A Yokogawa Company

DIGITALIZATION MANIFESTO

Now is the Time

All about EXCELLENCE

At KBC we believe in a world where plants operate with:

No safety incidents

No unplanned outages

Rigorous adherence to operating plans

Agile response to market changes and plant disturbances

A motivated and informed workforce

A culture of profitability

We call this 'Excellence'.

KBC exists to help its customers in the Energy and Chemical industry realize value through achieving excellence. Digitalization is one of the key strategies a plant can adopt in pursuit of operational excellence. We define Digitalization as:

> **The scalable application of the digital technologies, and alignment of the organizational capabilities that we believe an energy or chemical process operation should have and master, with digital information at the core, in order to achieve excellence.**

KBC is owned by Yokogawa. Founded in 1915, over a hundred years later, Yokogawa is one of the world's most successful industrial automation providers. Combining KBC's focus on operational excellence with Yokogawa's expertise in operational efficiency, safety, quality and reliability makes us the global leader in Digitalization in the Energy and Chemical industry.

This document presents KBC's Digitalization Manifesto. It outlines how we believe Digitalization can be applied wisely, demystifies the jargon, describes practical solutions and demonstrates value. It is based on our hands-on experiences working with some of the world's largest and most complex companies in the Energy and Chemical industry.

Now is the time

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1. WHY DIGITALIZE?

Applied appropriately, Digitalization allows the facility to manage day-to-day performance safely and reliably, learn from the past and respond to future swings in market dynamics, operate at a true optimum, squeeze down on the gap between potential and realized margin, create more utility for the end customer/consumer, and outmaneuver competition.

It also enables a process operation to extend its problem-solving ecosphere beyond the plant: to engage the support, brainpower and technologies of its key partners, customers and suppliers who can each bring their own specific expertise and experience to augment the plant's own capabilities and resources.

It can turn a distracted organization that is bogged down reacting to day-to-day issues and inundated with data, information and advice, into an agile, well-tuned machine that anticipates issues and organizes to prioritize and solve them before they escalate.

KBC recently commissioned a survey of 100 operations leaders across the oil refining and petrochemicals industry to understand how they are responding to current market conditions and setting themselves on a more sustainable path. One of the three major trends identified was the influence of technology on the industry. Respondents showed a strong desire to obtain a digital blueprint for the future, yet felt under-prepared within their organizations for the adoption of current technologies including the Cloud, IIoT (Industrial Internet of Things) and AI (Artificial Intelligence).

New technology will potentially disrupt the whole industry leading to closure of those left behind, but significant upside for the successful early adopters

Some plants will gain measurable competitive advantages from large scale adoption of new technology, but this will be the exception rather than the rule

We will adopt new technology for some valuable niche applications but on a large scale our industry will stay the same

We are quite conservative; our focus will be on the adoption of proven technologies, with new technology mostly on trial

Figure 1 - Views on the influence of new technology in the next 5 years.
Survey conducted for KBC by IQPC (International Quality & Productivity Center)

Our research shows that Digitalization leaders can access as much as 800% higher human productivity in operations, compared to industry laggards, and we believe Digitalization is only just beginning. The potential business impact is truly transformational.

KBC believes that a large part of the industry is confused or irritated by Digitalization. Some feel it is an IT issue and do not understand its relevance for operations; some are frustrated by the plethora of buzzwords; some see it as hype and fail to see the value proposition. Others have embraced Digitalization but don't apply it holistically. Digitalization leaders, however, are taking advantage of this confusion to make huge strides forward in productivity, efficiency, flexibility and agility.

We fear that without recognizing and responding to digital transformation challenges (change management and digital capability development) the potential for Digitalization will not be fully realized – it will not be completely adopted and risks falling into disuse.

We therefore wish to address in practical terms, and good for implementation today, how Digitalization technologies and best practices can help organizations to:

- Capture value through unexploited efficiency or productivity gains;
- Discover and generate new revenue;
- Execute and sustain that value in the face of continuous change and disruption;
- Solve problems that are not viewed as solvable today;.
- Improve competitiveness;
- Stay ahead of regulatory requirements.

2. PLANTS HAVE BEEN 'DIGITAL' SINCE THE 80'S – SO WHAT'S NEW?

The 1980s saw pneumatic and electronic control systems being replaced by digital controllers. Not only did they reduce the cost and increase the reliability of controlling a plant, but they enabled smarter, more advanced control strategies, and generated a significant volume of data for analysis and economic stewardship.

At the same time, the personal computer revolution was happening. Tools were available that liberated decision-makers from the data processing department fortress, empowering engineers and managers, and enabling a whole new world of analysis and decision-making.

But if we look at where we are 40 years later, an enormous amount of value is still left on the table. The tools of the 1980s are largely still the tools of today. We 'Digitized' but we did not 'Digitalize'.

By '**Digitization**', we mean the transformation from analog to digital or digital representation of a physical item, so it can be processed by a computer with a goal of better decision making and automation of processes or workflows. So even though today sensors are cheaper and more plentiful, processing power and data storage have grown massively, and the user experience is much better, most plants still use their digital systems to gather information and feed it to people to make decisions, or to automate standalone processes. They may do it quicker and with more data, but they are still doing today essentially the same as they did in the 1980s. With Digitization there is little or no change in the work processes, user experience, relationship with vendor or culture.

'**Digitalization**', by contrast, has a bolder ambition. It uses digital technologies and data (digitized and natively digital) to create revenue, improve business performance (not just business processes) and build a digital culture whereby digital information is at the core. It seeks to achieve all that we sought from Digitization in the past, albeit more effectively and efficiently, PLUS it aims to create new value.

Digitalization is more about the improvement of work flows and processes, organizational culture, changes in supply chain relationships and the application of knowledge and information rather than 'just data'. It represents a transformation within an organization.

If we think of a car factory today compared to the 1980s, they are unrecognizably different. The old factory ran to a plan and produced cars according to a demand forecast; it was largely a manual production line; quality was poor; customers had little choice and pictures showing fields of unsold inventory regularly made the news. Today, production is highly automated and demand-driven – every car is different in some way from the others according to each customer's individual requirements; robots pick and choose components for each build as it flies down the production line; quality is excellent, costs are down, and inventory is under control.

The music industry has gone through a similar transformation. In the 1908s the music industry digitized from vinyl to CD - the format changed and quality improved but the vendor-client relationship remained the same, costs were unchanged. Contrast that with streaming music services today - customized to each user's tastes, delivered as a service rather than a product, and served up to multiple devices in real-time. The music industry has now digitalized, new players have emerged and some old players have disappeared, and the customer-vendor relationship has changed completely.

In the context of a process plant where largely commodity petroleum, chemicals or power are produced, the Digitalization focus is not so much on each individual customer, but on the collective customer base – the market itself. A Digitalized plant will make the most of its capabilities (physical assets, supply chain, human resources) to operate optimally in the face of changing economics, feedstock/fuel availability and operational constraints. A static, out-of-date plan does not drive the plant – the market frequently adjusts the plan and the plant continuously responds in the most profitable way.

The tools provided by Digitalization are holistic and scalable in nature – they consider the impact of a change in one area on the end-to-end plant economics; they are smart enough to identify problems and recommend solutions, not to just present information without context; they are easy to use; they automate as much as possible; their reach extends via the Cloud beyond the corporate boundary. On a Digitalized plant, the human is an implementor and supervisor of strategy, rather than a number-cruncher and tactician; operating costs are minimized; production is optimized; assets are flexible and fully utilized; the plant is safe, and the environment is respected.

3. KBC'S DIGITALIZATION VALUES AND PHILOSOPHY

When KBC talks about Digitalization it is in the context of the digital applications and capabilities needed to achieve operational excellence. Applications and capabilities that derive their value from knowledge of how the plant has operated in the past combined with its current and future potential, and an actionable optimum path to achieving and sustaining that potential.

We are not talking about the discrete components of generic IT hardware or software infrastructure, the pros and cons of on-premise vs edge vs Cloud, or BI (business intelligence) systems and the like. We leave advice and deliverables on these specific components to others who focus on them. It is not that these do not matter, nor that we do not have knowledge of them or understand where and how they interact with operations, but rather that even though they are important IT components, they influence the main value drivers of operational excellence far less.

To decide what digital applications and capabilities are required, it helps to map out the various digital challenges that contribute to operational excellence (or indeed to a lack of excellence). Once these challenges are known and understood, rather than addressing each one in isolation, operational excellence requires a holistic approach that addresses all challenges simultaneously. Not only will this eliminate duplicate or conflicting effort, it assures an optimum outcome.

We call this being '**Digitally Wise**'.

KBC's proven customer value around Digitalization is therefore to help customers decide on their unique best set of applications and capabilities; assist with the implementation and accommodate legacy applications as required; innovate with new business models beyond the plant, and ensure the solution is always available and in use to deliver and sustain operational excellence.

For KBC, Digitalization embraces the following philosophy:

3.1. OUTCOME-ORIENTATION

In Digitalization, there is a strong risk of applying technology for the sake of technology, especially with the pressure to deliver something with one of the latest buzzwords – IIoT, Industry 4.0, Cloud, Edge, Big Data, Analytics. The industry must not fall into that trap.

KBC's Digitalization philosophy therefore focuses on valuable outcomes:

- Efficient delivery of value;
- Discovery and capture of new value;
- Shorter time to achieve value;
- Sustainment of value achieved;
- Competitive advantage.

To determine the appropriate Digitalization solutions to recommend to our customers, we developed the KBC OpX Management System. The KBC OpX Management System maintains a focus on achieving business and financial goals, and aligns all our recommendations (including Digitalization recommendations) to these goals.

Figure 2 - KBC's OpX management system: Built on a foundation of excellence, guided by leadership

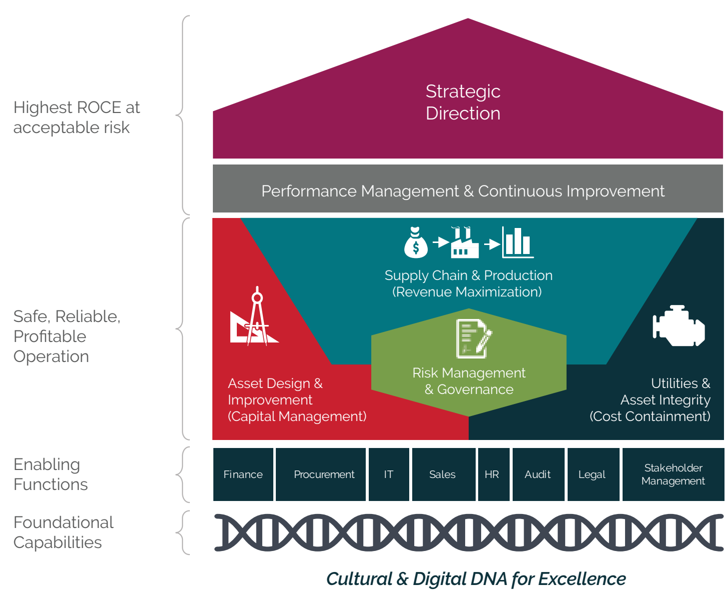
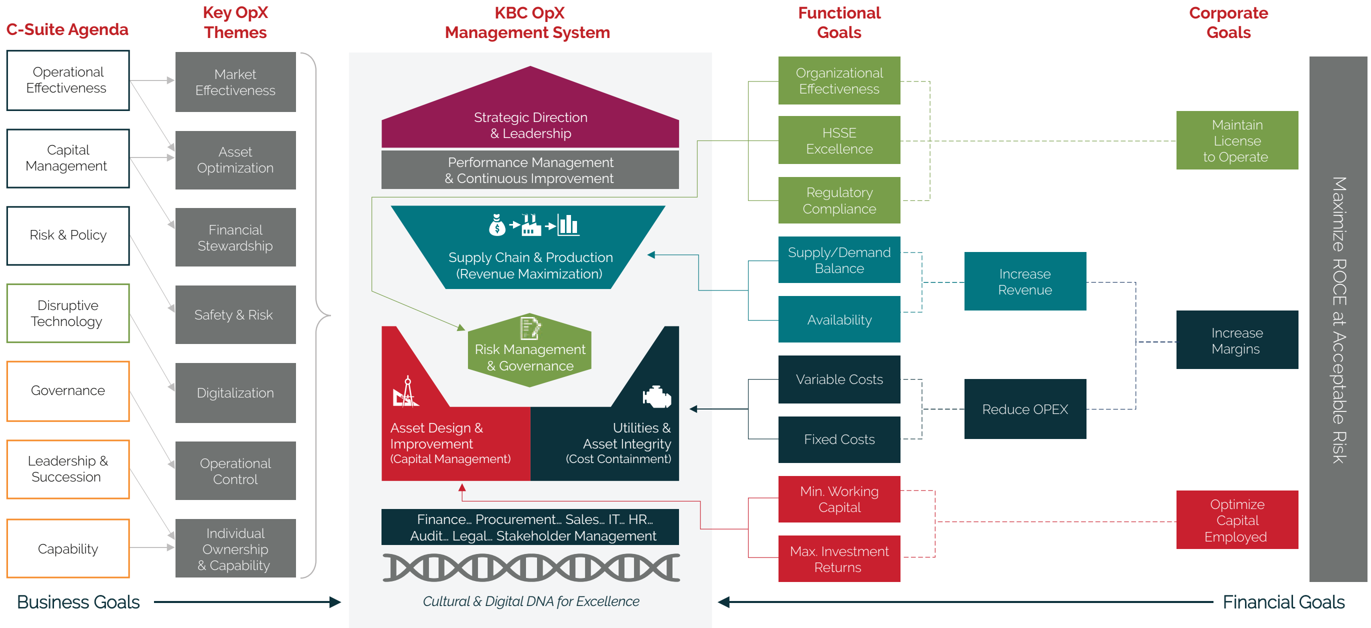


