The Curious Path to Industry 4.0

Executive Summary

In board room and executive committee sessions everywhere, manufacturers are discussing their next steps to achieve an Industry 4.0 (or Fourth Industrial Revolution (4IR)) future. And while the desire is definitely there, it's the path that's unclear. Why is this vision hard to achieve and what are the forces dragging down the adoption of innovations?

What many may not realize is that Industry 4.0 may not be immediately possible in facilities that have been starved for capital, have antiquated or poor performing operations, paper-based systems, etc. The dysfunctionality has to be dealt with prior to achieving these aspirational goals.

In our interviews and site visits, the move to Industry 4.0 is happening in two distinct paths. For many firms, their first focus is to bring new digital capabilities to their *internal* facilities, equipment, workforce, etc. That inwardly focused approach is often needed before considering a more externally focused Industry 4.0 approach. The inward approach often captures many new kinds of data at far more granular levels. It also focuses on: improving worker productivity; providing greater machine-to-machine integration; the acquisition of new manufacturing technologies; and, adding new quality and traceability capabilities.

> **Industry 4.0**
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> Industry 4.0 defines a new data rich manufacturing world powered by the output from capital equipment, sensors, scanners, customer reviews, suppliers, etc. This data is being used to enrich techniques, tools and insights possible in manufacturing today. Big data, dark data, unstructured/ structured data, biometric, geospatial, and many other kinds of data are being utilized by new powerful analytic tools, machine learning algorithms, augmented reality tools and much more.
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> Data is being analyzed by smart machines that are directing the actions of other machines and people. As a consequence, plants, warehouses, machine tools and more are becoming fully automated and connected.
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> Industry 4.0 technologies and data are changing how manufacturers design, prototype and produce new products. These technologies are dramatically shortening development cycles and helping to bring manufacturers closer to suppliers and customers.
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> Finally, the digital exhaust or digital thread produced by the Industry 4.0 devices may itself be a source of new revenues for manufacturers.

The good news is that reinvestment in manufacturing is underway. Capital budgets are getting greenlit and improvements to physical plant, machine tools, and IT are occurring. This change in investment thinking is long overdue and more strategic than ever. The investment priorities are often dependent on the current state of affairs within each facility. For some, the physical plant requires overdue rehabilitation. Some need upgraded (or net-new) technology to close critical process and/or information gaps. Some need improved processes and others are looking to transform their offerings to customers. Throughout all of these, there is a competitive need to craft a modern, digital connection between systems, capital machines, products, people and more.

How will your firm achieve a more digital future? The best firms will be keenly self-aware of their own situation as well as deeply knowledgeable of the technologies now available to them. In the process, each will likely develop a new, curious path to an Industry 4.0 future.

"Throughout all of these, there is a competitive need to craft a modern, digital connection between systems, capital machines, products, people and more."

One thing that's abundantly clear is this: incremental change won't win the race. It will take considered thought, vision and strategy. Those that choose leadership will win, while those that lurch from one incremental patch to another will not. What approach will your firm take?

Manufacturing and the Digital Thread

Change and *manufacturing* are two words that have rarely been used together. In fact, change has been glacially slow. Plants are typically land-locked and difficult to re-design. Capital equipment and legacy technology are very expensive. Processes are rigid. Change does not happen in manufacturing as it is quite difficult to pull off: organizations are rewarded for precise schedules, cost management, quality, and reliability. Change is disruption.

But in 2018, change must occur and changes are coming at an increasing frequency. Why? What will it entail? How do manufacturers adapt in sensible and meaningful ways? How can they avoid perilous rat holes?

Manufacturing, as a sector, is changing dramatically and strategically. A recent McKinsey report highlighted three major findings/priorities for adaptive U.S. manufacturers:
- New technologies and other changes are presenting new market opportunities for manufacturers
- The U.S. could increase manufacturing GDP by $530 billion
- U.S. manufacturers must make changes on several fronts to improve their competitive position [1]

And where past moves often involved incremental, piecemeal or stopgap approaches, today's investments are much more substantial. Businesses are creating factories of the future, automating ever larger swaths of production activities and reimagining the role of their products once they are placed in the hands of customers.

