficiency rate (E) or performance is, the average production rate as a fraction of the maximum production rate, when the line produces, and
- the 1st quality or 1st pass yield rate (Q), the fraction of the running rate producing 1st time right quality.
- In formula: OEE = A x E x Q

There are several ways to enable this level of **multi-disciplinary collaboration**. One effective approach is to create global coordination through a center of excellence (CoE) that coordinates contributions from central or remote and networked experts. Together, they can be a powerful team for expert **consultation, operational and strategic support**. They implement plans derived from approved strategies and contribute advice for strategy updates based on results of the implementations. The coordination of the CoE will allow to benchmark performance, uplevel it throughout the organization and allocate the best resource for the best task.

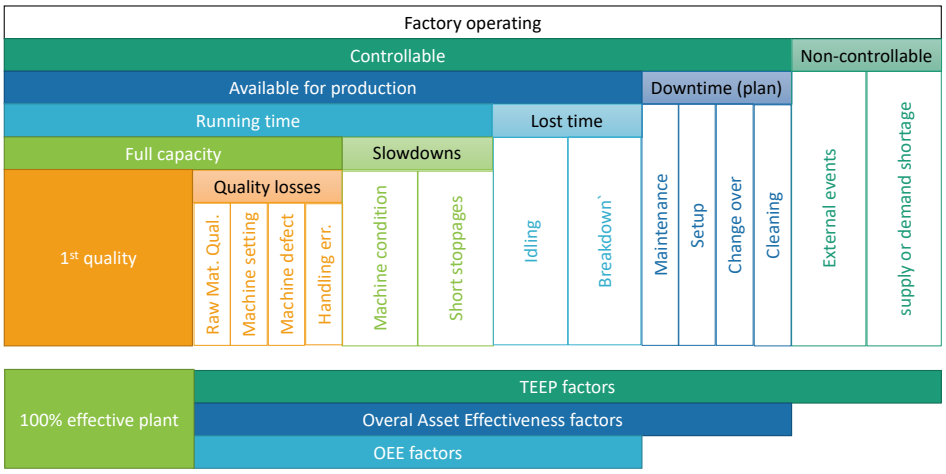
Using this approach, domain experts and operations management fully concentrate on improving operational performance, for example **Overall Equipment Effectiveness (OEE)**. Exploring complex relationships increases the organization's intellectual property (IP) about correlations between materials, production conditions, asset condition, operator behavior and qualifications, equipment availability, equipment efficiency, energy consumption, and quality, to name a few. Often, operators are required to enter causes for downtime, slowdowns and quality losses for downstream analysis. With this knowledge, the organization can set up **machine learning** (ML)and develop **artificial intelligence** (AI) that can advise operations how to modify production parameters, given the current conditions, to reach the optimal business outcome. AI could be a **digital twin** (DT), if it can match the performance of the actual physical equipment or line or, even better, predict behavior ahead of time, given certain decisions or conditions.

Total Effective Equipment Performance
Where OEE measures effectiveness based on scheduled hours, TEEP measures against calendar hours, and is a measure of the effectiveness of the asset management (reducing maintenance and repair time), scheduling and engineering (reducing setup, changeover and cleaning time).

Once the organization uses **advanced analytics** to better understand causes of performance losses and transforms them using continuous improvement methodologies, this approach can be transitioned into a **benchmarking** approach from which best proven performance levels become the operational

targets. Analytics models should also be deployed in operations for day-to-day use because of the benefits listed below:

- Improved OEE, that is, more production with the same or fewer assets.
- Improved asset availability, measured by the OEE availability rate, and reduced repair and replacement costs.
- Scheduled maintenance approach. Organizations can move from preventative maintenance to predictive maintenance.
- Improved quality and improved "once through" or "1st time right," measured by the OEE 1st quality rate, leads to less rework, scrap, reduced energy consumption and improved customer service levels.
- Reduced energy and material consumption and less assets, results in improved sustainability and reduced (carbon) footprint.
- Improved operator know-how based on feedback from advanced analytics, further contributing to productivity.
- Improved knowledge about root causes of efficiency losses and improvement methodologies. The latter two factors impact the OEE efficiency rate.
- Reduced cost and improved productivity from organizational alignment.
- Reduced attrition rate, depression, burnout and anxiety and improved employee engagement if change is implemented respectfully and job content is upgraded.



