A Fresh Look At Industry 4.0 for Manufacturing

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This white paper takes a fresh look at the vision for Industry 4.0 and suggests ways to take advantage of the broad view and applications of the concept. Implementations of Industry 4.0 have mostly focused on using new technologies to provide economic benefits. The sustainability and social aspects have received less attention, despite their great potential in terms of adding economic value. To increase profitability and competitiveness, manufacturers should apply Industry 4.0 and make smarter products with higher added value by empowered workers and intelligent assets.

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Executive Overview

This white paper takes a fresh look at the vision for Industry 4.0 and suggests ways in which to take advantage of the broad view of the concept. Implementations of Industry 4.0 have mostly focused on using new technologies for economic benefits. Sustainability and social aspects have received less attention, despite their importance and potential for economic benefit as well, as we will show. Industry 4.0 has agility and reactivity built-in, and in view of the current wave of disruptions facing the world, these are more important than ever. We reflect on the vision of Industry 4.0 and the benefits that can be realized. We also look at quantifying these benefits. This paper summarizes proven approaches to analyze and prioritize the potential of Industry 4.0 related actions and projects, using strategic, financial, and portfolio perspectives. Finally, we provide some suggestions to manage the multitude of possibilities for projects, while focusing on the bottom-line. See also our paper "Achieving Maximum Value with Industry 4.0 and Intelligent Asset Management."[1]

Industry 4.0 is not Industrial IoT, it is not only about technology, but is "the next stage in the organization and control of the entire value stream along the lifecycle of a product. This cycle is based on increasingly individualized customer wishes and ranges from the idea, the design, the development, the order, production, and delivery to the end customer through to recycling and related services."

The Vision

Over time, all of us in industry have made shortcuts and simplifications about Industry 4.0, which tend to get disconnected from the concept. We need to reconnect with the vision and its rationale before working out a methodology and an implementation strategy.

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[1] Text in italics relate to assets, directly or indirectly.
[2] The Industrie 4.0 Platform, "Implementation Strategy Industrie 4.0," Bitkom e.V., 2016. Available at this link (last retrieved: April 2022)

was formulated for people, technology, and organizational domains, which includes sustainability.

The **people** section envisions a human-centric approach to work, which includes self-organization and autonomy, increased scope of work, and inclusiveness towards diversity. Skills and competencies are developed through a rich palette of learning methods, improving qualification, job satisfaction, and also quality and productivity.[3]

The **technology** section mentions systems that are easy to understand and can be used intuitively by the user that promote learning, respond reliably, and are co-designed by multiple participants. Complexity is reduced by modeling, simulation and self-organization. Larger scopes can be assessed quicker, and solutions found sooner. Resource effectiveness and efficiency are continuously planned, implemented, monitored, and optimized. Intelligent products are active information carriers, which are addressable and identifiable throughout all lifecycle phases. The same holds for production assets and components that provide their functions as services. Finally, a new security culture will lead to trustworthy, resilient, and socially accepted Industry 4.0 systems.

In **organization**, the vision includes enhanced value networks that integrate product, production, and services, with flexible assignment of labor in the network. Cooperation and competition lead to new structures, legal frameworks, contractual and business models. Value networks can be regional and can also include developing markets, which can coincide with developing countries.

The Rationale

Changes in society have an important impact on industry and vice versa. The European "Green Deal" and the transition to a circular and net zero carbon economy is a result of society realizing that economic development has happened by destroying the natural environment, to a degree that it becomes a threat for humanity. Work from home during the COVID pandemic made workers reconsider their work-life balance and many are dissatisfied with

[3] For details on individual and organizational change, please request: De Leeuw, V.V., ARC White Paper "Digital Maturity, Supporting Digital Transformation Industry"

their work and its environment. This led to the Big Resignation, most pronounced in the US, and with a move out of the cities, frequent in Europe. Workers have "always" wanted satisfying work with a maximum of autonomy in a positive work environment. Now resources have become scarcer and more in-demand, workers are able to get more consideration for their desires, often social in nature. The era of the empowered worker has begun.

AI Quality Inspection as Operator Aid:

A recent case study illustrated well how technology can support and benefit the operator (human). A company fabricating injection-molded products is planning to put an automated AI-based quality assessment in place. A robot, with help of cameras will pick an object from a bin, inspect it for both form and surface qualities, and place the object in bins with compliant and rejected pieces. This will not only reduce the accuracy of the decision compared with a human and reduce processing cost downstream, but also considerably reduce the physical strain on the operator. The quality station will be placed next to the operator's assembly station and assist him in the process, giving the operator more quality time for assembly and decision making.