Figure 3 - KBC's OpX management system aligns business and financial goals with actions



KBCs philosophy is therefore to work backwards from business goals and constraints, to define the Digitalization technologies and approach to deliver on those outcomes, rather than start with new technologies and look for places to apply them.

3.2 HOLISTIC IN SCOPE

We take a holistic approach to Digitalization.

In Oil Refining and Chemicals, by holistic, we mean from feedstock receipt through processing to blending, quality control and outbound logistics as well as utilities and environmental. In Upstream Oil and Gas we mean life of field. In Power we mean generation (thermal and renewables), transmission and distribution.

In general, our holistic scope involves the integration of various factors, including supply chains, planning, asset operations and optimization, operational risk assessment, maintenance, health and safety engagement, and asset management and integrity. It means our solutions often cross internal organizational boundaries. Our business processes and best practices form a structure of effective governance that ensure that solutions adopted are measurable, repeatable and auditable as required.

3.3 FUSION OF TECHNOLOGY AND EXPERTISE

We believe consideration of human factors and technology are equally important in crafting a Digitalization solution. Technology is supposed to support and empower the human; it is supposed to capture and enable the spread of human knowledge and experience; it is supposed to offload mundane, repetitive tasks to free the human to innovate.

We build technology that works the way our customers do. We are operators and engineers at heart. We emphasize the practical, the safe and the environmentally sensitive in the solutions we offer. We nurture these abilities and re-tune our business competencies to digital ways of working.

We also recognize that the maturity of an organization will determine the necessary balance between technology and expertise. We expect digitally wise companies will already know where they can gain value from Digitalization and will be seeking technologies over services – we therefore tailor our services for these organizations to be specific to the technology being applied. Developing organizations, on the other hand, seek more advice and support, and therefore our solutions usually start with consulting services to discover sources of value, understand impediments to success, and align solutions to address them.

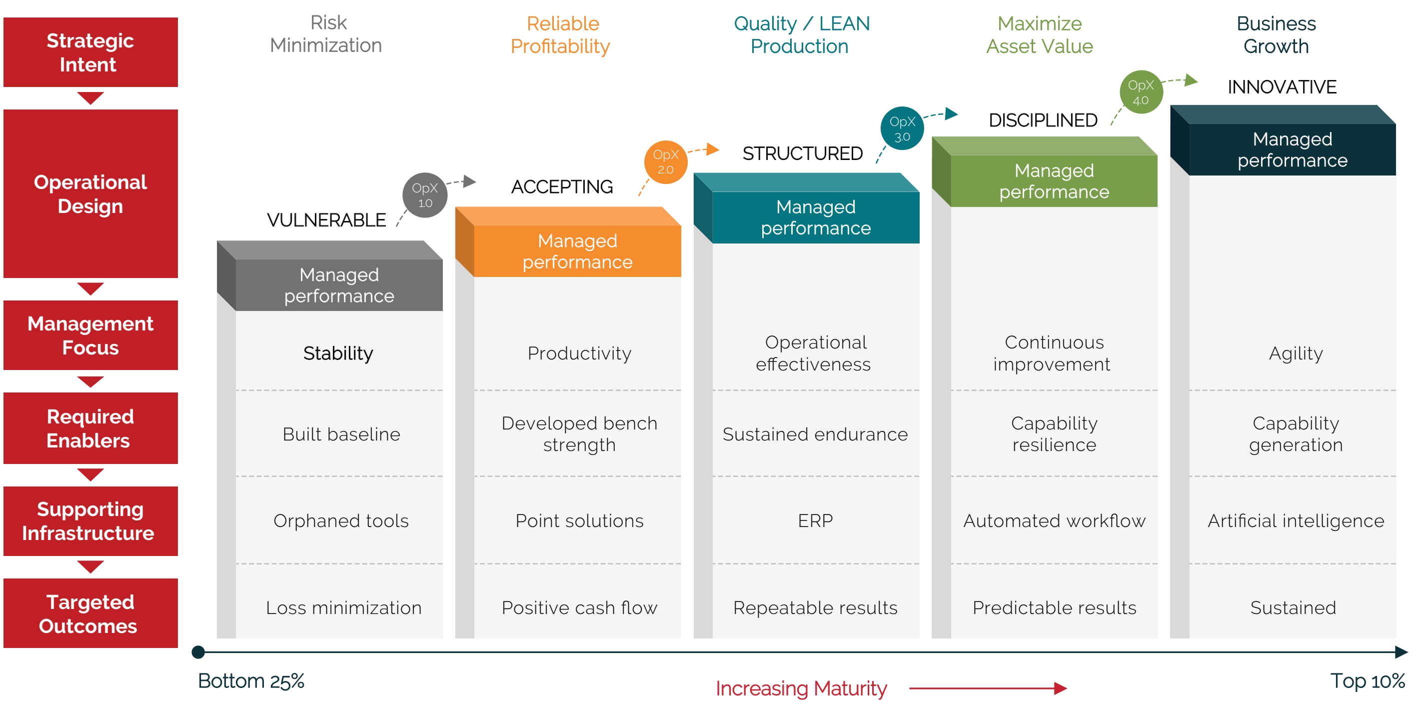


Figure 4 - KBC's OpX maturity model guides the technology/service balance

3.4 CLEAR AND DELIBERATE DIGITAL TRANSFORMATION ACTIONS

Digitalization brings organizational challenges and opportunities. As well as introducing new technologies (which requires new skills) and new business models (which requires a new mindset), it crosses typical organizational boundaries (which requires collaboration and deep understanding and buy-in to underlying goals).

For developing organizations in particular, adoption of new digital technologies is difficult to accomplish. For all organizations, Digitalization is a potentially profound transformation of business and organizational activities, processes, competencies and financial models to fully leverage the changes and opportunities of digital technologies and their sustaining impact on operational performance in a strategic and prioritized way.

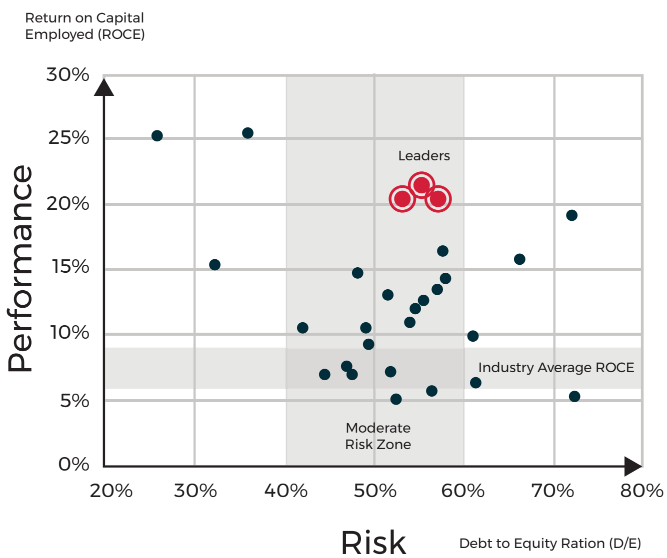
We therefore provide **Digital Transformation** services (change management and digital capability development) to help our customers on their journey to Digitalization.

Our heritage uniquely qualifies us to effectively drive Digital Transformation where it matters most – with front line operators, unit engineers and operating management on the 'shop floor'. The Digitalization journeys we chart with our customers are tangible and grounded in reality. The approaches we recommend deliver clear line of sight to goal achievement.

3.5 KNOWING WHAT EXCELLENCE LOOKS LIKE IN ENERGY AND CHEMICALS

KBC specializes in Energy and Chemicals.

Our Digitalization solutions are specific to our industry, not generic ones. We know this industry well because we came from this industry. With this knowledge and experience we know what 'excellence' looks like. We know how to take the best from other industries and carefully apply it to ours.



Note: 2012 – 2016 data averaged for oil companies. ROCE defined as EBIT divided by long term debt plus total equity minus cash. Source: Bloomberg, company websites and KBC analysis.

Figure 5 - In our industry, leaders consistently find the trade-off between performance and risk

3.6 RESPONSIVE AND ADAPTIVE – LEADING EDGE, NOT BLEEDING EDGE

We recognize that digital technology changes fast and therefore we keep on the leading edge. We are quick to change and evolve our offerings and preferences as the world changes, always with an eye on how such changes actually create value for your plants and how you will manage any transition.

We screen out the noise and buzzwords. We pay specific attention to digital risks:

- An obsession with your data security and confidentiality;
- Solutions that are consistent with your organization's current maturity, strategic ambitions and associated resources and capabilities;
- Awareness of safety and environmental consequences of digital developments;
- Recognition that hiring and retaining digitally wise employees is costly and challenging.

3.7 COLLABORATIVE AND SMART

We understand that our customers have invested in legacy solutions that will be around for many more years to come. By focusing on their best economic outcome, we accept inclusion of anyone's technology in our proposed solutions, even our competitors'.

We build open and connectable tools. Our software products are modular – there is no obligation to accept a full technology stack from us.

We have a longstanding history of collaboration with our customers. We share our expertise freely and have established a reputation that we can be trusted to respect the confidentiality of information and data shared with us.

We pick our business partners based on their capabilities but limit ourselves to those partners whom we believe share the same Digitalization values and philosophy that we do.

We leverage the advantages that our parent, Yokogawa, can offer – their excellence in automation technology; their proven track record in taking on and managing large and complex programs of work, their financial strength and their global reach.

We co-innovate with our customers – commercializing solutions that have been built in-house and co-developing solutions to meet specific needs.

3.8 A DIGITAL TWIN. WITH TEETH. THAT WORKS.

A digital twin aims to be an accurate representation of an asset over its full range of operation and its full lifecycle. It is ideally created during the initial study to evaluate the feasibility of the asset. It is used and further developed during the design, construction and commissioning of the asset. It facilitates the optimum design of the asset and the training of the staff who will operate the asset. It works in the present, mirroring the actual plant in simulated mode, but with full knowledge of its historical performance and accurate understanding of its future potential.

