WHITEPAPER

AEGIS SOFTWARE

DISCOVER YOUR SMART FACTORY IQ

Smart factories have various areas of strengths and weaknesses, just as people do. Strengths bring the opportunity for positive differentiation, whilst weaknesses offer challenges to address in order to deliver consistently on expectation.

Many people like to measure their IQ to see how they compare in terms of being "Smart"— so why should we not do the same for the data-driven Smart assembly factory? This helps reveal both strengths and weaknesses, builds the roadmap for improvement and development, increases visibility of unique values, and eliminates risk derived from bottlenecks and inefficiencies. **It is time to put our Smart, data-driven manufacturing operation to the test, ensuring preparedness as the industry transforms toward the elusive Industry 4.0.**

In this whitepaper, we will show how data can highlight the areas of the factory that are contributing to Smart advantages**—and which areas are holding business back.** We'll detail how to take a balanced approach towards Smart manufacturing, and how to choose the right tools in order to make it happen.

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Hard and Soft Automation

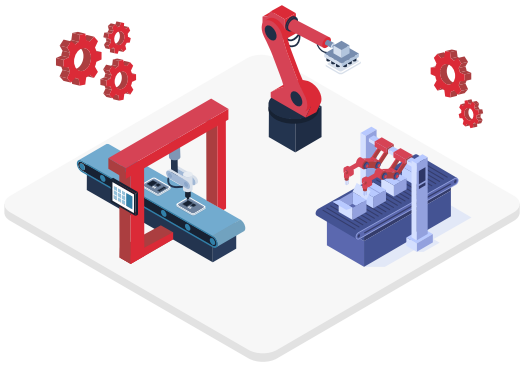
Industry 4.0 continues to represent, for many, a utopian view of the future of manufacturing that always seems to be just out of reach—yet we're told that we need it in order to survive. During this period however, there has been significant evolution in software automation solutions alongside the development of automation hardware. **For true Industry 4.0, both hardware and software need to progress and work together to establish the next level of sophistication and capability.**

It is easy to see strengths in the hardware domain, increasing capabilities that replace manual, laborious, repetitive tasks, with automated solutions, reducing costs and increasing quality with the reduction in process variation. The challenge in doing this has been to avoid the loss of flexibility, the need for which is also accelerating.

A step-change in automation with robots has been the addition of spatial awareness technologies, like visual processing and progressive touch sensors, such that robots and cobots have become trusted to interact with their surroundings, including being side by side with human operators. Robots now make alterations to their actions, corrections and collision avoidance, as well as having some degree of self-learning, which is where—from the process perspective—the hardware and software fields meet.

In the software domain, technology progression of solutions, both as part of the hardware automation, and the factory operation as a whole, is at least equally important, but is not as easy to recognize with a casual glance. The availability of precise and timely data with clear and defined meaning vastly increases the potential of software to help with analysis and decision-making that once only humans were able to do. Core industrial engineering technology principles were chronically limited by human capability. **With the addition of software automation, simple and effective manufacturing management and engineering tasks can be performed quickly, simply, and more completely, with a scalability that humans could never achieve, and certainly not without mistakes.** Data-driven automation in manufacturing represents a step-change in operation and management improvement opportunity.

Aegis' FactoryLogix IIoT-based MES software has been uniquely created to meet this opportunity, specifically designed for the Industry 4.0 live decision-making manufacturing environment, making it unique in its class amongst MES peers. This is the Smart Factory platform on which the intelligence for transitioning from Industry 3.0 to Industry 4.0 is achieved, bringing Smart, data-driven intelligence to the factory-floor.



The IIoT-Driven Smart Factory Platform

The positioning of new technology within the manufacturing operation is critical, as the new IIoT-driven Smart platform will be expected to work effectively and augment incumbent enterprise solutions and technologies, whilst facilitating the evolution or replacement of "point solutions," mostly based on the shop-floor.

