GAMBICA

I4.0 & the Process Industries

How will the fourth Industrial Revolution change process manufacturing for the better? An Industry Perspective.

Position Paper

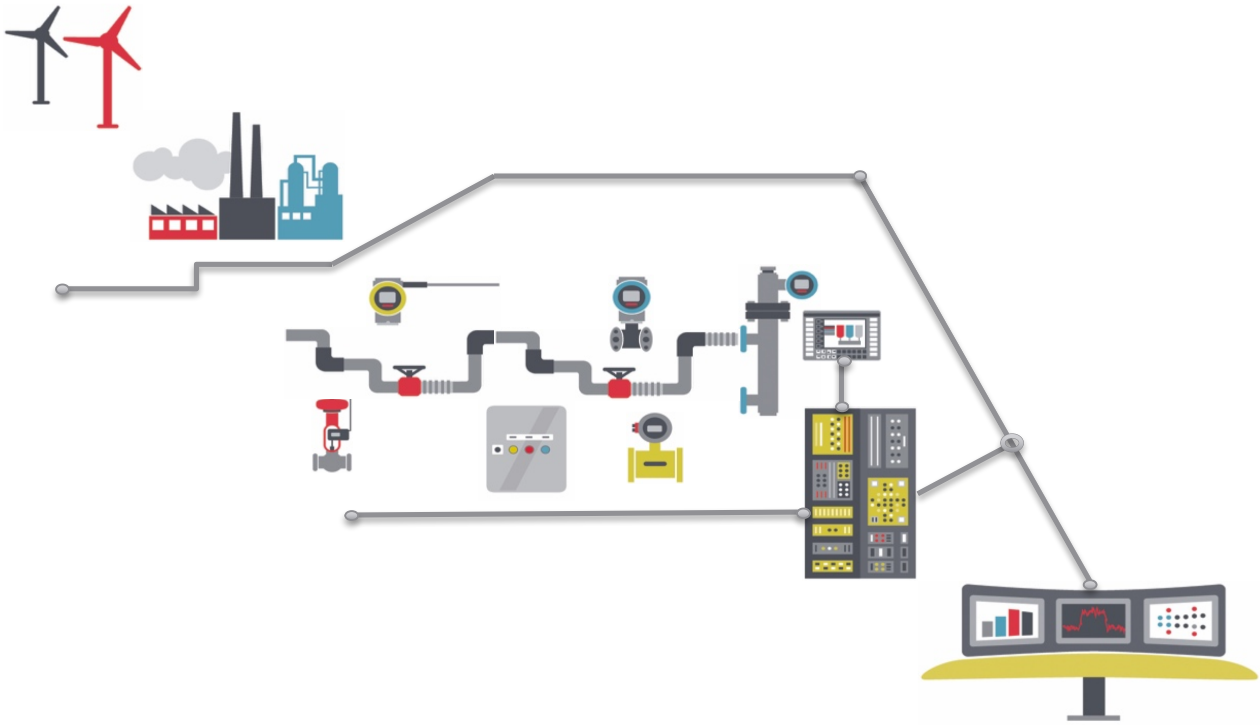

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Table of Contents

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Does Industry 4.0 apply to the Process Industries, and if not, should it?

Introduction

Industry 4.0 has a primary focus on discrete manufacturing though even now, a generally accepted understanding of the term does not exist [(1)]

The key driver behind I4.0 as defined by the German government is the "computerisation of manufacturing". The UK Government is still toying with definition but "the digitisation of industry" appears to be their most recent label. I4.0 is described as a "revolution" though from the process industries perspective, it is possibly more accurate to describe it as an "evolution".

If we make the assumption, that I4.0 will interweave many stand-alone processes with a communications backbone allowing data and information to be shared across the supply chain, we are starting to develop an acceptable general definition. Process Automation has forged ahead with secondary uses for extracted data where industrial automation solutions have lagged behind. However, M2M and integrated manufacturing has been led by Industrial Automation.

As the concept of digitised industry solidifies, it requires the creation or updating of standards to enable it to develop and the process sectors. As a minimum, these need to provide a structure within which to innovate. Process manufacturers and suppliers will need to review what its needs are and how advances in discrete manufacturing can be beneficially incorporated.