There are also benefits for companies in this transformation that they may not realize. Greater work satisfaction creates multiple benefits, as it does not only increase productivity, but also reduces turnover and absenteeism. The associated hidden costs of the latter two are high and can be considerably reduced. If the subjective work environment improves, such that harassment and stress-provoked anxiety, burn-out and other illnesses are reduced, social charges and absenteeism are further diminished.

Lot sizes of pieces produced do not only decrease because of mass customization or individualization of products. As regulations become more complex and more diverse from country to country, with sometimes contradictory demands from different companies or countries, the optimization of production orders and traceability of components in products becomes very complex as well. With energy and materials prices soaring, this optimization has much greater cost implications than before. The operator can play an active role in resolving bottlenecks or breakdowns, and *keeping overall equipment efficiency (OEE) up*, or adjusting energy consumption as a response to real-time KPI dashboards that indicate where to act, when and which parameter to adjust. The automation will do the optimization much better than the human, but the human will be much more effective in making judgement calls. The win-win is that the companies gain efficiency, and the operators gain in work satisfaction, because they make an impact.

This example of local optimization should be flanked by global optimization. The recent crises in the world, starting with the pandemic, compounded by extreme weather events such as storms and flooding, the blockage of the Suez Canal, followed by the geopolitical tensions leading to massive material and energy price fluctuations plus flow pattern changes of materials and

goods, made it clear that agility and the capability to replan and adapt, are differentiating capabilities for the enterprise. This is true at large scale, for industry majors, but also for internationally operating medium-sized enterprises, as well as national or regional retail chains.

The observation that industrial manufacturing creates prosperity but also damages and exhausts the environment, deteriorates health and work conditions, and creates fragilities in supply chains is factual. Nobody doubts that the use of clean energy, environmentally and socially respectful raw materials, production and products, the highest possible degree of circularity, and ideally the gradual restoration of ecologically rich ecosystems, sustaining life and its resources is the way to go. It is good to realize that there are important interdependencies related to sustainability: clean and reduced use of materials and energy will reduce emissions, curb climate change, improve health of workers and population at large, help to become compliant with progressively stricter regulations, and reduce direct and indirect costs, ultimately impacting profitability.

In hindsight, the vision of Industry 4.0 was impressively to the point. The broadest interpretation of Industry 4.0 has the highest potential, the interrelatedness of the domains multiplies benefits. The above examples of sustainability, supply chain and production optimization, illustrate that technology is an important piece but not the entire Industry 4.0 approach. Industry 4.0 offers many more possibilities than the ones discussed, and companies need to assess these systematically. We will address the methodology for doing so in the next section.

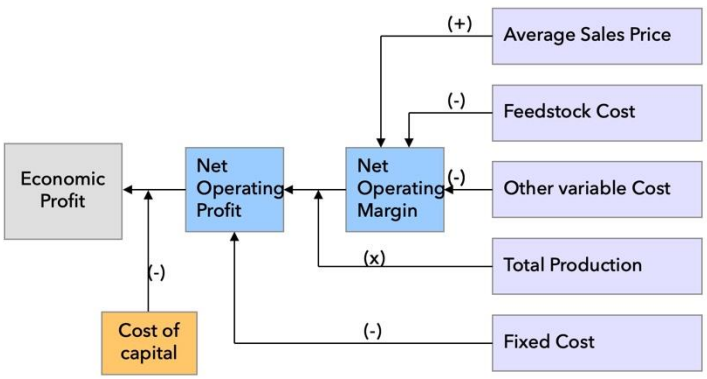
The Methodology

Some things have changed in the realm of industrial systems, some have not. IoT sensors are far cheaper than industrial-grade instruments and software development has become far more agile and rapid. The cost and time to operational readiness of industrial applications are less, and this improves competitiveness. Experimentation has also become faster and cheaper, and this should be exploited.

What hasn't changed are the laws of economics. A business case is still required, and its mechanics are still the same, even for IoT-based solutions. Of course, the values the variables in the equations take, change with the

disruptions discussed above: energy, materials, and supply chain costs change, and strategic priorities such as sustainability may change the weighting of certain factors, or make what we consider secondary effects of changes with more fine-grained detail. We will take one example of this, after stating the basic principles.

Every enterprise should take its income statement, and consider the levers it has on added value, EBIT(DA) or a similar metric. At the highest level, this is the total quantity produced times the net average sales price, that is, after subtracting the variable cost per unit produced, minus fixed cost, *minus capital cost*. Levers are therefore producing more, with lower variable and fixed cost, with lower capital investment.