What exactly are the drivers and enablers behind these changes? And why now? The short answer includes these factors:
- Capital spending within the manufacturing sector is up
- Investments in plant, equipment and equipment automation are also up

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[1] https://www.mckinsey.com/global-themes/americas/making-it-in-america-revitalizing-us-manufacturing?cid=other-eml-alt-mgi-mgi-oth-1711

- A major focus of those investments is on improving worker productivity
- Technology is no longer a highly constrained and expensive impediment to change
- Manufacturers now can access many more technologies to improve operations beyond basic ERP (e.g., manufacturing execution systems)

In this paper, we will cover these topics, offer a self-assessment and provide other suggestions for manufacturers to use as they embrace an Industry 4.0 future.

The changes impacting manufacturers have a distinctly *digital* feel to them today. Manufacturers that want to modernize their businesses are trying to capture significantly more detailed data on both their production activities and their extended ecosystems. This is partly because they can do so cheaply and partly because of new customer and regulatory requirements regarding traceability and quality. To collect this digital fingerprint across the entirety of the value chain requires manufacturers to have modern systems, integrated tools and new skills.

Changing customer demands are also triggering digital solutions. Customers now want shorter supply chains and faster production times. They want smarter, digital-readied products. They want manufacturers to monitor, repair and/or replenish their products just before a customer/user needs it. The entire value chain around manufactured goods is changing and it requires manufacturers to re-imagine what they make, how they'll make it and what additional value-added services, capabilities and information they can provide with these products.

The digital age is even altering how manufacturers prepare business plans, forecasts and even predict product recalls based on various non-ERP sources such as social sentiment data, blockchain signatures,

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Retooling for the Future

Accuride Corporation, a maker of wheels, brakes and related parts for the truck industry, has been on a re-invention wave the last few years. U.S. and newly acquired overseas operations have been the principal beneficiaries of this modernization with some of the changes undertaken to rehabilitate capital starved plants.

These renovated plants now have the right to reclaim lost business. The renovation had to deal with a number of physical, process and technology issues. Some capital equipment/machine tools needed replacement with more modern gear. New or old, machine tools needed to be better connected to one another and to Accuride's information systems. Buildings needed repairs. And, of course, old or missing technology needed upgrading.

As part of the modernization effort, Accuride now uses a number of new technologies including a new cloud ERP (Plex), Workday back office applications, a MES, and the Niagara platform. This inward focus was a pre-requisite for the next effort where Accuride will drive additional costs/inefficiencies out of its supply chain.

Productivity within the plants is up materially due to better automation, improved information/systems and interconnected capital equipment. In some cases, a few dozen workers are now producing what used to take hundreds to deliver.

Accuride sees the outwardly facing Industry 4.0 hitting their industry soon. The rise of self-driving/autonomous vehicles will require more sensors, more analytics, etc. on many vehicle components including those made by Accuride. The company expects to offer more intelligent tire pressure monitoring systems, heat sensors in brakes, more telemetry technology, etc. within its product line. But, those product changes will also trigger the need for greater predictive analytics, in-memory solutions, scalable technology – technologies their old systems could not easily (if at all) support.

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customer Point of Sale (POS) transaction data, online search queries and more. The world went digital while many manufacturers were still analog, manual or paper-based.

Capital Spending & Equipment Investment

In interviews with numerous manufacturing executives and reviews of published reports, we documented a resurgence of capital investment in U.S. and Canadian manufacturing facilities. Specifically, we've noted firms:

- Upgrading capital equipment
- Repairing or rebuilding their physical plant
- Integrating machine tools to other machine tools
- Redesigning workflows to require fewer (albeit more experienced) operators
- Replacing information systems
- Automating the ordering process and reducing the need for direct sales personnel
- Integrating more and more of the value chain
- Improving product quality
- Shortening delivery times
- Etc.

To better understand why this capital spending is occurring now, let's examine what's happened vis-à-vis capital in a couple of major industries.

Automotive
The automotive sector was one of several that chased low-cost labor sources around the globe. Over the last few decades, many U.S. and Canadian automotive parts manufacturers opened new plants in Mexico as their large OEM customers wanted parts sourced close to the point of production (i.e., the OEM Maquiladora plants). These new supplier plants often got new buildings, new capital equipment, etc. while older plants in the U.S. and Canada were starved for capital budget.