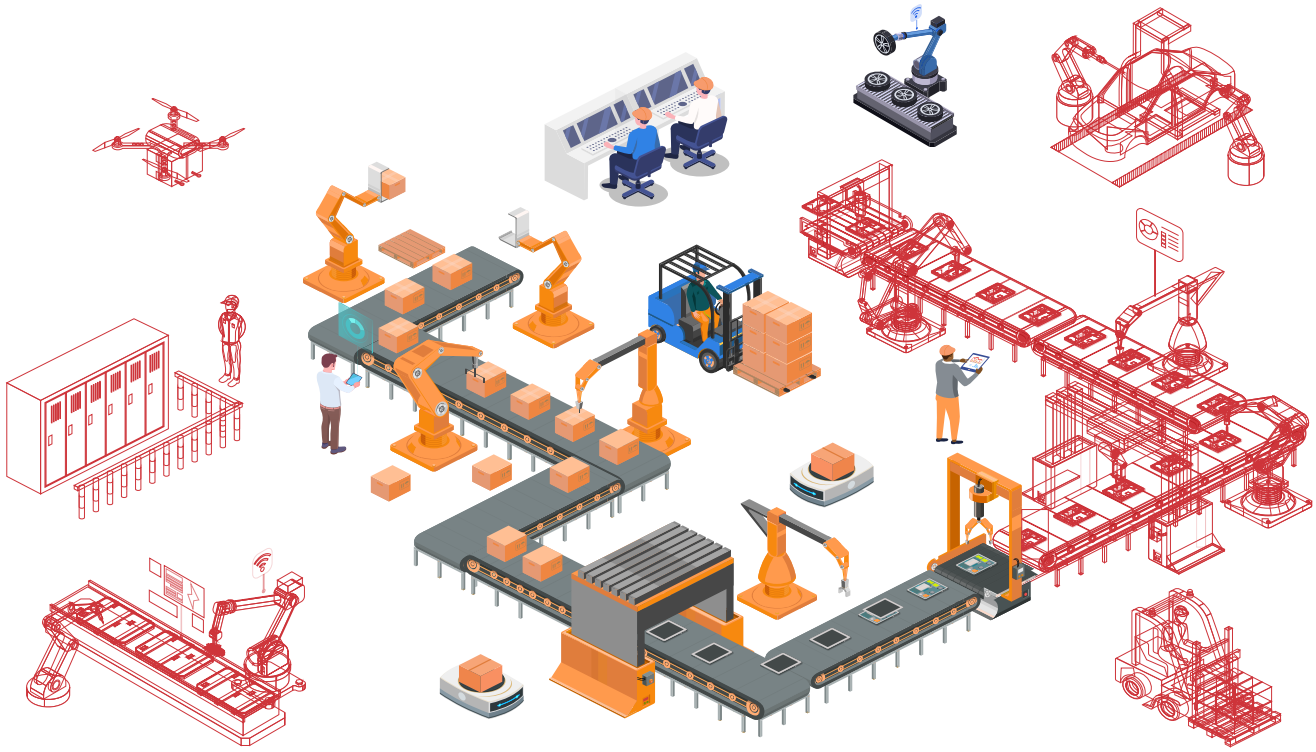
ERP (Enterprise Resource Planning) has long played a crucial role in the way the factory operates, yet is a generic solution unable to consider specific Smart attributes and practices associated with the variety of differing production operations. Such is the case for many legacy MES (Manufacturing Execution System) solutions, as well as more modern PLM (Product Lifecycle Management) implementations. **The IIoT-driven Smart factory platform acts to greatly enhance the operation of these legacy solutions and technologies, enabling them to regain their relevancy and full potential in modern, data-driven manufacturing environments.** Shared responsibilities between solutions relating to materials, planning etc., are handled interoperably, with each solution having different perspectives of detail and time intervals with which operations are considered. Configuration of exactly how each role is transformed can be configured progressively, as the operation transitions from the constrained legacy environment into a true data-driven operation.

The IIoT-driven Smart factory platform greatly **enhances the operation of legacy solutions.**

The replacement of incumbent systems revolves mainly around point solutions, isolated systems purchased or internally developed to address specific needs. It is likely that several such solutions have accumulated within the manufacturing operation, dating back to the early days of computerization within manufacturing. Though valuable in isolation, the lack of connectivity and interoperability between these solutions has created multiple duplication of effort, for restricted value. This remains true for the majority of commercial point solutions, that have often been crudely combined under an MES solution umbrella, which has not been successful, nor Smart, as legacy compromises remain hidden beneath the surface. This direction of evolution has been the real barrier for progression of solutions based on multiple older technologies.

One of the most impressive trends in Smart manufacturing is the success of machine vendors exchanging data with each other, creating machine learning (ML) and closed-loop solutions. As well as helping drive the increasing popularity of the use of IIoT technology within manufacturing, these solutions also more closely connect machine providers and MES vendors with the interoperability of mutually beneficial data exchange.

The successful Industry 4.0 environment includes the whole gamut of production processes, physical and transactional, based on a single platform that eliminates duplication and inconsistency, reducing cost of ownership. FactoryLogix singular IIoT-based platform, with easily configurable modules, provides the ability to rapidly support an operation's immediate needs, as well as supporting multiple expansion paths, allowing manufacturing companies to create and execute their own strategies towards Industry 4.0 in a way that suits their individual dynamic business needs.



The Smart Factory "IQ" Test

The question is not whether hard or soft automation is Smart or not, but to what extent it is Smart. Not all Smart solutions are the same. Some measure of "AIQ" (Artificial Intelligence Quotient) helps us not only to compare our relative merit against peers in the industry, but also helps track progress on the evolution of Smart technology in line with internal business goals and vision.

Aegis' vision of Industry 4.0 is centered around soft-automation that empowers discrete manufacturing operations to meet the modern, often volatile customer demand variation day by day, without resorting to the accumulation of stock or materials, whilst maintaining optimum efficiency, productivity and perfect quality. This represents an impossible task, if left in the hands of humans aided only by aging legacy enterprise systems and point solutions, no matter how well they may be disguised.

To determine the AIQ level of a factory, we need to establish a set of metrics, with two distinct stages. **Firstly, we consider the Smart potential of data that is being collected and exchanged across the operation, and then secondly, we consider the ways in which that data is utilized in a variety of Smart applications.** Our metrics should be based on rules and calculations that allow for scale, such that a company twice the size of another, is not necessarily twice as Smart.

Stage 1: Connectivity

The first stage is connectivity. There are many facets of data value associated with each key data exchange point, or "station," that needs to be measured, which include both automated machine processes, and manually executed stations. An initial allocation of 10,000 AIQ points, are divided equally between the number of stations. A factory with 50 stations will then, for example, have a potential of 200 points per station. We then look at each of the production stations in turn, in order to qualify them against the criteria needed to achieve that level. In the event that there is some gap, then the number of points for that station is reduced, which reflects the reduced value of potential contribution to the Smart Factory as a whole. **The effect of compromise in the data from just a small number of key stations can radically affect the performance of Smart applications, which in some aspects are only as Smart as the "weakest link."** The rate at which the number of points is reduced bears this in mind.