Levers Impacting Economic Profit

Taking one example: with increasing material and energy costs, variable costs increase, thereby lowering margins. This can be countered by using less material and energy. "1st time right," that is minimizing scrap and recycling, improved insulation, and improved heat recovery are possible answers. *Available engineering approaches in heat integration to improve the process characteristics* are underused in our opinion.[4] Real-time KPI dashboards could provide feedback to operators on materials and energy consumed. The next level is to provide the feedback relative to the best performance for a product, relative to the size of the lot, and the theoretical minimum consumption. Real-time performance can become a healthy game against the possible, and a competition among teams. More sophisticated would be to provide target material and energy consumption taking transitions between products into account. Also, transitions can be optimized for consumption. These examples give a flavor of the type of actions that can be taken.

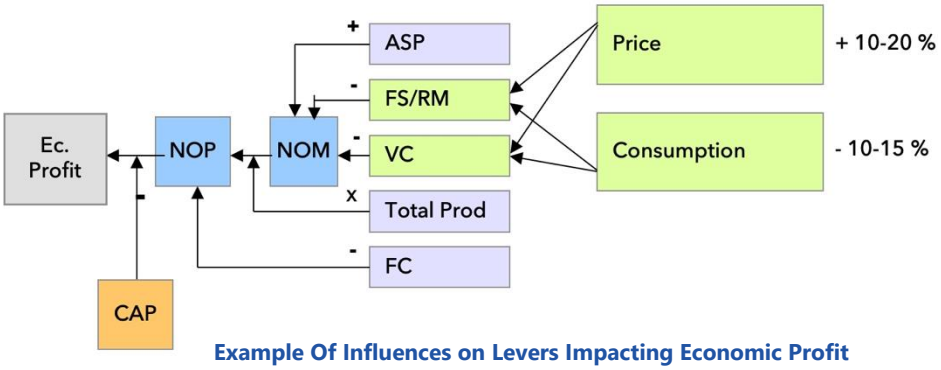
Be aware that several actions can impact the same economic lever, and that several technology projects can impact several levers. In addition, an action can be a business process improvement and can, but does not have to, involve the use of technology. And a technology can involve digitalization or

[4] An example is the application of heat integration using Pinch technology that provides important potential to significantly improve energy efficiency with small capital investments.

IoT but doesn't have to. One should brainstorm all the possible impacts on levers, identify the projects or actions that would realize them, and then group by project. Often encountered projects that impact the four operations management domains are:

- *Overall Equipment Efficiency* and energy consumption dashboards for operations to improve throughput and reduce downtime and energy.
- *Condition-based and predictive maintenance to reduce maintenance cost and increase asset uptime.*
- On-line and in-line quality measurements with or without AI, to improve quality and quality consistency, and reduce cost of quality.
- Optimizing plant and enterprise planning, scheduling, and logistics.

Of course, there are many others. To get the opportunity to strategize and prioritize, the user must therefore analyze all influences with significant impact. The next step is to estimate the total potential, the realistic mid-term goal, and a conservative short-term estimate for projects. The latter can serve to determine the limits of an investment that will provide returns in an acceptable time frame.[5]



Example Of Influences on Levers Impacting Economic Profit

Every company should assess which actions and projects are their highest priorities. The technologies used in a project should be the most favorable from a cost-benefit perspective, relative to the planned application lifetime. These can involve low-cost IoT sensors for applications with medium lifespan and reliability, or they can involve industrial grade instruments and actuators, where highest reliability or safety are paramount. These choices should be aligned with the company's configuration and strategy.

[5] We have explained the principles of this approach in more detail in this article. The approach is not new, nor unique, but it is worth applying.

There is a chicken-and-egg effect. Especially when considering approaches or technologies that a company has not applied before, the cost-benefit estimation can only be approximate. For those cases, small-scale experimentation and pilots can provide the data to decide whether a rollout is worthwhile or not. In the meantime, a financial and project plan can include assumptions and estimates that are firmed up over time, when data become available[6].