KBC's digital twin has teeth. And it works. It is built on our rigorous first principles simulator. The plant model inside the simulator synchronizes with the plant model inside the EPH (Enterprise Process Historian) to ensure their separate representations of the plant remain aligned. Data gathered from the plant in real-time is validated and statistically reconciled to ensure that all physical and chemical laws are respected; and electronic noise and dynamic effects are eliminated through filtering, thereby ensuring that data quality issues are identified and mitigated.

Our digital twin allows "What if?" and "What's best?" scenarios to be run automatically to determine available strategies that maximize profitability. Experts can review the recommended strategies to assess the impact of each recommended approach. Planning and scheduling linear sub-models can be updated to reflect the proposed changes.

Only this way does the digital twin have teeth – it is not just a technological nicety but is powerful and effective; a digital twin you can trust to reflect reality and rely on for the quality and accuracy of its predictions. Our digital twin moves from design to operations with ease. Others force fit a design model into an operating environment without success.

The digital twin provides a single source of the truth for what's going on inside the plant at a molecular and asset level. It enables everyone to see inside and perceive things that are not being directly measured. It is wired up so that the insights are instantly available without data and model wrangling by end users, and run in a consistent way that everyone can understand and agree on. It drives convergence in comprehension and unity in decision making and action.

3.9 CONVERGENCE ALL AROUND

One of the challenges of Digitalization is that it does not conform to the neat organizational or technological 'buckets' many companies have created to manage their business. Most of the Digitalization action is happening at the intersection of two typically separate worlds:

3.9.1 IT / OT CONVERGENCE

Our customers acknowledge that data is a critical asset that needs to be harnessed to drive improvements in safety, reliability and profitability. The IT industry has established systems of record for various types of data such as the ERP system for all financial data; the CMMS for all maintenance assets and activities; the CRM for all sales matters; and the HRMS for all employee matters. Data in these systems is governed (i.e. managed and validated) and ultimately approved as the 'truth' when it comes to understanding and stewarding the financial health of the business.

OT (Operational Technology) data is at least as important as financial, maintenance, sales and personnel data. It is a critical asset that needs to be governed and leveraged through people, processes and systems to drive operational excellence. In most plants, process data is generated by various OT systems such as the DCS or SCADA, blending systems, dosing systems, fault detection systems, smart instruments, etc. We embrace the idea that the EPH should be the system of record for all operating data and its single source of truth.

The desire to have a single source of truth for all data types that can be consumed in decision making and execution is driving IT/OT convergence. We believe that for now, this ambition is held back by the slow pace at which our industry replaces its OT solutions. Our industry holds onto its OT solutions much longer than its IT solutions (25+ years for OT vs 5+ years for IT) because the risk associated with OT change is high – OT systems are typically mission-critical and have the potential to cause major economic and physical damage if they go wrong.

Instead of a single 'ocean' of truth, we believe there will still be multiple 'lakes' of truth for different types of information for the foreseeable future, each with overlapping representations of the models that describe the assets the data belongs to.

Our Digitalization philosophy is to adopt a best practice that ensures synchronization of the asset models among the various data lakes so that software applications can address problems by asset rather than by data source and data point and will always find the right information for the problem at hand.

3.9.2 FIRST PRINCIPLES / CORRELATION-BASED ANALYTICS CONVERGENCE

Our heritage is the application of rigorous process modeling built on scientific first principles. This has made us a global leader in the field of analytics especially in simulation of hydrocarbon systems and processes where the models are used for process design, investigation of change and performance management. Our simulators are widely recognized as best-in-class when it comes to fidelity and scalability. Uniquely, the same model used to design a plant can also be used for stewarding and optimizing the plant's performance once it is operating.

Recent trends in application of AI are claiming to provide similar capabilities but based on statistical methods – typically machine learning algorithms that observe patterns in behavior of the plant and attempt to correlate such patterns with positive or negative outcomes such as energy savings, yield improvements or machine failures.

Such AI approaches have proved unsuccessful for all but the simplest of problems – those where a correlation-based model is good enough to represent reality and where the optimum solution lies within the operating window already encountered by the AI algorithm.

We believe that AI based on correlation-based analytics will eventually have a strong role to play in driving operational excellence because it is relatively simple to use and fast to execute. It appeals particularly to the IT organization because it relies on technologies they are more familiar with and does not require deep chemical / mechanical / electrical engineering knowledge. It does, however, need some added intelligence to be included in order to overcome its shortfalls.

KBC's Digitalization philosophy is therefore for correlation-based analytics to work in ensemble with the first principles analytics. It can happen in two ways:

- For real-time performance management, the first principles model can act as the training ground for a correlation-based AI algorithm. First principles models can explore operating worlds well outside the operating window the plant has ever experienced and generate valid linearized models for the AI to use in those previously un-encountered regions.
- Cognitive AI can be trained to interpret the results of the rigorous simulator, homing in on what the problem or opportunity might be and presenting the engineer with a triaged, reduced set of options to explore further.

3.9.3 ON-PREMISE / CLOUD CONVERGENCE

The Cloud is already the infrastructure of choice for most business applications, especially outside the Energy and Chemical sector. However, it remains unexploited for most operational applications. The reason is that most valuable operational applications rely on a continuous feed of plant data which means they can never be isolated from the plant in a way that say an HR performance management system or capital budgeting system can.

This is partially addressed with 'Edge devices' living in the 'fog' between the real world of the plant and the virtual world of the Cloud to bridge the gap, but there is still a potential pathway for a 'bad actor' to reach the plant even through an Edge device.

From an IT point of view, the Cloud offers some compelling savings vs on-premise. But unless the operational risk associated with exposing the plant to the Cloud is offset by value created by the people and applications it serves, its use will remain marginal.

Our Digitalization philosophy is to make use of the Cloud where it truly creates value:

- **The Cloud can engage people and technologies from outside your corporate boundaries.** Expertise is leaving energy and chemical companies as the workforce ages, and it is becoming challenging to recruit and retain new talent in face of stiff competition from the tech industries. In remote locations and in developing countries, talent is just not available in sufficient quantities. The Cloud allows experts working for your vendors or working independently from home to remotely join in the day-to-day troubleshooting and profit improvement activities of the plant as if they were your employees present on site.
- **The Cloud enables applications to subscribe to external data feeds;**
- **The Cloud allows analytical capabilities to be offered remotely** by 3rd parties.
- **The Cloud supports and nourishes agility.** It allows experimentation and rapid deployment of new solutions. It makes solution updates trivial. Because cloud software does not have to be developed for many possible environments, it can be released much sooner as a minimally-viable product suitable for a single well-defined cloud environment – resulting in shortening of 'time to value' and easy replication of successes. Similarly, the Cloud also reduces the cost of termination - if a solution does not work out as expected, a cloud solution can often be switched off with little to no on-going cost because cloud commercial models are service-based (hardware can be re-assigned to other uses or even other clients and software licensing ends as the service ends).

3.9.4 PLANNING / SCHEDULING / MODELING CONVERGENCE

Planning and scheduling systems exist to solve specific problems. They are, however, usually based on the same underlying models of the asset and are both a simplistic representation of reality – dumbed down to make the solution process practical.

In Oil Refining, for example, planning tools are answering the question "Given forecast demands and economics, and the capabilities and constraints of my operating assets, which feedstocks should I buy, and which products will I make, and in what quantity?" Any error introduced because of simplicity of the LP (linear programming) model will result in a non-optimal answer to that question, and when applied in the real world changes in inventory will mop up any inaccuracies in the predictions during execution of the plan.

Scheduling tools in the same Oil Refining example are answering the question "Given my choice of feedstock and its estimated yield of products, how do I feasibly receive and blend feedstocks, arrange my storage facilities, move materials, blend and ship finished product" Similar questions are answered in the Power industry where the energy demands, economics, buy/sell opportunities, disturbances due to weather, and asset capacity and flexibility determine the best way to generate and distribute power.

Eventually, however, planning and scheduling tools will converge into one – they do not need to be different from each other if they can be easily configured to answer both questions. In fact, they don't need to be different from the rigorous simulator used for unit performance monitoring either. Planning and scheduling tools compromise rigor for convenience because the constraints of hardware and software technology available today do not make the use of a single rigorous product to solve all three problems practical – but that will inevitably change.

Our Digitalization philosophy today assumes there will be three tools for solving these three problems, but technology is driving towards a single unified tool based on rigorous simulation (in ensemble with statistical analytics), and this will result in major savings and will reveal as-yet undiscovered value.

3.9.5 ORGANIZATIONAL CONVERGENCE

For many companies, human productivity is quite low – a lot of time is spent on manual tasks manipulating and processing data and reporting. Because of this, each individual can only cope with a narrow range of responsibilities. This means that any holistic decision (and almost all significant value adding decisions need to be holistic) requires engagement and coordination of many stakeholders.

With Digitalization, automation of data processing, analysis and reporting drastically increases productivity. It allows individuals to manage and make decisions across a much broader scope. These 'asset decision managers' still consult point experts inside and outside the organization on deep technical matters, but carry responsibilities spanning traditional silos of engineering, operation, maintenance and planning. More and more, execution of the asset decisions will be undertaken by machines, and by a seamless mix of in-house and outsourced people spread geographically across the globe, collaborating via the Cloud.

3.10 PLANT DATA AS AN ASSET. GARBAGE IN: GARBAGE OUT.

No sound operational decision can be made without relevant and accurate plant information to support it. No timely decision can be made if accessing source information is difficult. And no automated actions should be allowed without reliable data inputs and confirmed availability of final control elements.

Our Digitalization philosophy considers plant data as an asset upon which operational excellence is founded. This means it needs to be governed like the valuable asset it is. People or software applications that will consume the data need to be able to trust it, and so the plant needs to be ready to supply it by applying a graded approach to software testing starting at the source, since only quality software produces data with a high level of integrity.

We recognize that this aspect is a critical step in building a digital success story. Digitalization from KBC will use such a graded approach to software testing to increase the integrity of data and mature the decision support capabilities of the plant.

3.11 EVERYTHING AUTOMATED WELL ALMOST EVERYTHING...

The more that tasks are automated, the more repeatable the outcome. If a start-up or shutdown procedure can be automated, experience shows that the number of unsafe and costly incidents is reduced. If it pays to drive a plant up against its operating constraints, then automating that strategy so it can chase fleeting opportunities for improvement has been shown to generate huge returns.

Automation comes at a cost, however, and with some risk. The cost is the number of sensors required and the need for them to be reliable. The risk is how it behaves in the face of circumstances it was not designed to encounter. Our Digitalization philosophy, therefore, is for our customers to invest heavily but wisely in automation, and to mitigate the risks through good design practices and supervision. Both KBC and Yokogawa are exceptionally well qualified in each of these areas.

3.12 SAFETY THROUGH TRANSPARENCY

Our Digitalization philosophy is to ensure customers understand how we arrive at their solution. We seek to deliver insight as well as results because with insight will come the outcome desired now and into the future. Without insight, it is hard to adjust strategy in the face of a future change in economics, constraints or environment; such failure could be economically disastrous or worse, unsafe.

For that reason, as far as possible, our technology is not a 'black box', but is open, and visible. We provide users with the ability to see, tune and customize its inner workings. We seek to develop the skills and capabilities of our customers to govern, modify and utilize the tools we put in place.

Challenge – How do I assure my plant is running at its full potential? Always?

A seemingly simple problem to solve:

Define the timeframe over which the crude feedstock is available to be processed; describe the main operating constraints of the refinery in that time period; obtain the crude assays for each available crude; create separate evaluation cases for each available crude (type and volume) to be added to the already known crude slate; run each case against the refinery LP model configured with the assumed constraints and applicable crude cost and finished product values; select the crude that generates the highest potential margin determined by the LP.

This gives the plant some level of assurance that it may be buying the right crude but gives no assurance afterwards that it was indeed the right crude or that when processed it delivered the anticipated margin.