Engineers rely on standards and specifications. Innovators look at the bigger picture. To satisfy the Engineers, TC65, the technical committee working on details for Industry 4.0 (I4.0), recently published a draft specification entitled "Smart Manufacturing – Reference Architecture Model Industry 4.0 (RAMI4.0)[(2)]". This, when applied to Industrial Automation is probably the key standard. However, before the idea gathers too much momentum and Engineers start working on a solution, the innovators in the Process Industries will need to identify the opportunities that can be gained adopting some or all of the ideas in RAMI4.0 which are directed more towards factory automation.

In reality, standards lag real world activity and this enables leading manufacturers to set rules with the possibility of multiple similar but incompatible solutions arriving. There are many interested parties involved in standards. What the standards attempt to do is level the playing field recognising that this may also hinder innovation.

Historically, the Process Industries are somewhat slower in adopting new ideas. In particular in the UK where it is seen as a benefit in keeping 30 year old technology running rather than investing in new equipment. Consequently, it may be that we have more time to review the standards developing in the process automation sphere before we move the process control solution environment forwards.

The following sections look at where we are today in the cycle of innovation and then focus on the business case.

Industry 4.0 – The Concept

I4.0 aims to extend and integrate further, attributes of the smart factory model. At the manufacturing level, it provides a digital history of product from manufacture to scrappage/disposal along with operational data, component and asset locations both in the process design and the physical space. This data crosses all areas that are critical to the design and service lifecycle, but with a focus on better integration of data and availability of information.

This larger repository of data also adds significant opportunity throughout the whole supply chain, not just at the process control level. It is the combination of control and supply chain that should benefit through innovation, with a greater emphasis on the connected world and business levels as addressed later.

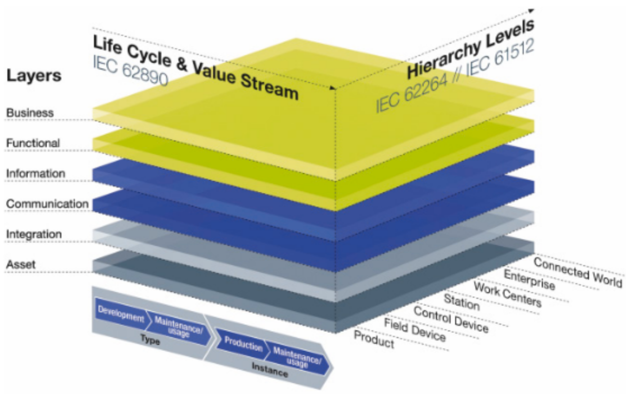
A review of the core RAMI4.0 architecture model from a process perspective reveals a new formal structure but is still heavily reliant on existing standards. The key ones being:

- IEC 62264-1 or ISA 95 – the system hierarchy and interoperability model or Enterprise-Control System Integration
- IEC 61512-1 or ISA 88 – the batch model

These standards have been around since the end of the 1990s and Distributed Control Systems (DCS) have been implementing them for well over two decades. I would question if a development of these standards (evolution) is applicable to our future or should the opportunity be taken to start again with a clean sheet (revolution)?

RAMI4.0 – Architecture Model

RAMI4.0 has developed a 3D architecture model that references lifecycle, hierarchy and layers, as shown below.



The process industries will relate to this model with little issue but it is complex, especially at the application level. It is necessary to take a step back and revisit the issues and needs of the process side and see how this model can be used, or not.

RAMI4.0 Model and the Process Industry Needs

So, some questions arise; what are the benefits to the process industries of this evolution of the automation model and is it more than documenting formally what we already do in the today? Does it lend itself to innovation or handcuff us? Before we look at this, we need to note some key issues with the RAMI4.0 model whilst wearing a Process Industry hat.

I4.0 is intended to create digital description rules for a technical object throughout its entire lifetime. This task will take assets from the physical world and virtually represent them in the information world, where an asset is defined as "whole installations or parts thereof, electronic modules, subsystems and systems, machinery, plants and networks, services, concepts and ideas, plans, archives and programs". In effect, a digital model of the complete process.

I would suggest that the process industries have been doing this already. The use of data warehouses for the storage of detailed information on an asset (drive, valve, instrument), networks managed by an IT department, services managed pre and post installation using asset management systems and of course, the complete solution design stored as application software images, drawings and manuals. The only difficulty today being the integration of the different packages required to manage this solution especially if an end user wants to use "best of breed" technologies.