Structure of Overall Equipment Effectiveness and Common Causes for Losses

Value-oriented Implementation

The most integrated and encompassing approach to implementation is building a change project with parallel, coordinated tracks. A rollout is a multi-variable optimization problem of several, simultaneously executed and connected tracks within a project. Each track provides input to the others and provides levers for optimization. This value-oriented change program targets the added value to the organization over the initiative's lifecycle. For example, a project that is promising from a technical and financial perspective may put strain on resources and demand attention in the project management and change management tracks. Monitoring added value provides the opportunity to tweak aspects of the tracks that boosts value or gets it back on track. A few practical suggestions for executing the tracks are:

The Analytic Cycle

Data model: understanding the context and meaning of available data types and implementing it as a structure in data analytics for quicker processing and interpretation.

Data: the ability to ingest multiple data sources, historical and real-time, into a ready-to-use data model.

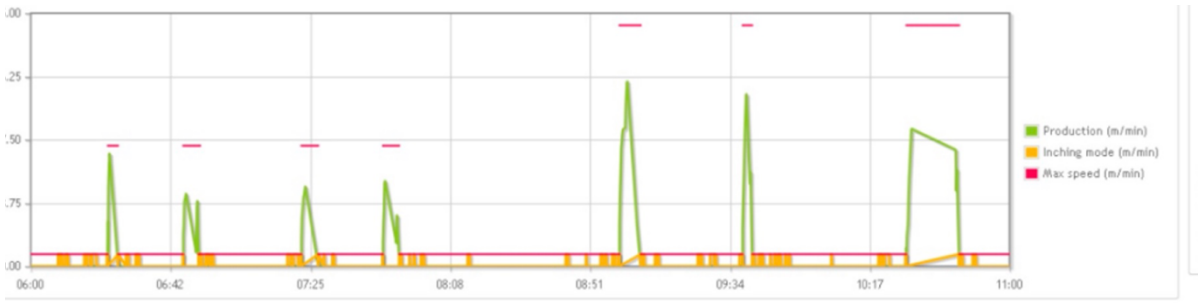
Discovery: ability to find complex cause-and-effect relationships using machine learning and statistical process control, capturing discovered relationships in models.

Deployment: Validate model accuracy, register, document and deploy models in 'production'. Maintaining and improving their accuracy over time, as decisions depend on them.

Competencies, roles, and responsibilities: different skills are necessary in the different stages (see text). The user is an operational professional, manager or domain expert, not a data scientist.

Project governance identifies a corporate sponsor with a personal stake in the project's results, supported by a steering committee with management representation from all disciplines and/or organizational units involved. In early phases, a **business case** keeps focus on areas and cases that promise both intangible and tangible impact. It provides input for setting priorities and selecting demonstration cases. The business case is adjusted when information becomes available and is used to steer the content of the program. **Business processes** must be adjusted to gradually incorporate advanced analytics, first in test implementations and later on a broad basis. People should be clear about expertise, responsibilities of different disciplines and functions of the "advanced analytics" team. In **technology**, IT will help configure and deploy software on the right hardware, in the cloud, on-premises or both to maximize the user experience. It will provide edge-to-cloud connectivity for streaming and file transfer and set up API calls to make data available for advanced analytics. IT will provide advice and help in deciding if data can be analyzed at the edge or, if machine learning in the cloud is more realistic, with the resulting AI application transferred back to

the edge to provide close-to-real-time analyses and operator guidance. OT will make sure historical operational data are made accessible and help connect any new measurements and IoT sensors and configure operator input screens. Maintenance and quality also provide information for analysis, assisted by OT and IT. Data scientists help domain experts gather data sets usable for ML and AI applications by cleaning, data modeling and data base structuring. They provide advice on the use of algorithms and approaches for the cases the domain experts suggest to study. The **sustainability** track monitors and improves the environmental impact of the project, taking the footprint of the users and that of the company into account. **People and social change**: Before the program starts, during implementation and when the approach is operational, project management and sponsors communicate to various audiences, creating awareness. Training is made available for all potential users when needed. Keen users can be stimulated to create results that attract and convince the slower movers. Management can coach their collaborators and stimulate a responsible, fact- and data-driven attitude.