As a result, many U.S. and Canadian plants fell into competitive disadvantage and/or disrepair. Labor costs at these older, inefficient facilities were higher than those of other countries. Customer defections occurred and this set the stage for firms to undergo a death spiral. With ever fewer customers/orders, these inefficient plants created more expensive parts and became even less competitive.

Surviving manufacturers responded by automating more and more of their production processes. The effect has been to dramatically lower labor cost/part. And, as a result, global cost of labor has effectively been equalized. Labor arbitrage is losing out to increased productivity.

Industrial Hardware
The same story played out in home and industrial hardware. We observed a specific company whose core products are commodity items that have been made by firms globally for a couple of centuries. Like automobile suppliers, their business was being ravaged by low-cost, overseas competitors. To recover, this company:

- Automated the machine tools within their production lines. What used to take approximately 6-9 workers per production line now only requires one. The result is that parts now cost only 11 cents each (in labor) to produce. This is now within one cent of its offshore competitors.
- Replaced a patchwork mess of old ERP software, spreadsheets and manual processes with a new set of technologies. One major change here was that orders are now sent in by customers electronically, get quoted electronically, scheduled for production, shipped, etc. without any errors or re-keying. The impact is quite apparent in Sales as the firm rarely needs direct sales people to physically call on prospects. The new sales team is now one-half the old size but booking 3-4 times more business.

This manufacturer can deliver in days what takes offshore makers months. Once labor costs can be lowered to a competitively neutral level, local manufacturers can focus on other differentiators like short delivery times, personal service, co-innovation and more. In this manufacturer's case, these lower cost/rapid delivery capabilities have earned them the right to recover business long lost to offshore firms. Today, this company continues to focus on methods that eliminate friction within its value chain.

Equipment
An equipment manufacturer told us a similar story. In their situation, they had an old plant that had been neglected for years. Its roof leaked, the facility was filthy, its machine tools weren't integrated, labor costs were high, morale was abysmal, etc. Their executive team looked at selling the plant (and taking a substantial write-down) or upgrading it. They chose the latter option.

The upgrades for this plant included a number of physical plant repairs, additional (or improved) machine tools, integration of tools to one another, an MES and a new ERP solution. Today, that plant is a star performer in their firm. Its re-discovered competitiveness has also allowed them to recover business previously lost to competitors and their delivery times to customers are mere hours not months, forming a competitive advantage.

High-Tech
In a high-tech manufacturing plant, we saw the effect of long-term technology budget starvation. This organization had such a constrained IT budget that many systems were no longer under vendor support and when package software was purchased, it was in small bites from far too many vendors. The technology in use was not integrated well, and was so cumbersome it was effectively stunting the growth of the company. And, this is on top of a firm that has outgrown its production facility.

The board of this firm wants to create a factory of the future and simultaneously pursue the development of all-new, lower-cost products for its customers. To expand, the company will face a flurry of new digital traceability, compliance and cost accounting requirements. They'll need to replace a number of manual, paper-based and partially automated processes and systems to achieve this board mandate. More production in the current facility is simply not possible unless workers can be freed from expensive, non-value-added activities (e.g., time spent searching for misplaced parts, handwritten documentation, etc.).

Today, that firm is embarking on a major technology refresh that will include the digital capture of every movement and touch a component receives. They will also acquire new ERP, MES, complex assembly and other technologies, and, in a first for this firm, integrate it all together electronically.

A Growing Trend

Through all of this, we often saw plants that were designed decades ago yet the business has tried to slip in robotic welding equipment, 3-D printers and other modern machine tools into work spaces that never contemplated such gear. These new capital tools may be making a nominal difference in productivity and/or quality. However, the full potential of these solutions may be getting lost due to the workarounds needed to accommodate old building designs, process flows, etc.

Thankfully, manufacturers have been investing of late and, with renewed faith in the economy, are investing even more. According to a recent NAM survey, 21.3% of manufacturers surveyed plan to increase capital expenditures by more than 10%. [2]

Where capital investment is occurring, and is focused on the right priorities, the effects on the company appear to be profound. The inverse is macabre, too. Where the capital is being starved, there is no innovation, customers are defecting and the businesses are ripe to fail. In a period of dramatic market and technology change, reimagining of one's firm and its competitive strategies is not optional. Incremental change is not strategic and unwise in rapidly changing markets.