RAMI4.0 asks a question; "whether, and to what extent this information is made known to the information system, and how much of that information is presented in the system".

If a human is part of the system, surely it should be argued that where everything is available to review, better decisions will be made? However, the location and access/security would be part of this.

Prior to the information (not the raw data) being available, where should it originate? The asset, an edge system, the local IT servers, behind a firewall, or the cloud. How is it managed throughout the asset lifecycle and could this lend itself to new business models? If, as expected, the model is extended throughout the supply chain, this adds another access and security management headache and a review of IPR protection.

Each asset is categorised by its communication ability and in the case of the process industries:

- Without communications, e.g. a terminal
- Passive communications e.g. a wireless tag or barcode
- Basic communications ability e.g. a printer with Web management
- I4.0 communications, applied to protocols and transmission.

Identifying these attributes enables a focus to be made on populating data from passive and active systems and who is responsible for formatting the data.

So, it is probable that the Process Industry needs everything. However, we have learned from experience that having everything and then being able to use it gives us a headache. You only need to see the number of process plants that spend months doing an alarm rationalisation project. This history will guide innovators and quickly recognise that there is too much data for an operator to assimilate and software solutions will be required to automatically rationalise and even learn about the process.

Information and Communication and their relationship to other layers.

The Information Layer. This describes the data that is used, generated or modified by the function of the asset. The communications layer describes which data is used, where it is used and when it is distributed. Two subsidiary statements; "standardised I4.0 communication using a uniform data format" and that "relevant events can trigger events in the information layer and higher layers via the communication layer" introduce a complex data management requirement.

The Hierarchy Axis. This defines how data is disseminated, and the term hierarch, typically referenced from ISA95, builds up layers with managed communication. There does, however, appear to be a conflict with a statement later in the document that state:

> *"it shall be possible at all times for other users to query the state of each I4.0 component".*
>
> *"the model shall have state variables...in order to allow consistent querying of the state of the I4.0 component at a particular point in time"*
>
> *"there is a loose connection between the layers. Interactions may only take place between two adjacent layers or within a layer. Layers are never skipped. Interactions may be passed through".;*

These are key issues that will affect performance and data quality, to be discussed later along with the administration and security aspects of the solution.

Administration. Whilst the use of an administration shell provides a sensible container from which to manage assets, components etc., the connectivity is defined as being distributed on one or more IT systems. The ownership of the IT and Industrial Network "war" has raged for what seems like forever, thus a key point here has to be the definition of "IT" where there is a lot of discussion concerning the merger of IT and OT.

All of the above create complex design and management issues throughout the solution chain and should not be underestimated.

Data

For I4.0 to work, it requires data and the definitions of the types of data, while valid, fails to address the most common problem in Industrial Process Control; no one wants the responsibility of filling in the base data.

It is time consuming and often missed as a cost at the start of any project. The RAMI4.0 defines 4 levels of data; basic, mandatory, optional and free properties. How many asset management systems have been sold only to fail where no commitment is made to management resource to maintain it. I4.0 addresses the need but provides the escape clause by defining "optional" and "free". It will be up to industry to act upon it.

Data is not just asset data but process, production, financial, order, supply and quality, to name but a few. RAMI4.0 supposes that data is moved between layers. Once data moves from one layer it becomes information. By that, I mean that one layer may not keep the data in its original format, especially with timestamps. The argument here is that there should be one data repository, for example a cloud, and that, with sufficient security can be accessed by not only the internal process systems, asset management systems and forensic data analysis, but also by the external supply chain.

Proposals

Noting all the above, how could the process industries develop, as a minimum, with RAMI4.0 to maintain a lead in smart process manufacturing with integrated supply chain and customer management? There are several areas to engage in.

Issues to be addressed at the Process Level

It was noted above that one issue around information is who generates the base data and where is it stored. Once a system is delivered, the priority of the manufacturer is to make something, sell it and receive revenue, in most cases, as quickly as possible. If information about the plant is not available as the project is handed over, the chances of it being inputted to an asset or cloud database reduce. Certainly, the quality of the information is reduced. Similarly, once a new plant is commissioned, maintenance still focuses on keeping a plant running rather than investing in preventative opportunities.

RAMI4.0 does have data structures for equipment. If this is to work well, the data about each asset needs to be available and fully populated with the asset. Either on-board the asset where it can be accessed over the network, or on the internet as a downloadable document that can be automatically imported. Data entry during design is significantly reduced, possibly only to the level of formal name, address and location.