A digitally wise oil refinery would have a different culture. It would apply some deeper understanding and drive accountability for the outcome. After all, how good a representation of possible future plant conditions and constraints is the LP model? The digitally wise plant would use rigorous (non-linear) simulation – simulation based on the actual physics and chemistry of each crude and each processing unit. It would consider more than just the main plant constraints – it would also consider the scheduling challenge and opportunity, the environmental issues and the risk associated with lack of staff's prior experience of running the chosen crude. But even then, having selected the best crude, it would apply processes and technologies to ensure the anticipated gain from the chosen crude actually materialized.

Crude meters would be checked for accuracy; actual crude quality would be verified to correct the 'text book' assay to match reality; the rigorous model would be re-run against this new data. An operational strategy to maximize the return on the actual crude being run would be established. Actions to debottleneck temporary constraints would be taken; advanced control applications would be adjusted to meet new goals; performance would be checked and re-assessed against the simulator frequently.

A management dashboard would be set up to monitor actual performance vs the performance predicted based on what was actually shipped vs performance predicted based on what the refinery thought it was buying, showing the actual economic return in comparison to the various versions of 'predicted' economic return. A digital twin of the refinery operation would be established to bring in outside expertise remotely, via the Cloud, as an extra set of eyes on the process – maybe the plant is short of resources; maybe the outsider has seen this crude being run before and can advise on how best to handle it.

A digitally wise oil refinery would be sure that the 'best' feedstock turned out to be as good or better than its predicted potential.

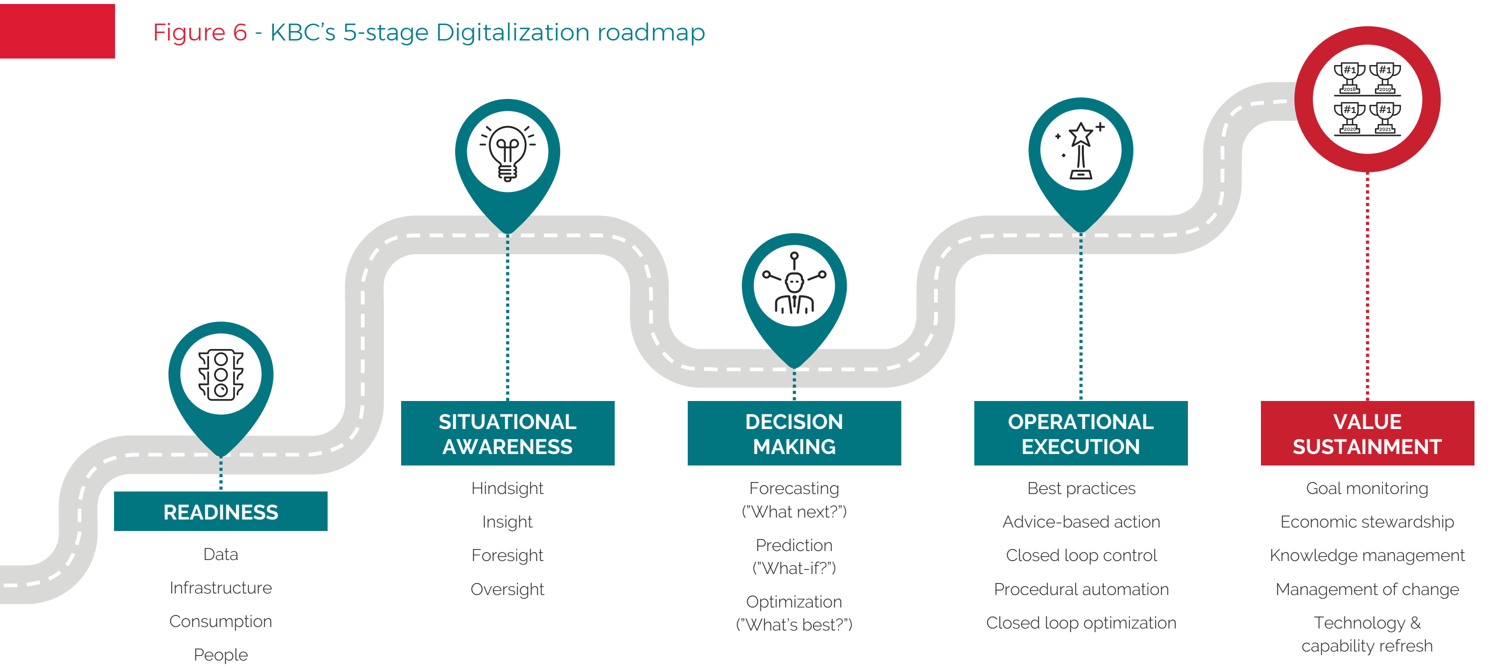
5. A DIGITALIZATION ROADMAP TO SUCCESS

All companies are at a different stage of their Digitalization journey. We have designed a 5-stage Digitalization Roadmap that we believe all Digitalization initiatives should follow.

When applied to a given operating challenge, our Digitalization Roadmap reminds us what to consider in order to recommend, design and build the applications and capabilities needed to achieve and sustain excellence. It also overcomes the barriers to success.

The following are the main components of each stage of the KBC Digitalization Roadmap:

Figure 6 - KBC's 5-stage Digitalization roadmap



5.1 READINESS

It has been estimated by Frost & Sullivan that process industries utilize less than 5% of the data that is collected – 95% of the data is either siloed (used selectively), dark (unused data) or lacks consistency in use. Problems of assigning context to data, and poor quality have also been identified.

To be ready for Digitalization, the impediments to data utilization must be addressed.

5.1.1 DATA READINESS

Before being ready to use data to make decisions or data that is being fed to software applications, a process needs to be in place to systematically assure its quality. Only then is it fair to declare its data store (the EPH data lake) as the system of record and make it available for critical decision making and automation.

Issues that we consider important are:

- **Data sufficiency** – Do you collect all the necessary values? Is there enough redundancy to be able to validate their readings?
- **Data trust** – Are instruments of adequate accuracy and reliability for their intended purpose? Are meters well calibrated and is the data properly labeled?
- **Data propagation** – When a change is made in the field, how does the system of record know about it? Which applications are affected by these changes? Are they designed and tested to cope?
- **Data governance** – Is there an ownership record for each data point? Is an audit trail kept of changes? Can automated data be overwritten and if so what happens to applications that used the old value? Are applications properly tested to ensure validity of source data? Is security set up to allow exposure of data within the organization yet limit risk of exposure outside?

5.1.2 INFRASTRUCTURE READINESS

Having data with a high degree of integrity is important, but not sufficient. It needs to be accessible to the users and systems that rely on it. This means that critical communications and storage infrastructure needs to be in place, designed with adequate capacity and secured against mis-use and bad actors.

Issues that we consider important are:

- **Physical infrastructure** – Is the appropriate segregation of plant and business networks in place? Are systems adequately sized for performance and scale? Do aging IT assets pose a risk? Are you compliant with applicable regulatory requirements/ commitments?
- **Security, privacy and confidentiality** – Is security up to date and tested? Is there adequate monitoring? Are processes in place for adding, deleting users and allowing external access? Do such processes extend to 3rd party access? Is there an incident response plan? What is the disaster recovery plan?
- **Software infrastructure** – Are software versions up-to-date and aligned across the organization? Are application interfaces secure, up-to-date and supported? Is application usage and license consumption tracked? Can applications easily port to the Cloud?
- **Cloud infrastructure** – Public vs Private vs Hybrid Cloud? Dedicated vs shared resources? How flexible is the service/support agreement to you and your 3rd party users? Are costs aligned with value? What happens on termination? Can you tell if data from the Edge is updating or valid? How secure is it?

5.1.3 CONSUMPTION READINESS

You've got the right data, it is in good condition, it is available on the corporate network or through the Cloud… But is it fit for consumption? By people? By software applications?

Anyone who has worked on a production plant will be familiar with the fact that sensors are not 100% accurate; measurements are not 100% repeatable; instruments fail or drift; and redundant readings are never the same as each other. Process engineers will be aware of the challenge of consistency within data sets – all the output flows must sum to the inlet flows; energy and momentum must balance too. Control engineers will understand the concept of dynamics – a measurement at one location is related to an action at another location at a different point in time because of transportation delays and thermal or chemical lag. IT people will know that only solid software quality assurance by means of a graded approach to quality will provide a high level of integrity of information as it is passed around the enterprise.

Most well-run plants will have a simulation model of the plant – maybe it was created during the plant's design stage, or maybe it has been created since. The simulation model can be a major contributor not only to one-time design changes or changes to operating strategies, but also for continuous performance monitoring, adjustment and optimization. To make this practical, the model needs to be set up as a digital twin, constantly synchronized with the plant via always up-to-date asset models of the plant for context, so that engineers can ask the model without delay how to improve from the current situation and the value of doing so.

For the digital twin to create value, inputs need to be right in context, so they can be relied on to make sound decisions. And the engineer needs to know what to do when the data is not right: Is it ok to substitute a bad or suspect value with a known good value or an estimate? How does knowledge that this is a substituted value propagate through applications? Is the model consistently a valid representation of the actual plant?

5.1.4 PEOPLE READINESS

Successful Digitalization solutions require informed leadership, and leaders who are strong enough to accept greater empowerment of users and consumers.

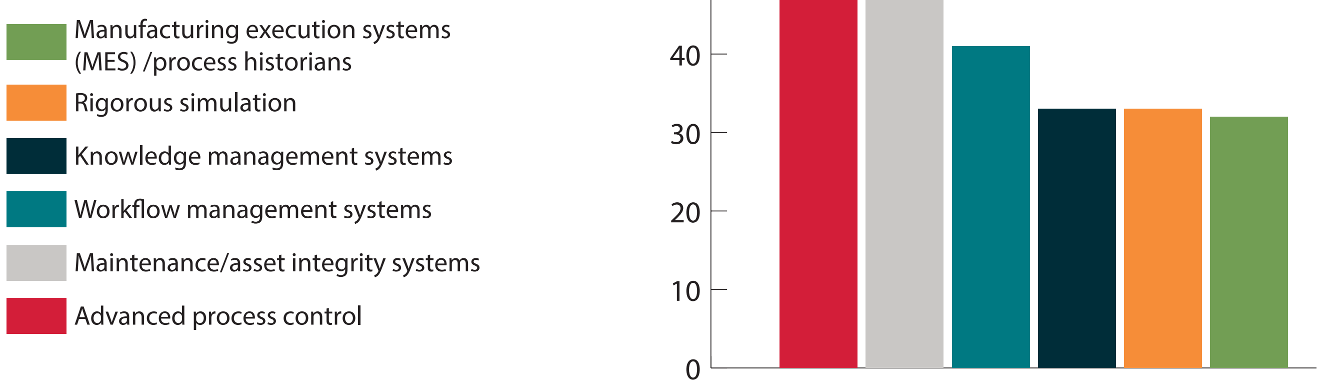
Informed leaders will understand the digital world and champion the investments required. They will recognize that technology is changing rapidly, and the digital world is one of agile development, rapid deployment, continuous refreshment, recognition and acceptance of failures, and a willingness to kill off unsuccessful initiatives without punishing the proponents. They accept a more dynamic workforce and more flexible work practices. They believe in continuous training and skill enhancement yet must tolerate higher staff turnover than they are used to.

Strong leaders are comfortable that users will be able to make better decisions, faster, and will encourage them to do so without heavy-handed oversight. They also understand that software applications and control systems that consume data are going to make more holistic recommendations and take actions that will drive the plant closer to its operating limits in pursuit of the economic optimum.

Digitally wise leaders will accurately understand the value that is derived from the Digitalization solutions. Failure to accurately tell 'the value story' to the organization can leave pockets of people isolated and unwilling to change. Pushing the 'I believe' button starts at the top and is filtered through the organization to gain adoption and acceptance of Digitalization changes. Successful transformations have the backing of the whole organization.

Despite the industry willingly sharing their views on which individual technologies the more mature organizations have been prepared to adopt, we believe the value-add of Digitalization is less about the technology itself and more about the environment that the technology is being installed into.