Workforce Productivity & Workforce Scarcity

Manufacturers are becoming more "productive". To economists, productivity occurs when the revenue per employee increases. If machines do more work without adding more headcount, then the increased production will drive revenue per worker up. As more businesses utilize more automation, they can scale without adding more headcount. But, the introduction of more automation on the shop floor, shipping, receiving, testing, etc. means that a more skilled worker is needed to operate, repair, program, replenish, etc. these robots, 3-D printers, CNC machines, etc.

This isn't theoretical. It is a broad, accelerating trend:
- Since 2000, manufacturing jobs held by non-college graduates have declined by 45% while those requiring a college degree are up 17%[3]
- Across this same timeframe, manufacturing production in the U.S. is at an all-time high[4].
- 60% of all manufacturing GDP growth in the U.S. has occurred in just 10 cities[5]
- Women make up 30% of the manufacturing workforce in the U.S. today[6]

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[2] NAM (National Association of Manufacturers) Manufacturers' Outlook Survey, Fourth Quarter 2017, pg. 3 or
http://www.nam.org/Data-and-Reports/Manufacturers-Outlook-Survey/2017-Fourth-Quarter-Manufacturers-Outlook-Survey/
[3] "Why American Manufacturing is Booming", Angie Hicks, IndyStar, December 24, 2017 pg. 22A
[4] ditto
[5] Manufacturing in Growth and Transition", Michael Hicks, Supply Chain Management Review, December 20, 2017 or
http://www.scmr.com/article/manufacturing_in_growth_and_transition
[6] https://www.resourcemfg.com/news/2016/6/40128395/Manufacturings-changing-workforce

- The workforce must get younger as approximately 10,000 baby boomers retire every work day[7]

"Right now, according to the Bureau of Labor Statistics, nearly 3,000,000 jobs are available for those who are willing to learn a skill that's in demand. The vast majority of these jobs do not require a four-year degree; they require training. Fortunately, many excellent training facilities exist all over the country. And yet, none of those schools are ever included in the "Top 100 Colleges in America." Why? "

Source: http://www.educationandcareernews.com/career-development/mike-rowe-debunks-the-myth-of-a-modern-manufacturing-job

Finding that highly skilled worker will be a challenge. In one study, manufacturing executives identified the top four skills deficiencies within the employee and candidate base. These were:

- Technology/computer skills (70%)
- Problem solving skills (69%)
- Basic technical training (67%)
- Math skills (60%)[8]

Last year, in an interview with Mike Rowe of television's **Dirty Jobs**, Industry Week reported:

"In 2017, after all, thanks to technology opening just about every last bit of information and knowledge to the masses, you can be a philosopher and a welder.

"This idea that you have to be one or the other, that's craven, and that's hurting manufacturing and the skilled trades," Rowe says. "It's really hurting the current crop of Millennials, who are still being raised to believe that this is the path and the other paths are mutually exclusive. The biggest thing we can do to create a more well-rounded generation is to get the vocational arts — and they used to call them that, it wasn't always shop — back into elementary, middle and high school.

"You gotta start somewhere. That's where I'd start, if you really want to close the skills gap and reinvigorate manufacturing."[9]

What is happening to the new, digitally-savvy manufacturing workforce is simple: manufacturing employees must be more skilled and, in the process, will no longer have *'jobs'* but *'careers'*. The smart manufacturers see this change underway and are getting in front of it now.

The Technology Opportunity: Today's Bright Line

Most manufacturers today possess a MRP/ERP software solution. One study indicated that around one-half of manufacturers use a MRP solution and up to 61% of manufacturers have or will acquire one.[10] The larger the manufacturer, the more likely a MRP solution will be in use. As order volumes, revenues and/or BOM (bill of material) complexity grows, a MRP solution becomes a necessity.

For many firms, implementing an MRP/ERP solution is all they've done with regard to automation. The MRP tool gives them macro level visibility into production planning, bill of material content, etc. For smaller manufacturers this may be sufficient especially if their growth aspirations are limited.