Automated Data Acquisition

For automated stations, we reduce the initial number of AIQ points depending on achievement of the following criteria:

IIoT Technology

The key aspect of IIoT architecture is that the connection is "one to any," meaning that data may be exchanged with many other different stations, and used for many different purposes. There is no specific focus on a specific point-to-point application or use-case, as is typical for non-IIoT-based interfaces. **If the station interface is not based on true IIoT technology, then the number of AIQ points should be reduced by 25%.**

Common Defined Language

The meaning of data content should be clear and easy to understand. Computers are not like humans. If there is any variation in the way in which information is expressed, then continuous additional interpretation and translation of the data content meaning is needed. This introduces ongoing potential issues with data management across the whole operation, including how to establish a baseline language for all of the different possible interpretations. **AIQ points should be reduced by 25% if the data format requires significant translation due to variances.**

Middleware

Where a third party is required to help acquire or translate data, the result is middleware. The use of middleware introduces significant ongoing risk, with the need for potentially unlimited amounts of ongoing support, should anything about either side of the data transfer change, which can happen at any time when using non-standardised data formats, for example at machine upgrade. **In the case where middleware is used, the number of AIQ points should be reduced by 50%.**

Timeliness

Data exchange should be event-driven, with information being made available to Smart applications immediately. Where information about an event is delayed for a period of time, especially where the interface is based on a polling narrative, where, for example, a database is interrogated at a set number of times per hour, **AIQ points should be reduced by 25%.**

Exact Association

Data exchanged should relate to an exact trigger, for example, a material consumed came from a specific identified carrier. If the association, in this example, of specific source material unique ID, or the consumption point component reference designator, cannot be guaranteed, **then the number of AIQ points should be reduced by 20%.**

Level of Detail

The requirements for the minimum level of detail differs between equipment. It is essential however that the common data across all equipment meets a minimum requirement, such that the most common uses of Smart data can be satisfied. The best reference to use in order to assess this is to refer to the IPC Connected Factory Exchange Standard (IPC-2591), v1.3 or later, which has a section that lists the minimum requirements of data exchange. **If any requirement from this list is not met, then the number of AIQ points should be reduced by 20% progressively for each item that is missing.**

Bi-directional Capability

There are many use-cases where information is received by a station, in addition to the station sending data out to others. **If the station does not support the bi-directional flow of data, then the number of AIQ points should be reduced by 25%.**

Security

Manufacturing data in sensitive applications, such as that regulated by ITAR foy example, should be encrypted at source, so as to retain security of the data. **If there is no option to secure the data at source, then the number of AIQ points should be reduced by 15%.**

Less than perfect results in the above assessment highlight significant hurdles to Smart factory adoption. The deployment and support of interfaces with production stations has long required specialist engineering know-how, as well as good machine vendor co-operation. Compromises, however, remain.

In order to completely address this problem, and eliminate both the work needed and potential compromise, Aegis has been co-chairing the IPC "Connected Factory Initiative" committee, that has created the "Connected Factory Exchange" (CFX IPC-2591) IIoT standard for data exchange across the whole of assembly manufacturing, available since 2018. Connecting FactoryLogix to any IPC accredited CFX machine or device, results in a perfect AIQ score for station connectivity. **The use of CFX has already become very popular in electronics manufacturing, and is equally adoptable for any discrete manufacturing process.**

FactoryLogix Connectivity

A perfect AIQ score is achievable with FactoryLogix when connecting with machines and devices with accredited IPC-CFX support. Using any one of our other advanced x-Link interfaces, available as standard with FactoryLogix, provides a near-perfect score, depending on each machine's communication capability. **Either way, having a single IIoT-based platform that supports your whole Smart-Factory evolution journey, brings unprecedented opportunity for Smart factory value creation, with a realistic investment and return, from day one.**

Manual Data Acquisition

Assessing the Smart value of data obtained from manual stations involves a greater degree of specific operational understanding. If data is being recorded from a manual station through the use of paper, then the AIP score for that station should be zero. Manually created notes are not checked or qualified at the time of origin of the related event.

In other cases, manual data entry remains a key part of the data-driven factory, as operations at many assembly, test and inspection stations continue to be performed manually. **There is a great deal of value to be gained from timely, accurate and detailed manual data entry, though input should be done with assistance, as part of the operator's paperless work environment.**

For paperless manual stations, we reduce the initial number of AIQ points depending on achievement of the following criteria:

Level of Detail

As with automated data collection, the requirements for the minimum level of detail differs according to what actions are performed. For manual processes, the best reference is to use the section in the CFX standard that lists the minimum requirements according to process type. **If any area of data collection from this list isn't supported, then the number of AIQ points should be reduced progressively by 20% for each that's missing.**

Input Qualification (List)

Wherever possible, free-form data input must be avoided. Choosing an input from a contextualized list of possible choices ensures no interpretation of data is needed, and input is accurate and complete. **Where free-form data is used to record key data, the number of AIQ points should be reduced by 50%.**

Input Qualification (Range)

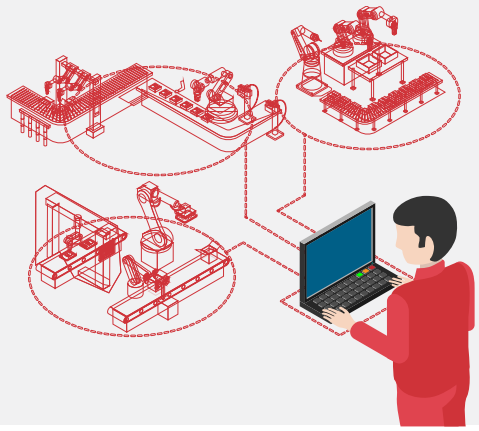
Where it's necessary to enter values, like measurement taken, the entered value should be compared to the limits expected for the measurement. It's good practice to not share the limits with the operator, but to prompt for confirmation if a value is entered that's out of range. **Where input qualification of values entered is not performed in this way, the number of AIQ points should be reduced by 15%.**

Timeliness

Data capture at manual stations should be event-driven as in the case of automated data capture. **Where information about an event is delayed for a period of time, the number of AIQ points should be reduced by 50%.**