Industry will need to consider the following:

- Where an instrument is intelligent and has network connectivity, data is embedded and can be requested by the main IT or asset system. Where not, the manufacturer supplies the data from a web based file.
- The data structure needs to be standard so any device can be purchased and integrated regardless of manufacturer.
- Take the opportunity for developing self-aware, plug and produce solutions, i.e. put the instrument on the network, it lets the relevant applications know where it is and starts operating.

Issues to be addressed at the communication level

There are conflicts in the RAMI4.0 model with respect to the use of the ISA95 layered communications model and the potential of an Industrial Internet of Things (IIoT) model that is basically flat in nature.

"It shall be possible at all times for other users to query the state of each I4.0 component" with the caveat that "Interactions may only take place between two adjacent layers", creates a conflict.

There is a lot of discussion concerning two new open protocol standards to address this, OPC UA(3) and MQTT(4) but I would think that a flat network with producer consumer protocols would serve the best way forwards to making sure systems work with data and not information.

Networking will be required from the basic instrument and onwards up the network and powered networks, for example Ethernet Powerlink(5) are starting to become available and reliable.

As a suggestion, Process Industry equipment suppliers will need to look at a product development plan that takes this into account.

They could provide an asset which only has a digital connection. For an industry brought up on 4-20mA this is a huge change, but such a solution would enable the asset to transmit its PV and status on a regular basis and respond to a background configuration request. The key benefit here is that no longer do applications such as Asset Management or Historians need to extract their data through various layers, with the possibility that the data received has been corrupted or sanitised by the systems in-between, but they get actual live data. True producer/consumer.

Start to look at physical I/O becoming a thing of the past. Instrumentation takes the readings and reports the values digitally. Control setpoints to drives or valves, for example, are transmitted digitally. Even real I/O modules that would be needed for none communication enabled equipment, would communicate digitally. The days of the marshalling cabinet are numbered, which was a view of Fieldbus which may have arrived before the networks and processing power was sufficient to realise the idea, especially with larger systems.

What we now aspire to is a fully digital network that is secure, fast and resilient and that exceeds the available solutions of today. Each asset is known about on the network, documented automatically and has its full lifecycle managed. Not only that, but the I4.0 approach reaches into the application software control solutions and so on.

Management and Security

These are very emotive subjects. If the development of a secure and highly available Ethernet based network is required, manufacturers of Industrial IT solutions need to envelop these demands and supply them.

Industry 4.0 is a full mix of broadband internet, industrial and office network requirements. All have a different focus. In particular, office/database systems have occasional high bandwidth demands whilst industrial networks have steady demands. Internet suppliers have demand throttling. There cannot be any favouritism in design and management of such networks, thus manufacturers will need to amalgamate their IT and OT departments and work closely with external broadband suppliers. Without this, the move from an ISA95 model to a flatter I4.0 model will be very difficult.

Security then becomes an issue. RAMI4.0 makes a statement concerning who should have access to the data. In reality, there is no real reason why everyone should not see everything, but only certain people can modify it. This would reduce the administration of a system. Network security overall will develop with cloud based computing having to prove its security and thus data access managed under this remit.

Drivers for the Manufacturers.

The key drivers are productivity and efficiency. Industry 4.0 and RAMI(4.0) when applied to the process industries, could provide cradle to grave management of an entire operation. Innovators and suppliers see that best of breed sells, as integration is a given. Maintenance solutions are inherently self-configuring. Design, implementation and commissioning costs are all reduced as are delivery time.

But this is only looking at the benefits to the process control side, some of which have been implemented over the years. The RAMI(4.0) satisfies the Engineers but not the innovators. Innovators are looking at the big picture:

- How can forensic analysis of data improve performance before a system fails?
- How will suppliers and customers link into the digital supply chain?
- Where will Industry 4.0 provide cost savings?
- If cloud computing becomes the norm, what is really required to integrate the supply chain?
- How do we get a specific manufacturer from here to there when investment is so limited?
- When will we change the idea that keeping something running for 30 years is a good thing?
- An integrated supply chain that knows when to deliver feedstock, automatically invoices and gets paid along with a customer who knows when to collect goods and also automatically pays has to be beneficial.