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[7] ditto
[8] *http://www.themanufacturinginstitute.org/~/media/827DBC76533942679A15EF7067A704CD.ashx*
[9] http://www.industryweek.com/leadership/save-us-mike-rowe-show-us-how-work-again
[10] https://softwareconnect.com/manufacturing/tools-of-the-modern-manufacturer-report-2017/

Decades ago, the bright line separating struggling manufacturers from prosperous ones was the presence of a MRP/ERP solution. Today, that line has moved.

It turns out that the manufacturers that are growing today are not stuck on just MRP/ERP software. ERP has become table stakes with multi-tenant, cloud solutions becoming the new de rigueur standard. In a recent Grant Thornton study, rapidly growing manufacturers were moving forward with new technologies and innovation:

> *"It was interesting to find that the respondents who had experienced earnings growth of at least 20 percent in the past year had invested pretty significantly in new technology, such as the Internet of Things, robotics, additive manufacturing, artificial intelligence and supply-chain automation."*[11]

What is clear is that a lack of innovation may be impeding growth for some manufacturers. New technologies allow innovative manufacturers to create an ever-widening gap between the technologically-savvy and the technology impaired.

It is interesting to note that beyond ERP, the next three most common technologies used by manufacturers are: MES (manufacturing execution systems), Robotics and 3-D printing (aka additive manufacturing). However, the market adoption of these technologies remains half or less of that of MRP/ERP.

So, what's the drag on innovation adoption in manufacturing?

Innovation Inhibitors

Not all that's innovative gets implemented. In fact, many things must get done before any innovation initiative gets greenlit. These activities may include:

- Creation of a business case
- Assessment of the change impact assessment
- Acquisition of funds
- Scheduling of the implementation (to avoid conflicts with other projects or activities)
- Etc.

While the list of approval items can be long, there are many other reasons that innovation doesn't happen in manufacturers. These include:

- **Long-lived manufacturers often operate out of facilities designed for a different time and set of business requirements**. While it is great to show visitors that this is the building where the original product was made 91 years ago, it doesn't mean the original building is optimal for today's volumes, machine tools, power requirements, etc. Facilities are no different than other assets and have a useful life. However, if the life cycle of your products is accelerating, you should expect your facilities to require more frequent re-design, too. Nostalgia isn't a strategy but it will make you less competitive and slow-to-grow.

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[11] **"The Future of Manufacturing: A Progress Report",** SupplyChainBrain, November 16, 2017

- **Given a choice of re-designing the production environment or implementing a new shop floor technology (e.g., MES), businesses often choose the latter**. Innovations like a new process/tool (e.g., robotic welding) will get implemented in the old facility even with that facility's obsolete layout and other inefficiencies. Manufacturers do this for one very practical reason: they can't change their building easily (if at all) but they'll find a way to alter workflow to accommodate something new. When these successive changes get compounded, massive inefficiencies can arise in these fragile environments.

Not only is this risky, it can also strangle growth. One manufacturer in Silicon Valley has clearly outgrown its production facility and cannot easily move its now massive products through its own building without performing complicated, highly choreographed maneuvers. This firm has been avoiding this change for decades but now finds it unable to grow as its physical plant is the scaling constraint.

- **A lack of timely information will spawn a vibrant spreadsheet, whiteboard and paper-based work environment. Unfortunately, this leads to information gaps, errors, reconciliation activity, data latency and other inefficiencies.** On these plant tours, one will hear the stories of valiant efforts made by personnel to work around systems inefficiencies to keep production moving and customers happy. We heard of three-hour searches to find key parts hidden in unmarked bins. We saw massive spreadsheets that required a small team to complete just to develop the next week's project plan. We saw whiteboards with magnetic and paper status reminders of parts movements. While it is great that these firms have

> ### Nudged into the Future
> [Kamco Industries](#) (a subsidiary of Kumi Kasei) is an injection molding manufacturer that serves the automotive industry. It's also a study in contrasts.
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> A few years ago, Kamco had a few automated but not integrated systems and a lot of spreadsheets. For example, scheduling production for 30 machines was accomplished via email and Excel spreadsheets. Invoicing was a manual process. There were also significant differences in shipping and routing documents between plants. The environment was labor and error intensive.
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> Kamco got nudged into the future by its largest customer: a global automotive OEM. At their urging, Kamco made a number of investments, a principal one being the implementation of a full, modern ERP suite. That 'nudge' was a fortuitous event.
>
> Kamco's a different company today. The company now has full visibility across their value chain (i.e., from order to shipment). They have real-time, cross-plant visibility into inventory levels. Printing of inventory and production labels is now on-demand. Production scheduling is no longer a labor intensive effort. Product traceability is automated. All of these initiatives were an inward facing move to a more Industry 4.0 world.
>
> Next, Kamco wants to sift through all manner and types of data they now capture from machine tools and robotics. Data analytics will trigger preventative maintenance and other useful outcomes.
>
> The nudge has definitely triggered operational improvements and it has permitted the firm to pursue growth opportunities that were not possible a few years ago.