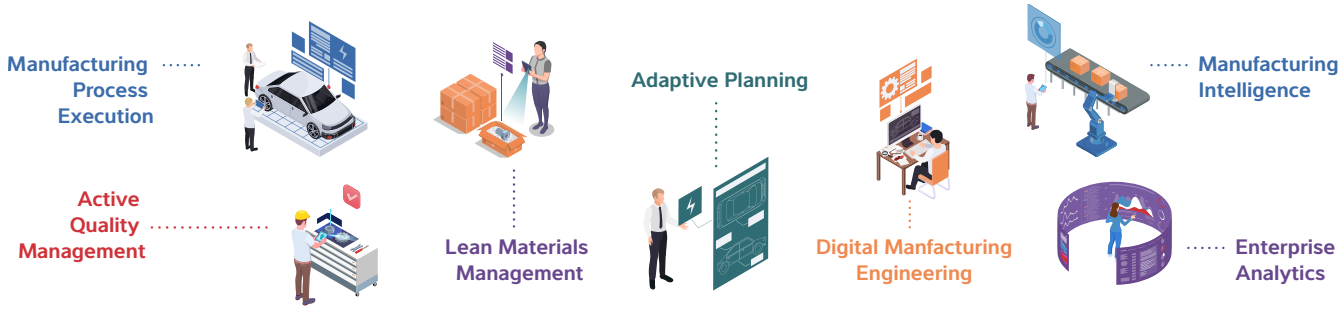
FactoryLogix Operator Cockpit

The FactoryLogix Operator Cockpit is an immersive experience designed to focus on everything that an operator needs in order to fulfill their role, whether using PCs, tablets, or Augmented Reality (AR) technology. Clear, simple, graphical information assists the operation step by step, with the opportunity to capture data and feedback from the operator, with full data qualification as it is entered. With connected devices such as barcode readers, cameras and local device or tool interfaces, input can be automated whenever possible. **A Smart factory perfect connectivity score is realistically possible for every manual operation with FactoryLogix.**



Stage 2: Data-Driven Manufacturing Values

As a result of completing the first stage of the AIQ assessment, the Connectivity AIQ score can be calculated as the sum of remaining AIQ points across all stations. **The next stage is to work out whether the data from each station is being used effectively in potentially many key Smart manufacturing applications.** In the next stage of assessment, we will measure the effectiveness of the accumulated "Smart data," as it is used in real-time for automated decision-making, as well as analyses that contribute to the overall performance of the factory. **There are seven key Smart application areas to assess, as follows:**



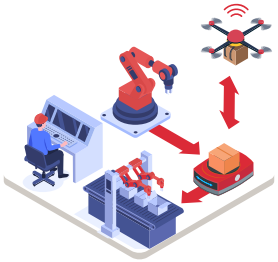
Each of the applications may be relevant to some or all of the identified production stations. In each case, the assessment should be done for those stations that are directly involved in the activities listed. Individual station scores are therefore likely to be affected by more than one application. The AIQ assessment method for each of these applications is to take the currently accumulated AIQ points for each station as the starting value, following which various aspects about how the data is used in these applications will determine how the number of points for each station should be adjusted. If there is no use of data in a particular application, then all the reductions apply as basic requirements are not fulfilled, and no increase of points due to advanced use of the data can be gained. **The greater the degree that each area of the factory is data-driven, the higher the score for each station will be.** At the end, the total points from all seven application areas are added in order to get the final AIQ result for the factory operation.

Manufacturing Process Execution

There are three key ways in which data drives manufacturing execution:

Visibility

Creating contextualization of information, providing views on the status and progress of manufacturing, orientated from different role-based perspectives. Potential areas of optimization and challenge are highlighted, prompting appropriate actions, increasing productivity and on-time delivery.



Control

The ability to action commands to production stations, such that production flow is maintained in accordance with stipulated route, avoiding situations that may result in defects or delays.

Coordination

Ensuring that operational stations continue running without delays or challenges caused by areas on which they are dependent, such as supply-chain, tool management, as well as availability of production units to be processed.

Smart MES starts when the quality data reaches the point at which key roles are automated in the software domain, without the need for manual involvement. Such decisions include the qualification of production units as they enter stations, the prevention in the operation of a station due to a quality issue, or in very high level of autonomy cases, to alter the routing of work-orders in the case, for example, of unexpected equipment breakdown or a last-minute change of a customer order. There is differentiation between basic and Smart MES functionality, based on the degree to which automated decisions are made. For basic functionality, AIQ points are decreased if the expected requirement is not met. For advanced functionality, AIQ points are increased where value has been derived from an extended use of data. The MES application affects all production stations through which a production unit is processed.

Basic Functions:

Process Status

Understanding the status of every production station, whether automated or manual, is vital in terms of identifying needed actions, as well as creating the strategy to increase asset utilization. As the production station is running, supervisory systems determine important things such as the minimum cycle time, productivity etc. Calculations of various basic performance metrics are determined or qualified by the basic process status, which includes maintenance, waiting for work, in setup or test mode, broken down, etc. **If Smart data is not used to show continuous visibility of the status of the station, then the number of AIQ points should be reduced by 50%.**

Processing Event Information

As each production unit is being processed, information about the operation, including stop-codes, the use or change of tools, and other key measurements appropriate to the environment of the station, is used in order to create full traceability information as well as more refined productivity calculations. Should the station stop or pause for any reason, the exact explanation from the point of view of that station must be communicated. **If Smart data is not being used to provide analysis of the operation determining accurate productivity levels, identifying causes of lost opportunity etc., then the number of AIQ points should be reduced by 50%.**

Production Unit Qualification

As products arrive at the production station, the exact ID of the production unit should be read and confirmed. Many quality issues happen where the incorrect production unit is processed at a station, perhaps as a result of a loading mistake, the skipping of a station, or worse, the repeat of a station or testing of a production unit which has not successfully completed prior tests. Without reading individual production unit IDs, data collected during processing cannot be specifically applied, meaning that routing control cannot be used and process traceability will not be exact. **If the automated qualification of the specific production unit is not being done prior to entry to the production process, then the number of AIQ points should be reduced by 40%.**