OEE Computed From The Production Rate Of A Metal Slitting and Packing Line (Producing, Reduced Rate, Stopped), Was Deployed In Operations. Productivity Improved By 10 percent. (Source: ThyssenKrupp)

Govern and Improve: Close the Loop

Advanced analytics, like any other discipline, is a journey, not a destination. Technology, processes, organization and priorities are constantly changing. To sustain performance in advanced analytics, the organization should transform project governance into a permanent process that measures results and adjusts the aspects of the implementation on a regular basis.

The following is an example of how such a process may be structured. The CoE makes proposals for changes in the (rolling) strategic plan and submits them to a steering committee that helps formulate priorities, resource

planning and adjusted policies. The combined proposals for a prioritized strategic plan, associated resources and policies are discussed until approved by the steering committee. Based on what was approved, business units make a short-term plan tailored to their scope and resources and implement the corresponding projects or activities. Experts in the business units support project implementation and contribute to functional activities in a global expert network coordinated by the CoE. These activities could be improving of methodologies, documenting processes, use cases, standard data models and templates, or creating and providing training. During the next cycle, the CoE collects the results from the projects and activities managed by the business units plus those of the expert networks, compares them against the goals, and proposes a strategy update to determine the best possible adaptation to changing circumstances.

For implementation, topics need to be organized according to the organizational scope they can address and prioritized according to their impact. This is referred to as portfolio management. Companies that fail to do so struggle to transform implementations into bottom-line impact. At the start, experiments and pilot projects are carried out, having been chosen based on local and global priorities. Some of these projects will be successful enough to be rolled out globally, others will be useful as local implementations but not as corporate strategy and some will be discarded. The successful projects selected for global rollout will create the most bottom-line impact, because of their multiplier effect. It is rational to keep experimenting with new projects while doing global implementations, but resources need to be distributed according to the prioritization of their impact. There is a real risk of getting lost in experiments and giving too little attention to rollouts.

Conclusion and Recommendations

Advanced analytics contribute to positioning an organization as a market leader. These tools empower manufacturers to ingest the wealth of information the organization has and retrieve from it real-time and strategic insights that drive optimal decision making. To realize bottom-line impact, the organization must not only discover insights once, but deploy analytics models in operations to re-optimize and keep creating value.

This enables them to improve underlying metrics, like OEE, so they reduce costs, increase revenue, and gain competitive advantages, such as improved quality, available supply, better customer service and increased sustainability. Successfully implementing the use of advanced analytics relies on the right preparation and methodologies.

ARC's recommendations for successfully using advanced analytics in the discrete industries include:

- Use advanced analytics for complex dependencies, optimization and continuous improvement practices.
- Build capability in IT, OT and domain knowledge in operations, quality, maintenance, and the methodologies used.
- Implement change by adjusting a broad range of aspects including human aspects – do not focus only on technology.
- Consider all factors that could impact productivity, quality and availability; analyze dependencies; and optimize when circumstances change.
- Implement a strategic planning process for analytics and improvement with regular strategy updates based on result, allocation of resources and translation to projects.
- Use classic business case approach to prioritize topics and outcomes and portfolio management to focus resources on high-impact activities.

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Acronym Reference:

AI	Artificial Intelligence
CoE	Center of Excellence, Center of Expertise
DT	Digital Twin, Digital Transformation
IT	Information technology
IoT	Internet of Things
KPI	Key Performance Indicator
ML	Machine Learning
OEE	Overall Equipment Effectiveness
OT	Operational Technology
RCM	Reliability Centered Maintenance
TQM	Total quality management

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