paper status reminders of parts movements. While it is great that these firms have

resourceful people to find workarounds and are dedicated to their firms, it is also a sign of great inefficiency being present.

- **Inefficient operations are not scalable.** Time and again, we were confronted with operations that are meeting current demands but only via baling wire, bandages, luck, and superhuman efforts by employees. Management often spoke of major new market expansions that they desire but current systems limitations will blunt or outright halt these. At some point, firms outgrow old systems, facilities, machine tools, etc.

- **Business people believe innovation occurs linearly when it is actually curvilinear.** Author and inventor Ray Kurzweil has opined on this matter in his numerous works. He has documented how the rate of change tends to be exponential not linear and that humans were wired biologically to see the world linearly.[12] This is a key point as too many executives fail to see a step-change occurring in their plants, order volume/mix, customer base, etc. They incorrectly assume that competitors will take longer to implement or create innovations than they will. They also fail to understand how quickly customer tastes can change and how fast competitors might embrace new methods, business models, production tools, etc. Change is not linear and it's accelerating.

- **Manufacturers don't always take the most direct or logical approach to embracing transformational or necessary innovation.** The best executives recognize when an incremental change is or isn't better for the company than a one-time big effort. It's like deciding whether to yank off a bandage or do a lot of incremental pulls. Incrementalism often leads to sub-optimal results and re-work. Upgrading your ERP system, for example, from on-premises to hosted and then to a multi-tenant cloud solution within a few years' time is a waste of effort with little incremental benefit along the way.

The Smart Way Forward

If there's one constant in manufacturers today, their boards of directors and executive committees are clamoring for major changes. They want digital transformations and factories of the future. But have these executives really looked at their operations in detail lately? Have they compared their operations, processes, facilities, tooling, workforce, etc. with others within (and outside) their industry?

If they'd only take that self-assessment step, they might find the desired changes they so desperately want are going to be hard to do. Most every firm will see a gap between their current state of affairs and their desired destination. But how big is that gap? Why can't executives just demand change to occur?

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[12] Ray Kurzweil, *The Age of Spiritual Machines*, Viking, 1999, p. 30 and p. 32

It turns out the gap matters – a lot! Large gaps can't be closed in one fell swoop. You can't, for example, go full-blown modern and digital when you've haven't addressed your poorly designed processes, re-designed your obsolete production flow, eliminated non-value added activities, etc.

> *"Wantin' and Gettin' are two different things"*
>
> Oft-heard Texas euphemism

The best firms really understand their changing environment. They think strategically (not incrementally or tactically). They are not emotional or nostalgic (even if grandpa designed the original production methods 70 years ago). They adapt to changing tax, economic, regulatory, human capital, technology and other factors with cool determination and purpose. They objectively assess their own firm and its needs.

To do this, manufacturing executives must be self-aware. They know how great the journey is and the path or direction it must take. In our interviews, we routinely heard of several common self-assessments and each one colored the path to an Industry 4.0 destination.

One self-assessment is to simply determine whether your firm is dysfunctional, functional, process excellent, or transforming the industry you compete within. Let's look at these categories first.

Dysfunctional – Any firm can find itself in this category during its lifetime. Some of the dysfunctionality triggers include a loss of a major customer, a merger with another complex firm, a failure of an unsupported piece of critical equipment, a fire or other natural disaster, etc. Often though, companies are dysfunctional as they've outgrown their older ERP and other software. These same firms may possess all manner of unsupported applications, are overly reliant on spreadsheets and have poorly functioning processes. The proof, if you will, of a dysfunctional firm is found in its latent data, costly (bottom quartile) processes, and need for human beings to work 'miracles' to close books each month and 'find' all those missing parts. Dysfunctional firms are in a dangerous space as business failure could happen if problems aren't addressed soon.