Hurdles

There are, no doubt, many hurdles, but significantly more opportunities. The process industries operate in a conservative environment. However, with a new generation of engineers used to instant gratification, and many years of lessons learned, it should be possible to successfully address them.

Is there a Business Case for Industry 4.0 in the Process Industries?

The previous section looked at the ability of the Process Industries to innovate a supply chain operation taking benefits from standards and ideas emerging from the thrust of Industry 4.0

To meet the key objectives; improved efficiency, reduced costs, integrated supply chain etc., there is still a way to go, so the two key questions have to be:

- What will it cost?
- Can the benefits justify the investment?

In simple terms, a cost benefit analysis.

The development of a business case covers many interlocking and smaller unit scenarios. For example:

1. From the instrument manufacturers perspective:

   What is the cost of developing a range of standard instruments that meet the generic I4.0 specification (focused on data and protocols) and what is the likely market price and timescale for the return on this level of investment? Do we really want to supply digital only systems?

   A business plan would also need to identify how and when these new instruments would be purchased, especially as these items tend to have a long-installed life.

2. From the product manufacturers perspective:

   I4.0 will need to form the hub of the enterprise. Deloitte published a paper "Industry 4.0 and the chemicals industry. Catalyzing transformation through operations improvement and business growth"[6]. Some key points identified what will be required to extract the benefits, but as with all things, there will be a balance between investment and returns.

   To achieve full I4.0 benefits, developments will be required in:

   a) Process Analysis, Digital Virtual Models and Forensics. There is already a wealth of data available in various production databases and historians. The higher the quality of data coupled with more analysis, including the ideas around forensic process analysis, using cloud services to perform this, the higher the quality of product. The key costs here will be the implementation of a database structured to use both existing data and that from new I4.0 instruments. Whether this is generated in house or externally becomes a management decision.

   b) Predictive maintenance. This has already been discussed above and today, there is still a reluctance for companies to configure and use in anger PM solutions, still relying on reactive maintenance and redundancy of key components. I4.0 will help but the investment will require not only money but a change in mind-set.

c) Demand forecasting using more widespread data can significantly improve the production cycle. There are many examples of how this is done today, though the processes are not specifically integrated. For example, Google can report on the number of queries for the common cold remedy. This data can be used for supermarkets to increase their stocks and for manufacturers to increase production to meet the anticipated demand. So, demand forecasting from external data into the business models managed under I4.0 would be an asset for devising a truly accurate production cycle.

d) Supply chain planning becomes part of the demand planning cycle. If the raw materials suppliers are integrated into the production facilities demand plans, they can also increase or decrease production accordingly. This follows through to the downstream supply chain from factory to customer. Again, this will require the transport companies to be integrated into one system.

All of the above require significant investment in tools that will collect, analyse, report and initiate activities across the supply chain. However, this is one of the more costly areas of investment. It requires hardware in the form of large database support systems, analytics software, IT infrastructure, Security and people.

These are starting to become available with suppliers of large cloud computing centres, for example Microsoft Azure and analytics applications from companies including IBM SPSS Modeller, TIMi Suite and Angoss Analytics, to name a few. They reduce the initial cost and there are solutions now that allow the purchase of results and not infrastructure, but each company needs to invest in teams that present the data and understand the final requirements.

Some companies do not like the idea of outsourcing this solution as their data is key to the profitability of their business, thus they may wish to implement the analytics engines inside their firewalls.

3. From the supply chain perspective:

   For a supply chain entity, they will need to look at their investment in systems that are fully integrated into their supplier systems. Today, they would need to consider the longevity of a contract with any one company, however, I4.0 should produce standards such that is you are compliant, who your customer is will be irrelevant. Thus I4.0 investment will be required but not a risk. Peter Reynolds stated in an IoT paper on the benefits for Process manufacturing can be summarised where "the OEM develops stronger customer ties by enhancing service capabilities predicting asset performance[7].

4. From the End Customer perspective:

   A customer wants to place an order, plan for when it will be available and organise delivery. You can look to business model like Amazon for this. If the customer requires a batch of bitumen for road building, he will want ease of purchase and guaranteed delivery for what could be a very large quantity of product. Any I4.0 development must focus on the ease for customers to place orders and of course manufacturers to receive payment, preferably without any human interaction.

Develop a Business Investment Model

Cost **A view of the investment required.**

Hi – A large percentage of the available development budget as new technologies are required. Long period for the amortised cost. >5yrs

Med – Technology exists but will need reworking at hardware / application software level. >2yrs < 5yrs.