Figure 7 - Respondents who rated their company as having high levels of maturity in the adoption of technology



Unless the receiving organization is mature, aligned and has the requisite capabilities, a lot of work will get done but not a lot will be achieved. Digital solutions don't only need a receptive environment, but they also need to be integrated with others – they don't survive well on their own (sub-scale).

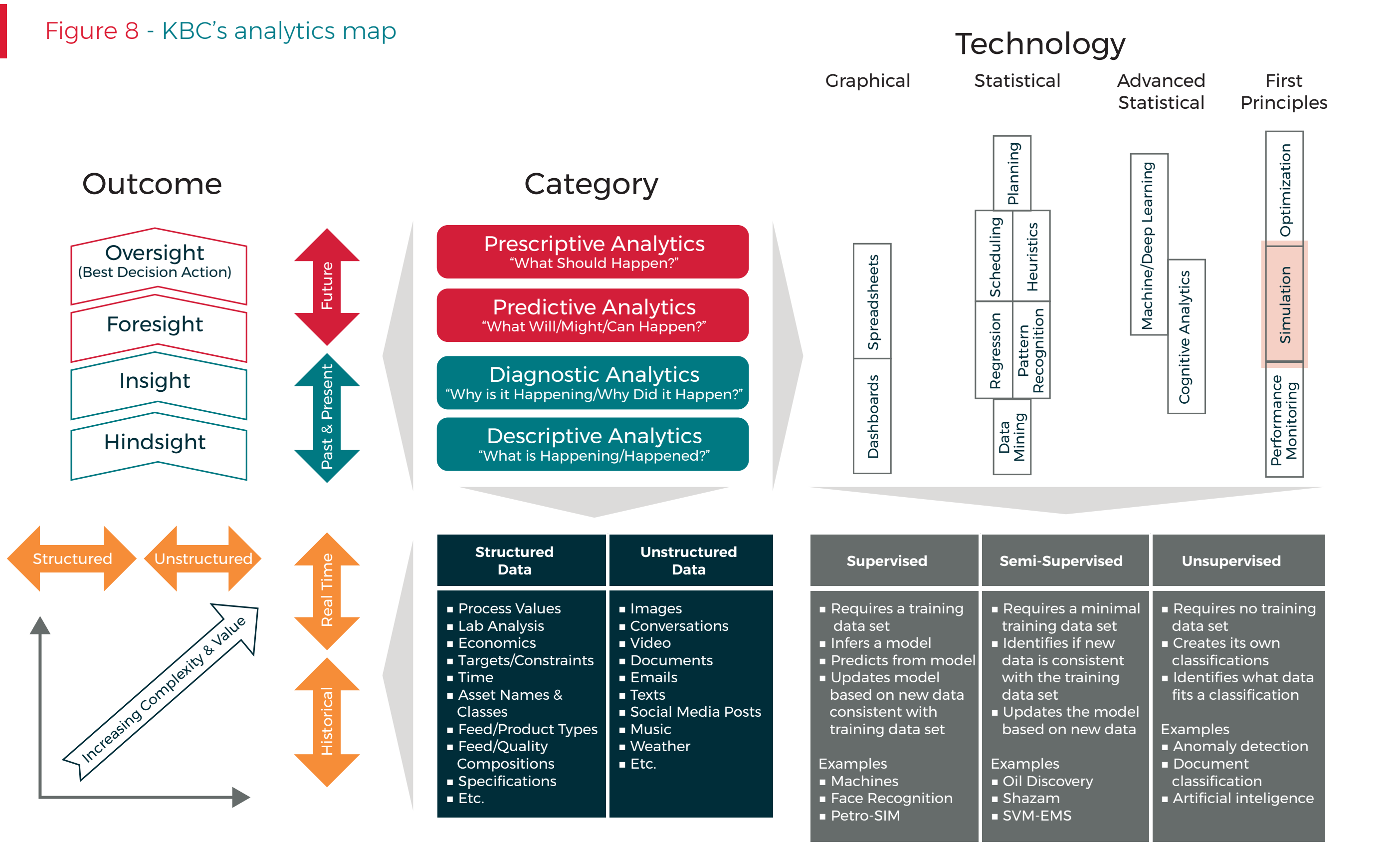
5.2 SITUATIONAL AWARENESS - ANALYTICS

To improve a plant's operation, it is important to understand its potential for improvement so that the right actions can be taken. Situational awareness is therefore a crucial step – knowing how the plant is and has been performing in absolute terms ('Hindsight'); understanding where it has capacity for improvement vs its constraints and optimum capability ('Insight'), predicting responses to changes ('Foresight') and assessing the value of such changes ('Oversight').

Tools associated with hindsight and insight are largely visual in nature – dashboards, BI tools, spreadsheets. These gain significant value when they align with goals, targets and constraints. Some goals are simple and static in nature (e.g. product quality) so presentation of performance against a target is simple; some are complex and a moving target. For example, cooling capacity of a fin fan is quite a simple thing to measure, but its ultimate capacity moves considerably with weather. The fluidization of a chemical reactor bed is complex – it is not at all easy to measure fluidization directly and the optimum point may not be easy to determine, yet getting it right can have a significant impact on the plant's economic success.

Therefore, to provide decision makers with valid information to present in dashboards, for example, the right tools must be applied to each situation being analyzed. We are strong believers in the use of first principles-based analytics tools for situational awareness: rigorous models respect the laws of nature, can handle non-linearities and complex relationships, they can infer information that cannot be directly measured. We are enthusiastic about the potential to apply such first principles models in conjunction with emerging correlation-based analytics (also known as statistical or stochastic analytics) for situational awareness – a so-called '**Ensemble Approach**'.

Figure 8 - KBC's analytics map



It is clear that such an ensemble approach is necessary for foresight and oversight, and we also consider it beneficial for hindsight and insight. First principles tools bring rigor due to their built-in understanding of physics, chemistry and dynamics, but at the cost of complexity and relatively high computation time. Correlation-based analytics suffer from lower fidelity without any guarantee of feasibility, but with the advantage of simplicity and speed of solution.

In our opinion, no plant should risk its employees, neighbors or economic well-being on tools that lack adequate rigor. In the pursuit of rigor, we believe long computation time will no longer pose a constraint as central processing units (CPUs) are augmented and replaced by graphics processing units (GPUs) or other processors with higher compute performance. Essentially infinitely scalable computing power becomes available via the Cloud rather than relying on processors on an engineer's desktop or site IT network.

To date, true AI applied to operational excellence still appears a long way off. AI machine-learning algorithms that can accurately model a complex, highly non-linear plant well do not exist in isolation of accurate first principles simulators. Cognitive AI that can scan unstructured data such as old reports, emails, texts and phone calls to distill out and interpret information to make performance improvement decisions is just not good enough – somewhere in the process human intervention is required to tag/catalog the information being gathered so it can be read by a machine, and to verify the outputs.

Today, and in the near-term, AI applications will be limited in scope to more structured problem solving such as interpreting machine faults or tracking human activity in hazardous environments.

5.3 DECISION MAKING

In the same way that we recommend an ensemble approach to situational awareness, we also believe that decision making should be grounded on first principles in conjunction with correlation-based tools as necessary.

Decision-making is about looking for answers. In an operating plant seeking to improve performance, there are three main qualities of answer that can be sought:

5.3.1 FORECASTING ("WHAT NEXT?")

A forecast is a judgment of what is likely to happen in the future based on knowledge of the past.

In the Energy and Chemical industry, a number of tools are available for forecasting asset behavior. Machine learning is an emerging technology that has seen some success when it comes to forecasting machine deterioration or failure. When it comes to forecasting chemical process behavior, rigorous simulation is required for all but the most basic forecasting due to the complexity of chemical reactions and the requirements to respect the laws of physics and chemistry (heat, material and momentum balances). Selection of the right tool is critical to the validity and quality of the forecast.

5.3.2 PREDICTION ("WHAT IF?")

A prediction is an estimate of what will happen in the future based on changes that could be made in the present.

In the Energy and Chemical industry, we ask ourselves what would happen if we changed feedstock or delayed a turnaround or adjusted reaction severity. Correlation-based tools are used extensively (for example for scheduling) but can only answer a limited subset of these types of questions because their models are highly simplified – they have a limited window of validity before their simplistic, often linearized, models no longer represent the plant faithfully. Rigorous simulators using scientific first principles once again excel when it comes to accurately predicting plant behavior in the face of radical changes or changes that have not been experienced before.

5.3.3 OPTIMIZATION ("WHAT'S BEST?")

> **Optimization answers the question "Of all possible changes that can be made, which has the best economic outcome?"**

In the Energy and Chemical industry, there are many complex optimization decisions to be made due to the vast number of variables that can be controlled and the large quantity of disturbances and constraints. Identifying the true variables and constraints is in itself a deep art. Correlation-based models are used for optimization when accuracy is not as important as feasibility. While LP planning tools do not represent the plant accurately, they have been the planning tool of choice for decades because they make the planning problem easy to formulate and solve; inventory is used to make up for inaccuracies in their conclusions. However, sloppiness in accuracy comes at a cost – the actual optimum solution is likely worth a lot more – yields will be better, energy consumption lower and required inventory holdings will be decreased. Again, rigorous models used for optimization will find the best answer. **Always.**

5.3.4 A NOTE ON TECHNOLOGICAL CONVERGENCE

Digitalization is not only about responding to a proliferation of data, but it is also about application of technologies that can look and act holistically.

The 1980s saw the emergence of 'siloed' optimization – individual process units or utilities systems being optimized without consideration of their impact on the whole plant. For example, optimum yield of a certain product might have required more energy which, if constrained, may have resulted in a turn-down of a neighboring unit that was not considered.

By the late 1990s, process and energy systems were being optimized together.

Only now do we have the computational power and simulation capability to optimize complete integrated facilities. And only now are we considering how Digitalization will bring about significant expansion in the scope of our optimization ambitions. Process, utilities, reliability, people and supply chains will all become optimized.

It is evident from the preceding discussion that there are purpose-built, yet partially compromised, solutions to assist with making each type of decision. Correlation-based models, while easier to apply, are limited in the accuracy and scope of their predictions because their model has only been trained on the observed past, and therefore there is a different type of model for each type of decision. Rigorous models are more difficult to apply, but the same model can be used for forecasting, prediction and optimization, and is valid and accurate over a much broader operating window since they are based on scientific first principles.

Our opinion is that Digitalization will cause these worlds to converge. Initially, correlation-based models will take advantage of the accuracy of first principles models by using the rigorous simulator as a training ground and will no longer be constrained by the observable past to make forecasts. Eventually, as computing power continues to grow, there will be no need to compromise on the model accuracy or quality – the rigorous simulator will dominate because a single model will be all that is needed, and it will be fast enough and easy enough to use.