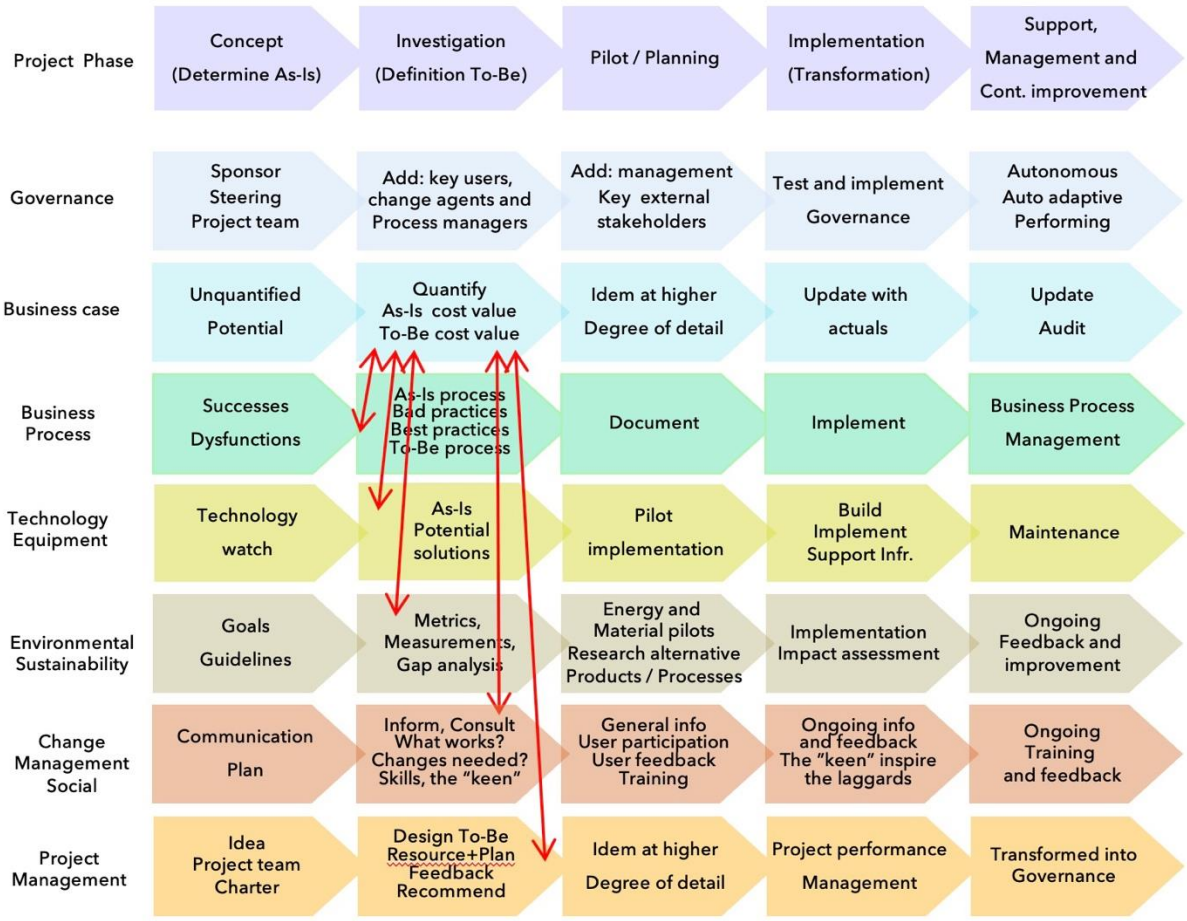
In the next section we argue that different aspects of implementation are interrelated. These include business processes, technology, human and social aspects, sustainability and environmental, legal and compliance. These same aspects should also be included, both from cost and benefits perspectives, in the business case.

The Implementation

Many companies struggle to transform implementations into bottom-line impact. Especially for large companies, the approach should be one of portfolio management. At the start, experiments and pilot projects are carried out, chosen based on local and global priorities. Some of these projects will be successful enough to be rolled out globally, others will be useful as local implementations but not as corporate strategy, and some will be discarded. The projects selected for global rollout will create the most bottom-line impact, because of their multiplier effect. It is rational to keep experimenting with new projects while doing global implementations, but it is important to distribute resources according to priorities in terms of impact. There is a real risk of getting lost in experiments and giving too little attention to rollouts.

A rollout is a multi-variable optimization problem of several, simultaneously executed and connected tracks within a project. Each track provides input to the others and provides levers for optimization. A project that is promising from a technical and financial perspective, may put strain on resources, and demand attention in the project management and change management tracks, etc. The projects should be placed within the project portfolio and managed for resources, impact, and timing as a whole.

[6] This approach has been described in: McGrath R.G. and I.C. MacMillan, "Discovery-Driven Planning," Harvard Business Review, Jul-August 1995.



Multi-variable Optimization Before and During Change

Recommendations

ARC's recommendations for Industry 4.0 are:

- It is more likely a company will be profitable and create jobs when it produces products with higher complexity and technology content and applying Industry 4.0 than by competing on low-price commodity products. Therefore:
- Take advantage of the broad range of aspects of Industry 4.0, including smart products, *smart assets*, *optimized factories* operating sustainably and creating optimal conditions for empowered workers.
- Multiply benefits by exploiting multiple types of benefits for a single action that act on several financial levers.
- Use classical business case and portfolio management approaches, enriched with discovery-driven planning for new solutions.

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Acronym Reference:

COVID Infectious disease caused by the SARS-CoV-2 virus
EBITDA Earnings before Interest, Taxes, Depreciation and Amortization
IoT Internet of Things
KPI Key Performance Indicator
OEE Overall Equipment Efficiency

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