Operational Result Capture

Data captured at the end of the operation at each station is used to determine the eligibility for progress to the next station, or diversion to an inspection or repair station, for example. **If Smart data is not being used to control automated routing of passed or failed production units, then the number of AIQ points should be reduced by 40%.**

Advanced Functions:

Poka-Yoke Control

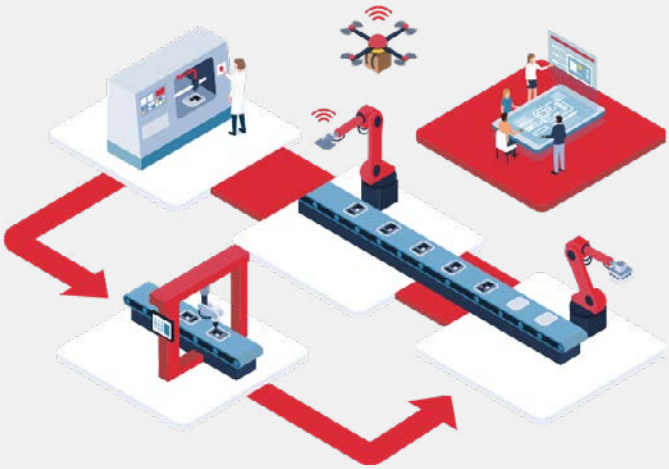
Automatically stopping a production station is essential, for example, in the condition where a repeating quality concern has been detected that is related to that specific production station. Active quality solutions detect these events automatically, based on Smart data, highlighting issues to the responsible parties, and in serious cases, safely preventing the station from continuing to make poor quality. **If the automated station can be automatically and safely stopped, or the manual station is automatically instructed to stop, then the remaining number of AIQ points should be multiplied by 1.5.**

Machine Learning / Closed-Loops

The principle of the analysis of data derived from production stations is used to discover sources of variation related to key measured process metrics, and subsequent decision-making process. In the case of a single machine, this is referred to as Machine Learning. An example of ML would be an inspection process, with the determination of a "grey area" and, where incorrect decisions of pass or fail are possible, should be reduced, based on the learning of how the data could be better interpreted in order to reduce the incidence of false call. Closed-loops follow a similar process, except that two or more stations are involved, with inspection data used to suggest corrections to be applied to prior and future stations in order to reduce the likelihood of variation becoming significant enough to cause a defect. **Where such ML and closed-loop software technologies are being utilised, the number of AIQ points for the station involved should be multiplied by 2.**

FactoryLogix Manufacturing Process Execution

FactoryLogix assures perfect execution through all automated and manual operations, providing all of the required functions to, for example, automatically enforce production unit routing, ensuring that products can only progress through assigned routing sequences in the right order. In addition, should an exception occur, the production unit is routed accordingly for additional inspection and repair, and then returned to the appropriate station to continue processing. Data from FactoryLogix can be exchanged with machine vendors to enhance machine learning and closed-loop analytics, in order to ensure contextualization with the correct product, bill of materials, material vendor changes etc. **No potential AIQ points need to be lost with the adoption of FactoryLogix MES.**



Active Quality Management

Active Quality Management is distinguished from other forms of quality management by its utilization of data exchanged between production stations, as well as incorporating other forms of quality management related to factory-wide quality activities. Instances of market defects have been shown to be proportional to the number of defects discovered during manufacturing, driving the need for "zero-defect" manufacturing quality. **As part of the Smart factory assessment, the degree to which Smart data is utilized for quality activities influences the number of AIQ points earned or lost.**

Active Quality Analysis & Control

As machine vendors utilize data exchange between machines as part of closed-loop solutions, the same concept should be applied to wider line operating conditions. Active Quality Analysis utilizes data from all sources throughout the flow, including repair stations and post-processes, to perform analysis that ensures that quality metrics are contained within control limits. The use of SPC, or preferable 6-Sigma methodologies, provides an early warning mechanism that identifies the increased risk of defects, before a defect actually happens. **Where the station is capable of contributing quality related data, and the data is actively used for analysis, the number of AIQ points for the station should be increased by 50%.**

Use of Traceability Data

As quality improves to near-perfect, most defects fall into the elusive one-off defect category. An advanced use of traceability data is to find the unique root cause of such one-off defects. Analysis of traceability data can not only find the most likely complex root cause of a defect through the study of the combination of variation in process conditions and irregular events, but can also go on to identify other products that had been made under similar conditions, and therefore may have a weakness, even though a specific defect had not yet been identified. This reduces the risk of early field failures. **Where traceability data derived from a station is being utilized in this way, the number of AIQ points should be increased by 50%.**

Electronic CAPA / FRACAS

Where variation or specific root causes have been found through analysis of quality or traceability data, it is important to document the corrective action taken, and define preventative actions to take in order that there is no recurrence of the conditions that lead to the concern. As well as associated physical activities, implementing this electronically, such that patterns in data which have been proven to cause concerns can be spotted, with alarms raised and even production processes stopped where there is acute risk identified, creates a superior level of active quality management, based on live data and intelligent rules. **Where data from production stations is utilized in this way, the number of AIQ points should be increased by 100%.**

Incoming Inspection with FactoryLogix

No matter how Smart a factory operation may be, quality is also dependent on external inputs, the most significant of which is incoming material quality. With repeated threats on material availability and supply, the risk of counterfeit or poor quality materials is on the increase, prompting renewed standards-based rules for the inspection of incoming materials before allowing them to be used in production. FactoryLogix includes full and specific incoming inspection support, bringing simplicity to complex testing and analysis procedures, without operational dependency on specialist knowledge.