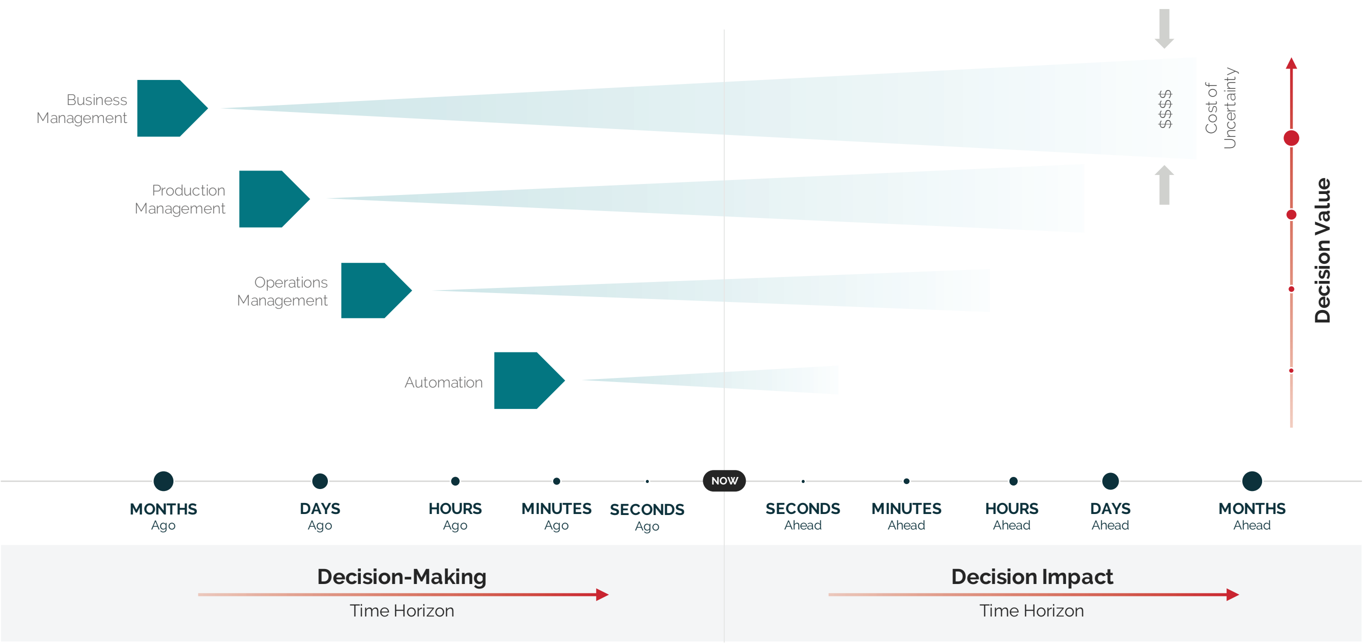
5.4 OPERATIONAL EXECUTION

Being ready, situationally aware and making the right decisions only guarantees success with efficient and effective operational execution. Digitalization compresses time horizons which means not only doing the same thing faster, but becoming liberated to do completely new things.

Figure 9 illustrates a plant's typical decision cycle. The more encompassing the decision, the longer it takes to make and the more economically and organizationally impactful it is, and for a longer time.

For example, a business decision to invest in new process equipment can take many months to analyze while different scenarios are examined. The cost of executing on the decision to buy and integrate the equipment with the existing assets may be very high. Once installed, the plant has to use and maintain that equipment throughout its economic life. A wise business decision may reap rewards for years, whereas a poor business decision may have long term costly consequences.

Figure 9 - Typical plant decision cycle

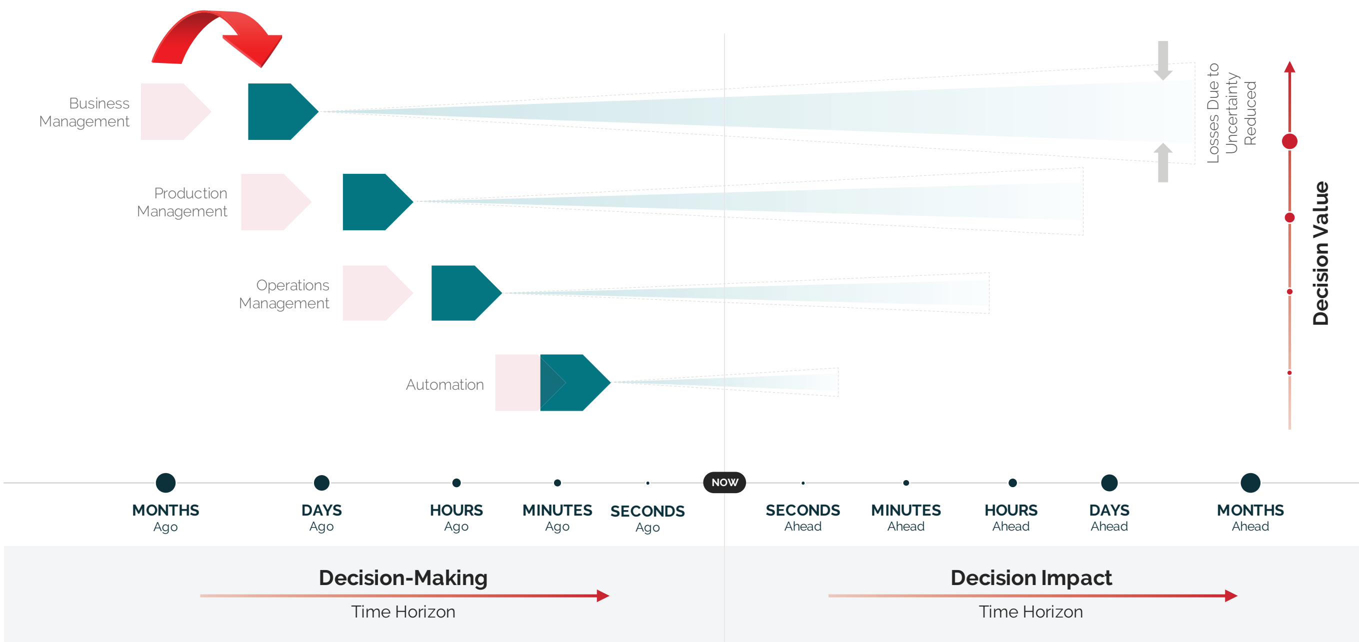


As another example, plant performance may deviate from its production plan. If the gap in performance can be attributed to poor operational execution it is relatively easy to correct in a few hours once detected – the cost associated with poor operational performance can be quite large, however, so the sooner it is detected and the sooner it is acted on the quicker the gap can be closed. But the gap in performance may not be associated with poor operations – it may be that the plan is no longer optimal because the market situation has changed. This is much harder to recognize and takes much longer to adjust – it may require rescheduling of ships, trucks and pipelines, as well as adjustments to process operations.

The time delays inherent in this decision cycle, especially at the production and business level, result in decisions being made based on dated information and assumptions, and inevitably lead to lost potential value from the asset.

Automation, on the other hand, by its inherent nature, makes decisions very quickly based on very recent limited data, and the scope is typically much more contained, and the automation actions can be suspended or terminated quickly.

Figure 10 - The digitally wise plant decision cycle



So, the timelier and more informed the decision process becomes, the better chance that the decision will be good, the quicker it will be to execute and the easier it will be to course-correct.

Digitalization accelerates information flow, increases the power of analytics and automates much of the execution, which greatly condenses the decision/execution time horizons, allowing strategic business decisions to be made in real-time, and the results to be visible and available almost immediately.

We can imagine the gap between future and past disappearing entirely – for instance in monitoring, with predictive analytics we can monitor the future and not just the past. The digitally wise plant decision cycle will look more like Figure 10.

The transition to Digitalization is not just optional, it is mandatory. Instead of viewing Digitalization as a change from a current steady(ish) state to a new slightly different steady state with a few more tools and a few less people, whether we like it or not, new technologies, new business models and pervasive connectivity mean that nothing remains static anymore.

Failure to adapt and transform means that the magnitude of value lost under the old model will continue to increase – the digitally wise will consume the laggards in the market.

In order to transform, the following processes and technologies must be addressed.

5.4.1 BEST PRACTICES

Technology is just an enabler of Digitalization. Technology on its own doesn't guarantee outcomes. The missing ingredient in order to achieve business outcomes is an organizational culture of excellence, of which operating best practices are a central component.

Replicating poor or average business processes in a digital environment does not assure delivery of superior results. The focus should be on acquiring best practices to execute the organization's work, and thereafter on finding the digital means to institutionalize automation of as much of each of these processes as possible.

At the core of KBC's values is a mindset of quality / lean production. This is all about maximizing value. Any time business processes do not conform to best practices, workflows are disrupted, and economic losses occur.

To manage change and sustain value creation, we have developed a set of **World Class Practices**. While all such best practices include a digital component, there are some that are specifically digital, such as data governance or asset modeling.

5.4.2 ADVICE-BASED ACTION

Advice is guidance or recommendations concerning prudent future action, typically given by someone or something regarded as knowledgeable or authoritative.

In the past those providing advice have been knowledgeable plant operators with decades of experience on how to run the plant.

Nowadays, the decades' worth of operator knowledge has been seemingly trivialized by AI machines. AI systems such as IBM Watson and Google DeepMind have become household names by using statistical techniques and brute-force memory and computing power to surpass the capabilities of the best humans in their field by applying superior statistical analysis and memory recall to problems such as Chess, Go and TV quiz shows.

Although a fundamentally good concept, in complex process industries these AI machines have been over-marketed and have under-delivered. The complexity of the physical processes and decision-making process required to execute business in the Energy and Chemical industry has been under-estimated. The effort to capture all the inherent knowledge of the experienced operator in an AI database has so far not proved technically or economically viable. As a result, the credibility of analytics solutions in this space has taken a knock.

While AI machines are still young and need to grow their capabilities in order to be trusted in highly hazardous work environments, the most knowledgeable or authoritative body is the plant's '**Co-Pilot**'. The Co-Pilot, a combination of the digital twin and the experienced human operating from a remote operations center, is a second pair of expert eyes on a plant's performance. It remotely supports the facility using a rigorous model of the plant that matches it in real-time, so the expert can perform What if? and optimization analysis to recommend better economic outcomes for the plant than the current situation. When adopted as an integral part of the operations team and used in their daily work, the Co-Pilot assures the facility always achieve its full potential.

The Co-Pilot concept is real today; much of analytics is hype. We see the eventual convergence of the two to remove the hype:

- Linear and rigorous models will work together as an ensemble in a single analytics environment; analytics will be trained by first principles models; domain knowledge capture will become economic; AI will become more trustworthy.
- Analytics that is trusted will triage the possible solutions for the expert to assess, presenting the most favored over the least, based on economics, feasibility and the organization's capacity to adapt.

The Co-Pilot concept can enable a central team to support multiple assets eliminating constraints of time and distance between the plant being optimized and the team doing the optimization. It also allows a plant to extend its ecosphere of support beyond the corporate boundary using the Cloud – the experts do not have to work for the plant as employees; they can be independent consultants or experts from among the many suppliers of equipment, chemicals, and catalysts that the plant already relies on.

Over time, the Co-Pilot expertise will be used to train analytics, allowing analytics to take an increasing share of the load. This will reduce costs, improve consistency and free up the human co-pilots to identify more creative and innovative ways to add further value.

A similar combination of analytics and rigorous dynamic models using on-line measurements from the plant can provide information about the status of the plant which cannot be directly measured, can predict the future trajectory of the plant and advise the operators on action required to keep the plant within its operating window and at its optimum operating point.

5.4.3 CLOSED-LOOP CONTROL

In closed-loop control systems, information flows around a loop involving Process > Sensor > Transmitter > Controller > Actuator > Feedback to process. This sequence then repeats as often and rapidly as necessary, without human intervention, until the desired process condition is achieved.

Advice-based action, on the other hand, is essentially an open-loop control system because it does not have automated feedback and requires operator intervention to monitor the resulting change in operating conditions.

Closed-looped control has advanced significantly as a result of the digitization that started in the 1980s. Prior to then, closed-loop control relied on physical (mechanical, pneumatic and eventually electronic) sensors, processors and actuators to perform. It was expensive, unreliable and very limited in scope. For the best part of 75 years it remained virtually unchanged. In the 1980s, MVC (multivariable control) was invented by Shell. It uses statistical and computational methods to model the process to be controlled in the form of a multi-dimensional matrix of the dynamic interactions of independent process variables and their dependent plant responses. The control algorithm inverts the matrix to determine an array of control outputs.

MVC technology has developed rapidly and reliably due to improvements in computing power, algorithmic enhancement to assure feasible outputs are always chosen, built-in self-calibration and incorporation of economic optimizers to choose ideal values for any spare outputs not required to solve the control problem. The scope of MVC is now vast – it can cover multiple plants at once and can degrade gracefully if a unit is no longer to be considered (as a result of a shut-down for example). Most digitally wise plants today use MVC extensively.

But it is also common, even at a digitally wise plant, to find that the MVC is not being well-applied. It is often over-constrained (limiting the window in which it can move the plant in search of economic improvement) or even turned to manual (essentially turned off). It functions as a 'black box' lacking transparency in its decision-making process, and is not trusted.