Functional – Functioning firms get the job done but, like sausage making, you don't want to know how they do it. From a benchmarking perspective, these firms are often all over the map. While they might do some things quite well, other processes could be terrible. Functional firms may not be in immediate danger; however, their ability to scale and grow is in doubt. Their competitive advantage, if it exists at all, is fading, too.

Process Excellent – Process excellent firms, as their name implies, are firing on all cylinders. They have great systems and processes with most processes scoring in the top quartiles. These companies' operations are often the envy of the industry. Not surprisingly, they often possess great quality programs, are socially responsible and are great places to work at.

Transformational – When a firm is highly efficient, has its processes in order and is meeting its financial targets, then it can turn its attention to developing new kinds of capabilities, services and/or solutions. Many of these will be quite innovative and may re-write the rules of competition in an industry. Manufacturers launching servitization and Industry 4.0 initiatives fall into this category.

In our meetings with manufacturers, a surprising number of executives admitted their firms are only **borderline functional**. They possess very fragile operations and technology that are often highly customized and cobbled together. Worse, the key persons supporting these may soon be leaving the firm or the vendor that created their critical technologies may no longer support them. This environment often works only because of the dedication of the people to see things through. It's not efficient. It's not cheap. And, most importantly, it won't scale. It's a boat anchor.

Often these barely functional firms need to complete a serious modernization of their manufacturing systems and practices just to maintain a semblance of competitive readiness. Some of the more common items that must be addressed may include:
- Use of an MES to track the movement, time, and costs of every component in real time
- Use of a more modern ERP tool. Products built in the 1980s-1990s are often out-of-date and no longer supported by the vendor.
- Replacement of custom applications wherever possible. IT should be focused on creating strategic applications – not developing the same kind of applications many software firms already offer.
- Elimination of scores of spreadsheets. Has your firm undertaken a root cause analysis for every spreadsheet in use at your firm? You'll likely find non-automated interfaces, data standards issues, etc. to be the culprits.
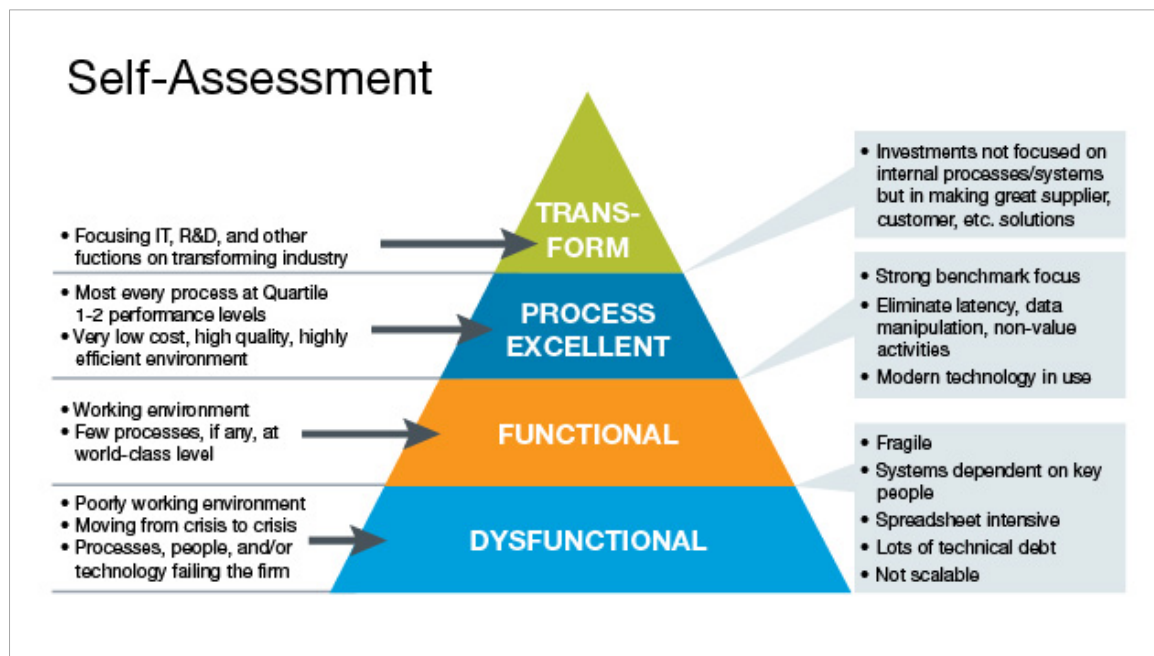
Another large group of manufacturers we met with rests on the boundary between **functional** and **process excellent**. In their quest to be a highly efficient and effective manufacturer, these firms are starting to utilize:
- Shared services for many back office (e.g., Finance, HR) and some front office processes
- Advanced machine tools (e.g., robotic welders/packers/pickers), 3-D printers, etc.
- Tight integration between machine tools that eliminates manual effort