Automated Compliance & Conformance Reports

In each sector of industry, different requirements exist for the reporting of adherence to specific rules and regulations, in specific approved formats. For quality systems that utilize Smart data, any required format of report should be able to be created, using built-in templates and populated automatically using data originating at production stations. **Where the station has data utilized for this activity, then the number of AIQ points should be increased by 20%.**

Lean Material Management

Lean Material Management has become the critical part of the manufacturing supply-chain strategy. The traditional method of simply creating material kits for each production work-order, creates a multitude of challenges and restrictions. Materials pushed from the warehouse into manufacturing are often waiting in queues ready for use. This practice creates several challenges, including being a physical restriction to flexibility, consuming valuable space on the manufacturing floor, requiring manual management to ensure integrity, as well as representing a vast over-supply of materials in cases where carriers are used, for example, reels, trays, bags and boxes. **In such cases, it is nearly impossible to manage unused remnants of material within material carriers after work-orders are completed, incurring costs of material re-count, local storage management, and consequences of inevitable material inventory discrepancy with the ERP solution.**

Lean Material Management operates instead using the "pull" system, where material logistics are continuously triggered and actions based on near-term production need and immediate planned requirements. This ensures that there is adequate time for material picking, as well as logistics optimization, and ensures that materials arrive where needed "just in time," and production processes never stop for lack of material. Physically committing materials to the shop-floor only when needed, promotes opportunities for flexibility, reducing the need for part-used material management on the shop-floor, reducing line-side material replenishment space, and providing near-perfect material inventory accuracy without the need to perform re-counting of materials on part-used carriers.

In terms of AIQ, there are several key factors that influence the degree of intelligence related to supply-chain material management:

Basic Functions:

Unique Material Identification

Materials are identified by ERP by their part number, and then some form of good received note (GRN) number assigned at arrival. Each carrier of material however, once booked into the site, starts its own unique journey in terms of how it is used, where it is stored, and the environment through which it is moved and managed. In any Smart factory therefore, the unique identification of materials on an individual carrier, and in some cases, on an individual material basis, is essential, in order to accurately manage storage, selection, consumption and spoilage, ensuring accurate inventory levels, thereby assuring elimination of unexpected internal material shortages. **Where management of materials is not controlled using identifiers that are unique to the carriers or materials, then benefit from advanced material management is negligible. In such cases the number of AIQ points for any station that utilizes materials should be reduced by 30%.**

Advanced Functions:

Advanced Storage Strategy

The organization of materials based on part number quickly becomes wasteful of space, with increasing difficulty for space allocation and re-positioning as new part numbers are created, and older part numbers become obsolete. Managing locations using a random method, where materials can be stored in logically defined locations, can effectively double the warehouse space capacity and halve related operational costs. **The number of AIQ points for all stations that utilize materials stored in this way using an automated solution, should be increased by 25%.**

Automated Inventory Count

As part of the assembly process, data can be used to automatically decrement the count of materials as they are consumed or spoiled. Smart supply-chain automation utilizes this information in order to maintain the accurate count of the number of materials associated with each individual carrier, ensuring no unexpected shortages, replacing the need for manual counting and periodic stock-checks. **Where data from each station is used to maintain inventory levels in such an automated way, the number of AIQ points should be increased by 20%.**

Advanced Material Management

Certain materials require specialized storage and processing, such as temperature control, anti-static, anti-moisture, with associated drying and baking processes etc. that keep the materials in a usable condition. **Where such rules for material management are automated, the number of AIQ points for stations that utilize such materials, should be increased by 25%.**

Logistics "Pull" System

The use of Lean Material Management, utilizing the need for materials as the trigger to supply materials to production stations, represents a very significant reduction of material associated costs, such as inventory investment, space and logistics. **Where the Lean "pull" system has been introduced as an automated function, replacing the ERP "push" system, then the number of AIQ points for stations that consume materials and provide data used to create triggers, should be increased by 150%.**

ERP Back-Flush Elimination

With availability of continuous information related to material usage and spoilage, the feedback to ERP should be immediate. In non-Smart systems, ERP decrements material quantities as a simple count of products completed, often referred to as the "back-flush" method, meaning that consumption data is not available until the work-order has been finally completed. **Where the "back-flush" method has been replaced with the use of live information, the number of AIQ points for each associated station should be increased by 15%.**

FactoryLogix Lean Material Management

FactoryLogix provides a comprehensive solution that covers every aspect of Smart Material Management. **For years, bloated material inventories in the form of pre-built kits with redundant materials, expanded buffer stock in the warehouse to cope with unexpected internal material shortages, have become major manufacturing investment bottlenecks.** Such investments still fail to deliver uninterrupted supply of materials to production processes over time. Implementing FactoryLogix Lean Material Management often represents a return on investment in as little as a few weeks, providing also the essential flexibility on the shop-floor to implement Industry 4.0.

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Adaptive Planning

Smart Industry 4.0 places a key focus on the planning operation within factories, though it is quite different from what was considered a planning solution in the past. Following Industry 4.0 principles, factories must be responsive to short-term changes in customer demand, without relying on an accumulated stock of finished product.

The logic within traditional planning tools is based on the maintenance and flow of stock, and so they have never been effective at efficiently planning complex manufacturing environments, with multiple dependencies. Such solutions miss the opportunity to deliver either the maximum productivity or the needed flexibility, as they have little understanding of the detailed nature of the production operation. In almost every case, this leaves the real, everyday physical planning to the human specialist, with their mission-critical Excel spreadsheet. This practice becomes unsustainable as Industry 4.0 demands further agility in manufacturing. Traditional planning represents significant productivity loss, which often is not measured or reported, and so cannot be improved upon.