Some of the key challenges with maintaining closed-loop control are insufficient expertise to support the applications, and operators not understanding what the applications are doing, and therefore turning them off or overly constraining them.

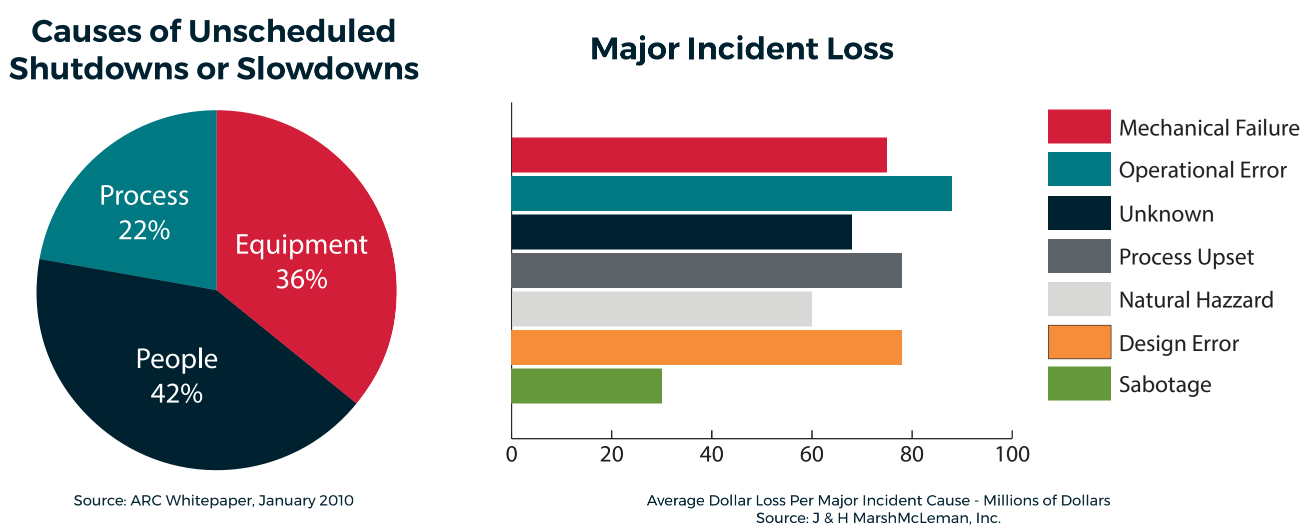
KBC has the rights to distribute and implement Shell's latest iteration of its MVC technology – called 'PACE'. Our stance is that with a combination of best technology, good design and superior Co-Pilot-like support, both of these challenges can be easily overcome.

5.4.4 PROCEDURAL AUTOMATION

While large continuous energy and chemical operations run for years at a time in an automated fashion, there exist plants that operate sequentially, and there exist procedures within continuous operations (such as start-ups, shut-downs, grade changes, feedstock changes and 'safe parks') that also operate sequentially.

According to ARC and March & McLennan research, 42% of unscheduled shutdowns or slowdowns are attributable to people and the highest dollar loss per major incident by cause is attributable to operational error. Such errors happen so often during start-up and shutdown because most operators may only experience them once every 5 years and even then, not in total as they often span multiple shifts.

Figure 11 - High cost of unscheduled shutdowns



Automation of the appropriate procedures will and should become the norm. The benefit of procedural automation is that it:

- Informs and prompts operators where and when needed according to the SOP (standard operating procedure);
- Affects state changes in the process control system upon operator acknowledgement;
- Verifies that each step or sequence is carried out in the time prescribed by the SOP;
- Sends notifications when a variance is detected between an SOP and actual conditions;
- Assists operators during abnormal conditions and plant upsets.

By capturing existing best practices from experienced operators and then automating and integrating those best practices into the control system infrastructure, mistakes can be drastically reduced by providing operator guidance in real-time.

Automation and integration of best practices into the control system infrastructure will soon be delivered across both control room and field operations. It will put the right information into the hands of control room and field operators at the right time through intelligent mobile solutions, such as wearables and other devices. The information being fed to operators will consider actual plant performance and other asset strategies to provide the optimal course of action for operators to follow.

5.4.5 CLOSED-LOOP OPTIMIZATION

Closed-loop optimization has been a largely elusive goal of Digitalization in the Energy and Chemical industry. The idea of rigorously modeling the physics, chemistry and dynamics of a process, and determining the economically optimum combination of all the possible output variables in real-time has proven to be technically possible but practically out of reach for most problems. The sheer effort to formulate the optimization problem, make sure the inputs are available and reliable, that the model is accurate enough and to be confident the outputs are good enough to be applied automatically has been too much of a challenge so far for many companies. The incremental returns for closed loop optimization over MVC do not always justify the additional effort.

This is less true for closed-loop optimization of utilities where the streams being measured are simpler (steam and electricity rather than chemical compounds and mixtures), their physical behavior is well understood, and economic drivers are unambiguous. Optimum decisions are more discrete in nature – "Open the valve to let down steam pressure", say. Much success has been had with real-time closed-loop optimization for energy management.

We envisage that eventually the successes for utilities will become as common for closed-loop process optimization. It requires improvements in computational capabilities, a culture that treats real-time data as an asset so that data sources are available and reliable, and improvements in technical usability of the current solutions. There are also opportunities to use analytics to identify and forecast equipment performance and take into account the impact of the operating point on the maintenance requirements of the equipment.

5.5 VALUE SUSTAINMENT

Digitalization is typically not a one-time hit, where the benefits are achieved and stay forever. Unless proactive steps are taken, benefits will almost always decline over time and the opportunity to capture incremental benefits will diminish too. This happens for a number of reasons:

- The economic basis for the solution changes;
- The goals change;
- The plant performance changes;
- Business priorities change;
- Focus by people (management, engineers, operators) changes;
- Technology changes.

Our approach to sustainment of Digitalization value entails going above and beyond compliance with how new digital applications are implemented, to one where there is a clear sense of ownership by the organization, especially front-line operators, through recognition of the added value of the applications. Achieving this entails:

5.5.1 GOAL MONITORING AND ECONOMIC STEWARDSHIP

Digitalization solutions are a combination of technologies and services aligned to specific business goals. Once value is captured through implementing the right solution in the right way, it is equally important to sustain the value in the face of continuous change and new opportunity.

Any data-driven approach for continuous improvement requires definition, ongoing tracking and reporting of key performance indicators (KPIs) against targets. What cannot and is not measured cannot be easily improved.

We believe in implementing a goal management system to monitor the solutions applied and to enforce accountability through the organization for achievement of goals set.

Such a system should report achievement and highlight those that fall short, bring non-compliance to the attention of the accountable person with organizational escalation as necessary. It should enable integration with other business systems to kick off maintenance work orders if, say, a worn or broken part is the source of the non-compliance.

5.5.2 KNOWLEDGE MANAGEMENT

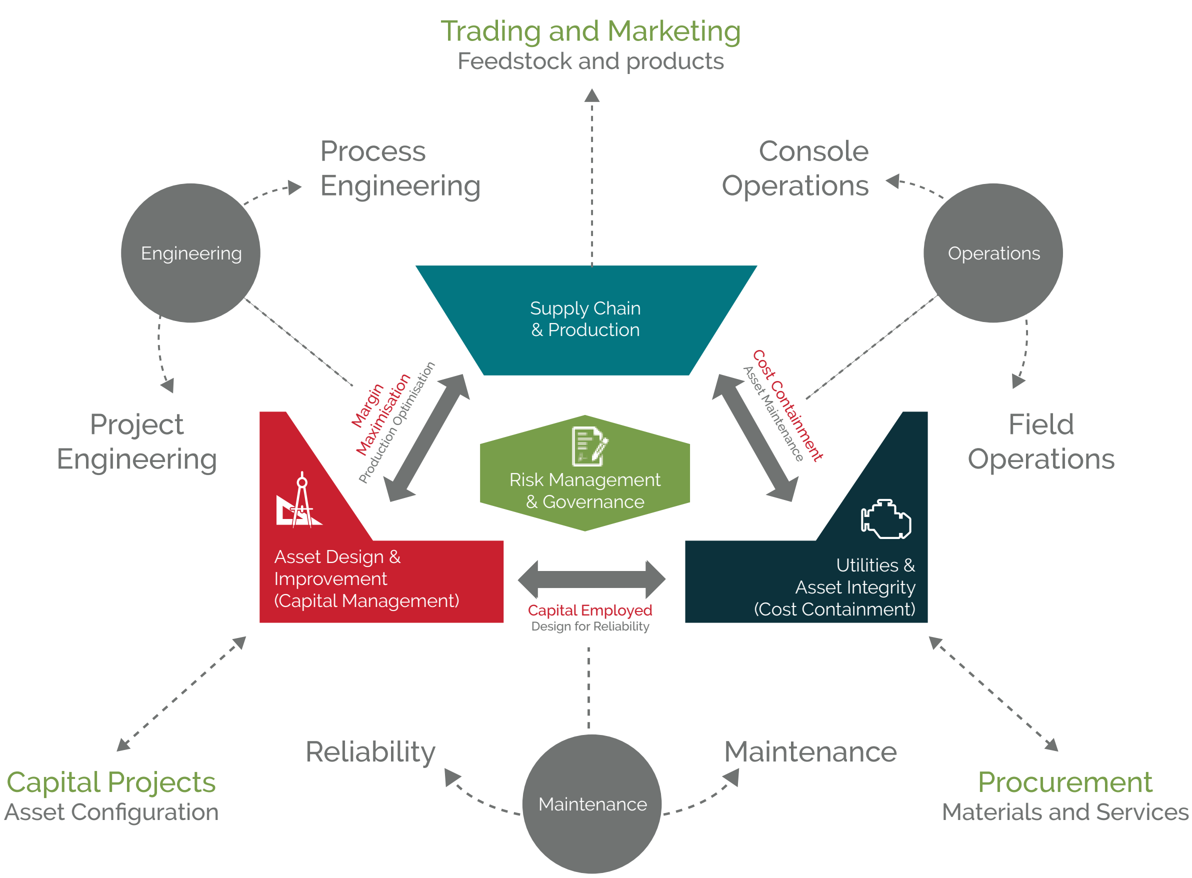
One of the biggest sources of trapped value in the quest for Digitalization is capture of an individual's tacit knowledge so it becomes the explicit knowledge of the whole business to assure organizational resilience. We view tacit knowledge as the skills, ideas and experiences that people have gained over time but are not systematically codified in a way that makes them easily expressed or transferred.

A strong knowledge base built into Digitalization solutions means that the owner of a goal can be quickly reminded why that goal is important (economic reason, safety reason, compliance reason...) and the consequences of not achieving the goal (also economic, safety, compliance...).