Low – Minor software upgrades.

Benefit **A view of the longer-term benefits**

Positive – Will improve sales and provide a return on investment within 1-2 years.

Neutral – Will maintain sales and provide a return on investment within 2-3 years.

Negative – Anticipated sales are unlikely to provide a return on investment within 5 years therefore may need to be considered a portfolio requirement.

Note: The actual GBP values of investments should be a simple ratio of company size. Larger companies have bigger budgets but more complex implementations. SMEs have lower budgets but similar investment ratios.

Instrument Manufacturer

Activity	Cost	Benefit	Comments
Become engaged with the vision and assist on standards developments but as a minimum, have an awareness of the new standards in development.	Lo	Positive	GAMBICA is positioned to support Instrument manufacturers in this process.
Add I4.0 communications onto a standard analogue instrument.	Hi	Neutral	The focus must remain on the accuracy and repeatability of the measurement and should not find that costs are being diverted from the instrument development cycle. Do not underestimate the costs.
Add I4.0 Communications structure into existing digital product.	Lo	Neutral	It would be hoped that any existing digital instrument will already have the communications available for other protocols e.g. HART. Thus, implementation of I4.0 as a data stack and protocol should be simple.

Supply Chain

Activity	Cost	Benefit	Comments
Integrate with customer I4.0 "cloud".	Hi	Positive	Many supply chain companies in the process sectors already have semi-integrated systems. Full integration will look to working with their customers data clouds and developing a formal sales relationship.

Product Manufacturer

Activity	Cost	Benefit	Comments
Define & Purchase IT and infrastructure	Med	Positive	IT Infrastructure should already be budgeted for, thus it should only be a redirection to other products.
Specify and implement cloud based virtual production solution.	Hi	Positive	This has to be right, well defined and accurate. Project & Cost control are key to success.
Develop a simple IT/OT management structure	Lo	Positive	Reallocation of existing resource
Define and manage key suppliers	Lo	Positive	Most companies will use an approved vendor list thus this can be updated to confirm availability of system integration.
Invest in productivity tools that can use the data you are generating. For example, large chemical processes may benefit on forensic process analysis comparing actual data with the virtualised process	Hi	Positive	If the standards develop, the manufacturer will be able to invest in the best of breed product for his productivity tools. However, the level of investment may well be dependent on unit price and production quantities.

Product Customer

Activity	Cost	Benefit	Comments
Define & Purchase IT and infrastructure	Med	Positive	IT Infrastructure should already be budgeted for, thus it should only be a redirection to other products.
Develop an investment programme to integrate local purchasing and	Med	Positive	Automated ordering, scheduling and billing offset by reduced finance and scheduling activities.

billing directly into manufacturers "cloud".			It is hoped that as integration standards emerge, this will not lock you in to one supplier.

Issues:

The report "Who uses I4.0 in Germany" [6] provides some insight in German thinking (though the data is based on 2015 research).

"49% of users and planners think that the can keep their sales stable..."
"72% or respondents say that investment costs are the main obstacle".

A more unsettling number comes from a statement from Cisco [8] who predict that the IoT, and by inference I4.0 as a percentage of this, could be worth $14 trillion over the next ten years. That is a huge cost to offset through improved efficiencies alone.

Conclusion

I4.0 and the transfer of ideas into the process manufacturing environment require a step back from the current hype in industrial manufacturing. Process companies across the supply chain need to get their innovators to be shown the problem and then with the information available to them around I4.0, develop a plan. This is not a 3 year plan but a 10-15 year plan for brownfield projects and an I4.0 ready design for green field projects. Where and when shall we spend our money and if I spend it now, am I on the right path to a fully integrated solution in the future with early adoption providing the 3 year return my accountants require?

The development of the standards must not be seen as strangling innovation, but as tools. As with all standards, it is the industry that writes them, so become involved.

I4.0 is here as a concept with early recognition of benefits in the Process Industries

The standards that exist will help the Process Industries set their development strategies.

Manufacturers must innovate their business models across the complete process, from orders, to production, maintenance and forensics and on to support at all levels. Suppliers must do the same. Look at selling the data not the products and extending responsibility for the life of the plant.

Ultimately, the question has to be "Invest or Risk it"? possibly an older idea is "Invest or die"!

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