Industry 4.0 requires a live planning engine, that continuously monitors production progress, together with changing customer demand, creating optimized plans that are adapted to each specific moment. This requires the use of Smart data in real-time to measure current progress, to extrapolate what is expected and likely to happen based on current commitments, as well as the ability to understand potential effects of dependent things, such as the availability of materials.

Advanced Functions:

Visualization

The status and progress of current production is visualized as a time-line, with extrapolation to the completion of current commitments, is a basic element of adaptive planning. **Where this is provided automatically, those applicable stations should have the number of AIQ points increased by 15%.**

Dependencies

Where the visualization described above includes the calculation of the availability of dependent items, such as the availability of materials, sub-assemblies from prior processes, tools, etc., **then the number of AIQ points should be increased by 10% for each of the three types of dependent items.**

"What If" Scenarios

As any planning decision involves the prioritization of some factors over others, it is important to be able to judge the effect of any planning decision before making a commitment. **Where a "What if" feature is included as part of the Adaptive planning solution, the number of AIQ points should be increased by 5%.**

Adaptive Planning With FactoryLogix

FactoryLogix takes on the role of the "super Excel" for shop-floor planning engineers. Being able to continuously see the live view of production unfolding, visibility of status and progress of production, with extrapolation of commitments going forward, provides the intelligence needed for safe and effective planning decisions to be made effectively, knowing all the dependencies, constraints and effects, within a single, simple visualization, before commitment.

Digital Manufacturing Engineering

In the literal sense, Digital Manufacturing Engineering is the process of converting information about a product into a set of work instructions for both human and automated stations, enabling them to be able to assemble the product. While this activity resides in the engineering domain, **key aspects of how the engineering process is done fundamentally impacts how smart the factory can ever become.**

The original, and still most common method of data preparation is the pre-assignment of specific products to specific production configurations, with engineering activities focused on that relationship. This builds a dependency on the production of the product, which planning is then expected to follow, preventing the realization of flexibility with Industry 4.0. Practices around the import of design data, both for PCB-based electronic products and 3D-CAD, as well as the processing of the Bill Of Materials (BOM), are key foundations of how resultant automation can be effective. **The method in the way that engineering is performed therefore influences the number of AIQ points for the factory, as follows:**

Basic Functions:

Design Data

Virtually every product in production has been designed using Computer Aided Design (CAD) tools. In many factories however, multiple documents and data listings derived indirectly from design are used to create manufacturing work instructions and machine programming data, leading to mistakes and inconsistencies that require significant time, and a number of iterations, to perfect. The use of digital twin data, made in part from the original design data, including 3D-CAD as well as electronic design data for products incorporating PCBs, ensures that the full potential value from design data is available for manufacturing, without risk of duplication of effort and mistakes. **Production stations that are set up, have operation documentation, or are programmed using indirect design data supplied on paper, in lists, emails, PDF files etc. should have the number of AIQ points reduced by 30%.**

BOM Processing

The Bill Of Materials flow starts from the design process and is altered and processed by both global and local purchasing teams following internal policies. This aims to guarantee the supply of good quality, cost-effective materials, that are often obtained simultaneously from multiple sources. The frequent omission of clear, unique identification of individual components using reference designators, and the plethora of different methods to identify part numbers, whether internal, supplier, or manufacturer, including cases where part numbers change between approved suppliers, means that BOM data is a frequent source of errors in the manufacturing environment. An advanced BOM management function within the MES solution eliminates these issues, with automated confirmation of every component and material instance. **Where a specific advanced BOM management tool is not utilized, the number of AIQ points for each affected production station should be reduced by 30%.**

Assignment To Configuration

Where engineering solutions create digital twins of potentially complex products, including variants, without pre-assignment to specific production configurations, flexibility is introduced such that the planning operation is free to select the best capable configuration available for the desired rate, as customer demand changes. **Where stations are operated without set pre-assignment of product allocation, the number of AIQ points should be increased by 30%.**

Paperless Work Instructions

In order to ensure quality assembly as part of the Industry 4.0 flexible factory, knowledge of basic steps, updates, changes, variants, and product tailoring has to be accurate. This cannot be guaranteed when using paper, as paper can be lost, misplaced, or simply be the wrong version. **Where paper is used at any stations for operation or work-instructions, then the number of AIQ points should be reduced by 50%.**

Advanced Functions:

Engineering to Order

There are many use-cases where products may need to deviate from an intended flow, such as to a secondary inspection in the case of a failed test, or to follow a bespoke path depending on work that is necessary, for example, of an MRO (Maintenance, Repair & Operations) work-order. The same principle is also important for manufacturing environments where only one or a few units are to be built, with configurations created on the fly, with the aid of templates. **Where production stations are designated as part of an Engineering To Order environment, the number of AIQ points should be increased by 25%.**

Configure to Order

Multiple variants of products are often made together in a factory, where the operation must adapt to different variants depending on changing customer demand. In many operations, each variant has its own bill of materials, with each variant processed as an individual product. In the Smart factory, a single, dynamic bill of materials is used, such that a specific variant can be chosen at the time of assignment of a variant to a production configuration. This method uses a single, dynamic bill of materials, greatly reducing engineering time and complexity, reducing the risk of issues when switching from one variant to another in agile mixed production. **Where such variants exist, and specific production stations are used in this way, the number of AIQ points should be increased by 12%.**

Automate to Order

The ultimate goal of Industry 4.0 is to realize "make to order with mass-production efficiency". Automate to order allows bespoke tailoring of parameters, for example, the length or finish of a material, to be tailored for each individual piece, or quantity of products, with subsequent work-instructions then automatically updated and adjusted with the determined values. This ensures control and efficiency of even the most extreme of bespoke manufacturing environments. **Where production stations are set up to perform this kind of work, the AIQ points should be increased by 25%.**