Knowledge management is a high priority as the industry is experiencing:

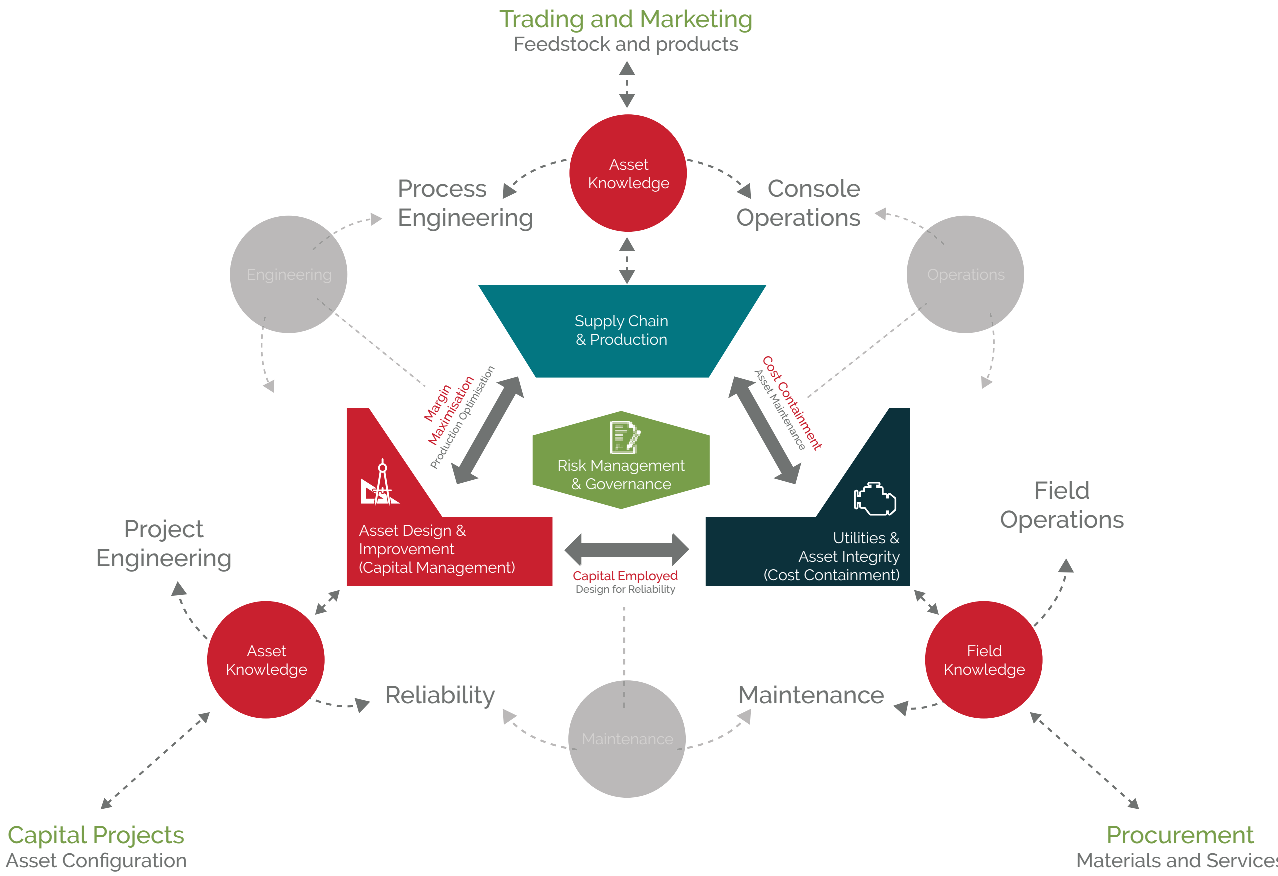
- Net loss of knowledge, especially in OECD countries, through a retiring workforce;
- Work force localization, involving entry of new, relatively inexperienced operators mostly in the Middle East;
- Skill shortages in certain ASEAN, Latin American and African countries.

Figure 12 - The shift from a tribal (functional) organization...



The siloed organization driven by 'tribal' functional grouping of roles hinders the knowledge transfer that is required to address these challenges and simultaneously embrace Digitalization. The solution is to move away from inefficient functional organizations where data is fragmented and there is significant waste, to value-driven, knowledge-based organizations where knowledge can be systematically captured and transferred.

Figure 13 - ...to a knowledge-based organization



5.5.3 MANAGEMENT OF CHANGE

We recognize that change management is essential to the successful delivery and implementation of any transformational project. An effective, well-structured and thought out change management program should be developed and socialized as a priority as soon as any project kicks off. Central to this should be a governance system to establish the controlling management framework that drives the overall program execution and the organizational aspects. This will capture critical success factors, considering not only technical aspects of the program but also the essential 'soft' people aspects that are pre-requisites for successful implementation of change and sustainable long term performance.

With any large or complex project, it is also essential to maintain a continuous active dialogue with all stakeholders to ensure buy-in and to maintain motivation levels. Communication of the program objectives and regular progress updates must form an integral part of the program so sustainable long-term performance is assured. KBC has a structured approach to change management that encompasses this:

- **Awareness:** define a shared need for change.
- **Understanding:** acknowledge cultural nuances and determine a vision to direct the change effort.
- **Adoption:** ensure a common understanding and adoption of the new vision and change strategies.
- **Commitment:** set medium and long-term goals to build on the change.
- **Advocacy:** anchor the change into a continuously improving corporate culture.

5.5.4 VALUE VS COST MINDSET AROUND TECHNOLOGY AND CAPABILITY REFRESH

Traditional efforts of addressing technology refresh across the industry have been reactive in nature. Decisions on obsolescence concerns have historically been based on schedule, remaining life, procurement cost, and other short-term gains.

Digitalization is a world in which technological change is happening rapidly. Experimentation, rapid prototyping, agile deployment and a willingness to accept occasional failures is the norm, and the only way to remain competitive. It is critical to adopt proactive scanning and screening for new, bigger and longer-term value creation opportunities.

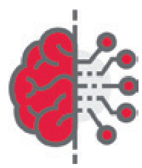
Without doubt, technology and capability refreshes will entail a significant cost. However, the value that is often able to be unlocked through the refresh is often orders of magnitude greater and enables the refresh to pay for itself many times over.

6. KBC'S DIGITALIZATION COMPONENTS

We offer a coherent set of solutions all focused on helping companies in the Energy and Chemical industry achieve their full economic potential.

Where we do not have an appropriate solution of our own, we can reach deeper into the advanced solutions of our parent-company, Yokogawa. We also have strong relationships with a number of key technology and business partners that enable us to offer their solutions along with our own. By working with these 2nd and 3rd party organizations we can extend our promise of excellence beyond our own in-house capabilities.

Our solutions are as follows:



DIGITALIZATION TECHNOLOGY

Analytics

- First principles simulation
  - Petro-SIM family
  - VM-EMS family
- Correlation-based modeling
  - Process data analytics

Manufacturing execution

- Planning
  - Petro
- Scheduling
  - VM-SCS
- Production and yield accounting
  - VM-PAS
- Operations management
  - OGM
  - OM

Automation

- Procedural automation
  - Exapilot
- Advanced process control
  - PACE
- Real-time optimization
  - Petro-SIM
  - VM-ERTO
  - VM-EMPO
  - PACE

Personnel learning & development

- Operator training simulators
  - OmegaLand
  - TechComm

DIGITALIZATION SERVICES

OpX consulting

- OpX Asset
- OpX People
- OpX Digital
- OpX Value Chain

IT & modeling services

- Process and data modeling
- Application software design and development
- Application implementation
- Software support and maintenance

Cloud services

- Co-Pilot
- Data-as-a-Service
- Software-as-a-Service

7. WHAT WILL THE DIGITAL FUTURE BE LIKE WITH KBC?

The digital future with KBC will bring greater certainty to decisions, reducing risks. Analytics will provide deeper insights that deliver more value. Decisions will be made faster through streamlined decision making and predictive insights, and actions will be taken earlier and executed more reliably via automation of processes. This will all lead to a drastic improvement in productivity and job satisfaction.

When making decisions, all the relevant data will be available all the time, and to every stakeholder, resulting in greater scope to optimize and simpler decision-making processes based on data rather than gut feelings.

Automated systems will highlight when actions need to be taken rather than relying on ad-hoc processes to prompt investigations or action. Data governance will be a serious focus, with digital and human systems to validate, reconcile, manage and improve the data used for decision-making and optimization.

Computing speed and automation will highlight issues and solutions instantly and speed up the cycle time to react to issues allowing all business functions to act proactively rather than reactively.

Business process automation will make execution of decisions and actions seamless and governed to ensure perfect execution against plan. Hand-offs of data and instructions between shifts, teams and departments will be managed electronically, reducing operator errors, allowing easy substitution of personnel and flagging up any failures to act.

In all of this, a vast array of mundane tasks involved in the generation and transfer of data, reporting and evaluation of paths forward will be automated. This will save around 50% to 70% of staff time. Some will use that saved time to make their operations more competitive; some will take advantage of the efficiency to operate with fewer employees.

Meetings will be dramatically more effective, with much less time spent communicating the issues and agreeing on the current situation, and more time spent deciding on solutions. Human intervention in routine processes will be by exception only, rather than the norm. The role of humans will be focused on interpreting information and making decisions, not facilitating routine tasks.

The end result for the digitally wise is worth the effort: operations with a massively-reduced number of unexpected events; excellent levels of reliability, safety performance and environmental compliance; assets running with extraordinary efficiency in terms of energy and process yield, as all possible improvement mechanisms will be constantly exploited. The entire operation will be enabled to act with agility and flexibility to respond to external threats and opportunities, making and then implementing increasingly rapid changes to maximize value. This will all be achieved with a smaller but more empowered workforce.

In an industry moving towards the future, don't get left behind.

DIGITALIZATION:
NOW IS THE TIME

8. 4 DIGITALIZATION PROJECTS TO START TODAY...

READINESS

Commission an as-is value audit and readiness assessment

The value-add of Digitalization is less about digital technology itself and more about the environment that the technology is being installed into. Often, it is necessary to upgrade technology or fill gaps, but for the most part it involves refreshing existing applications to address challenges and opportunities that didn't exist at the time of the original installation. To be ready for change, the impediments to success and sustainability must be addressed: Data Readiness; Infrastructure Readiness; Consumption Readiness; People Readiness. The digitally wise approach is to audit existing technology applications, build an application register and understand how effectively they are in relation to current goals. The findings can help you decide whether to "sweat" existing technology or invest in new, and how to ready the organization for change.

SITUATIONAL AWARENESS

Establish KPIs and implement fleet-wide KPI monitoring and assurance

All operations have goals and targets to achieve, constraints and limits to respect, and tasks to be done. Some are explicit and some are implicit; some are simple to measure and some are derived from complex chemistry, physics and math; some are static and some are dynamic; some are constant and some are conditional. A well-managed operation will know what these are, will document why they are needed and the consequences of non-conformance, and will have personnel accountable for compliance. A fleet-wide system for tracking and reporting performance, as well as assuring compliance is a necessary first step to operational improvement.

DECISION MAKING

Build a digital twin of your plant

Most well-run plants will have a simulation model of the plant – maybe it was created during the plant's design stage, or maybe it has been created since. To make it practical to use the model for continuous performance monitoring, adjustment and optimization, the model needs to be set up as a digital twin. A digital twin is constantly synchronized with the plant via always up-to-date asset models for context, so that engineers can ask the model without delay how to improve from the current situation and the value of doing so. Input data needs to be right in context, so it can be relied on to make sound decisions via a model that is consistently a valid representation of the actual plant.

OPERATIONAL EXECUTION

Manage and optimize energy use

Energy costs are a very large and necessary part of a plant's operating budget. Trade-offs between the electrical and steam system have become especially significant since the advent of electrical deregulation in some markets. The operational complexity is compounded with the introduction of emissions constraints due to ever-tightening environmental regulations. This presents a challenging scenario for management of steam, electrical, water, hydrogen, fuel, and other utilities. Significant cost savings can be achieved by using an optimization program that is able to leverage the holistic flexibility inherent in the site's energy systems in order to recommend lowest cost utility operation.

9. EXECUTIVE SUMMARY

KBC has presented its Digitalization Manifesto – our unique position on the application of Digitalization in the Energy and Chemical industry, demystifying the jargon, demonstrating value and presenting a clear road map for the industry.

As a 'sub-set' of Operational Excellence, we presented the 12 elements of our 'digitally wise' philosophy focused on these valuable outcomes:

- Efficient delivery of value
- Discovery and capture of new value
- Shorter time to achieve value
- Sustainment of value achieved
- Competitive advantage

We laid out a Digitalization Roadmap – our view on the structured, practical and actionable steps we believe all Digitalization initiatives should follow:

- Readiness
- Situational awareness
- Decision making
- Operational execution
- Value sustainment

We listed some key technologies and services that KBC offers to help our customers on their Digitalization journey. We described what a Digital future looks like with KBC and finally, we suggested four Digitalization projects that can be started today.

If you would like to discuss any of this further with KBC, please contact any KBC representative or email us at **digital@kbc.global**.

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