Use of Augmented Reality

In many factories, there are manual assembly, test or inspection stations that are assigned to specific products. As factories increase the mix of products that they make, many of these bespoke stations are idle most of the time. The use of Augmented Reality allows operators to move from station to station, performing their activities "hands free", with the same paperless work instructions and references, but without the need for MES IT hardware at each station, reducing investment in hardware and IT infrastructure, as well as promoting flexibility. **Where augmented reality "stations" are used, the number of AIQ points for each should be multiplied by 4 times.**

Engineering 4.0

FactoryLogix digital twin-based engineering architecture provides multiple ways that revolutionize the approach of how and when products are engineered and assigned to production configurations, automatically preparing and updating paperless documentation. An initial digital twin of the product is made, based on design and local bill of materials, which can include such complexities as variants as well as specific tailoring requirements. Assignment to a specific production configuration is then performed on demand, driven by Advanced Planning, matching perfectly the best available configuration that meets the immediate customer demand at the time needed, ensuring that all information relevant to the specific task is automatically communicated and maintained.

Manufacturing Intelligence

There are two very distinct areas in which data is used within manufacturing. For humans, visibility is a critical value, though the view of raw data has very little significance. The role of a Smart manufacturing platform is to take data from many different sources and set it into context with the myriad of related factors, such as factory and line configuration, materials flow, quality performance etc., so as to show data in a way that humans can easily see key metrics, trends and opportunities to take actions that drive improvement. **Within the manufacturing operation, reporting must be real-time and accurate, with dashboards capable of displaying meaningful metrics, that show the immediate situation across all areas of production.**

The second distinct area for the use of data is in the digital twin world, where automated decisions are made and actions taken in response to the recognition of events or trends. Such algorithms within FactoryLogix are collectively referred to as the "Active Rules Engine," which performs a multitude of tasks including alert generation, routing decisions, automated material pull, and more.

In terms of measuring the potential effectiveness of manufacturing intelligence based on Smart data, we consider the following points:

Basic Functions:

Dashboards

Each production station should be included in all relevant KPIs, that are continuously displayed at or near each production station. For every potential issue and trend that adversely affects the station, the dashboard must be able to clearly show trends and empirical information. **Where such information is complete, and correctly displayed, the number of AIQ points for the station should be increased by 25%**

Advanced Functions:

Reports, Alarms and Alerts

Most reports have no effect or bearing on the Smart production factory, as their content is historical, a record of what has been lost, with no opportunity for recovery. An exception to this is where the rules-based engine has detected a trend, using built-in algorithms, including configured SPC or 6-sigma analysis, such that an action has been determined that will prevent further detrimental consequences. In cases such as these, the report that is made, usually electronically delivered, and directed to the key responsibility for that specific issue, is a strong contributor to the Smart factory operation. **In such cases, where the production station is included for this kind of functionality, the number of AIQ points should be increased by 40%.**

Ontology

The way in which solutions understand the meaning and relationships of data, and how data elements work together to create actions, alerts and analytics, is referred to as the ontology within the solution. In many cases however, results are based on a set of fixed rules, where simplistic algorithms combine data elements to yield results. In such cases, a very small, and often un-noticed change can invalidate results, creating waste and lost opportunity, as subsequent improvement activities are based on falsehoods. A very good indication of a robust ontology is where the solution allows that, for example, a new type of machine, a factory configuration change, any process route change, new product or trace requirement etc., can be added ad-hoc with zero code or system changes, with all analytics continuing to work. **Where a robust ontology can be demonstrated consistently, the number of AIQ points for each affected production station should be increased by 40%.**

Simple, Intelligent Dashboards by FactoryLogix

With so many potential metrics and different aspects of measurements across production, including performance, efficiency, quality, waste, on-time delivery etc., the creation and evolution of dashboards that display metrics made up from countless data points, calculated and displayed in real-time, presents quite a challenge. FactoryLogix simplifies this by providing templates that incorporate many advanced gauges and other graphical constructs, to which defined contextualized data content can be attached. **Dynamic, controlled and meaningful dashboards created using FactoryLogix take minutes instead of hours or days to develop, providing unique visibility for people in every department across the factory.**

Enterprise Analytics

Contextualization and use of data to create value should not only be utilized continuously on the shop-floor. Enterprise business systems, many of which feature Business Intelligence (BI) tools, benefit from summarized and standardized data, that combine information from manufacturing across multiple sites, together with additional information such as financial metrics.

In most cases, these higher-level systems require very significant specialization and customization in order to make sense of manufacturing data, where raw data has been simply "sent to the cloud." Only around 20% of that data can be used to create value, and only then, by investing significantly in specific post-event contextualization software, which repeatedly consumes a lot of computing time and energy to run. **FactoryLogix revolutionizes this approach by creating a data warehouse of contextualized information, which is continuously updated synergistically with standard enterprise analytics systems.**

Using a standard interface means far simpler integration with existing common analytics solutions. All of the data using this mechanism is easily used to create value. The combination of these advantages means that standard "off the shelf" BI tools can be used effectively with manufacturing data, eliminating the need for software customization and adaptation. **Where non-contextualized data is utilized by enterprise analytics, the number of AIQ points for each included station contributing should be decreased by 25%.**

Conclusion

At the end of the second stage of Smart Factory AIQ determination, we add together the **final AIQ points for each station,** having been adjusted progressively through consideration of each Smart application. In isolation, the final result is not important, unless comparing factories within the same organization or comparing results with friends. The real importance is how the data highlights which areas are contributing to the advantages of being Smart, and which are holding the business back. Action can then be taken to ensure that a balanced approach towards Smart manufacturing is taken, and that the right tools are chosen in order to make it happen.

The Aegis FactoryLogix IIoT-driven MES solution has been designed to lead world-class Smart manufacturing initiatives, providing every opportunity for the maximum number of AIQ points, representing tangible and realistic, cost effective Industry 4.0 advantages. Learn more at https://www.aiscorp.com/.

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