- Sensors on equipment throughout manufacturing, packaging, receiving, and other functions
- Machine learning tools that continuously scan sensor and other data to identify anomalies, possible machine failure issues, etc.

Some manufacturers never quite make it to process excellent as they never truly complete their prior initiatives. We saw firms install sophisticated capital machinery that captures vast amounts of production data in real time. However, these manufacturers don't use or examine any of this information until a problem with the machine or a manufactured product occurs. If they only used analytic tools to detect a growing, potentially adverse trend, they could bundle preventative maintenance with scheduled downtime and that would likely save substantial sums over time.

Likewise, we've heard many executives tell us of how they *"intended"* to implement a full ERP suite but the project only got as far as implementing the financial modules. These are really sad affairs as the firm probably paid for the entire software suite and continues to pay maintenance on the few installed and many uninstalled applications.

This may also be a sign of a management failing, too. In their quest to solve a 'functional' problem (i.e., replacing an obsolete general ledger package) instead of a strategic one (e.g., how to drive scale and facilitate inorganic growth), the project team can quickly lose interest or focus. If your firm has these incomplete or unrealized projects, figure out why this happens before you commit to an even more transformative effort.

Another, albeit small, group of manufacturers is moving from **process excellent** to **transform**. These firms have their shop floor and back office operations already working at work class levels. The focus of these firms is on improving the way they work with customers, suppliers, researchers, governments and others so that they can deliver new kinds of solutions that will receive early and wide constituent support.

This last group is redefining themselves. They might be offering their products now as a service (i.e., servitization). Bundling products and services requires a new way of selling, accounting, and even bundling additional sensors/services into the products that it sells. These manufacturers are retooling their workforce to become leaders in a more digital future. They're investing in new disciplines (e.g., data science) and technologies (e.g., smart glasses, nanotechnology, natural language processing, etc.). In essence, they solved and optimized their Industry 3.0 world and are moving headlong into the Industry 4.0 existence.

There are some important considerations to ponder regardless of your firm's position on this hierarchy:
- **Manufacturers cannot skip levels.** For example, you can't go from dysfunctional to process excellent overnight. If you're dysfunctional, you won't have the luxury of time or money to do a massive transformation or renovation of existing operations and systems. No, you'll need to do triage and put out the biggest and worst fires first. Only after you've stabilized things can you move to more dramatic changes.
- **Stabilizing, Streamlining and then Revolution (in that order).** These are the likely phases a firm must pass through. It is a mistake to do things out of sequence. Ironic that an industry

where adherence to a specific assembly process is a key to success, the same discipline must also be used to do manufacturing reinvention well. For example, it doesn't do any good to implement new financial applications if the critical cost accounting elements are still not being captured automatically on the shop floor.

- **Create your as-is and to-be technology bill of materials –** Grade each of the as-is items and determine if an upgrade or replacement should also be on the to-be list. Everything on these lists should have a '*best when used by*' date associated with it. Are any of these past due for a change? Next, determine if a small step-change is justified or if the magnitude of change is great. Shouldn't there be an equally ambitious transformation project? Finally, don't forget to assess the physical plant and the production layout. Do these need a reworking, too?

According to consultancy McKinsey:

"The average US factory was 16 years old in 1980, but today it is 25 years old. Inside the plant, the average piece of equipment was seven years old in 1980 but is nine years old today. Production assets are even older in metals, machinery, and equipment manufacturing." [13]

Remember, it's not whether your assets are old; it's that they may no longer be relevant. If they were designed for a non-digital world, they may very well be obsolete.
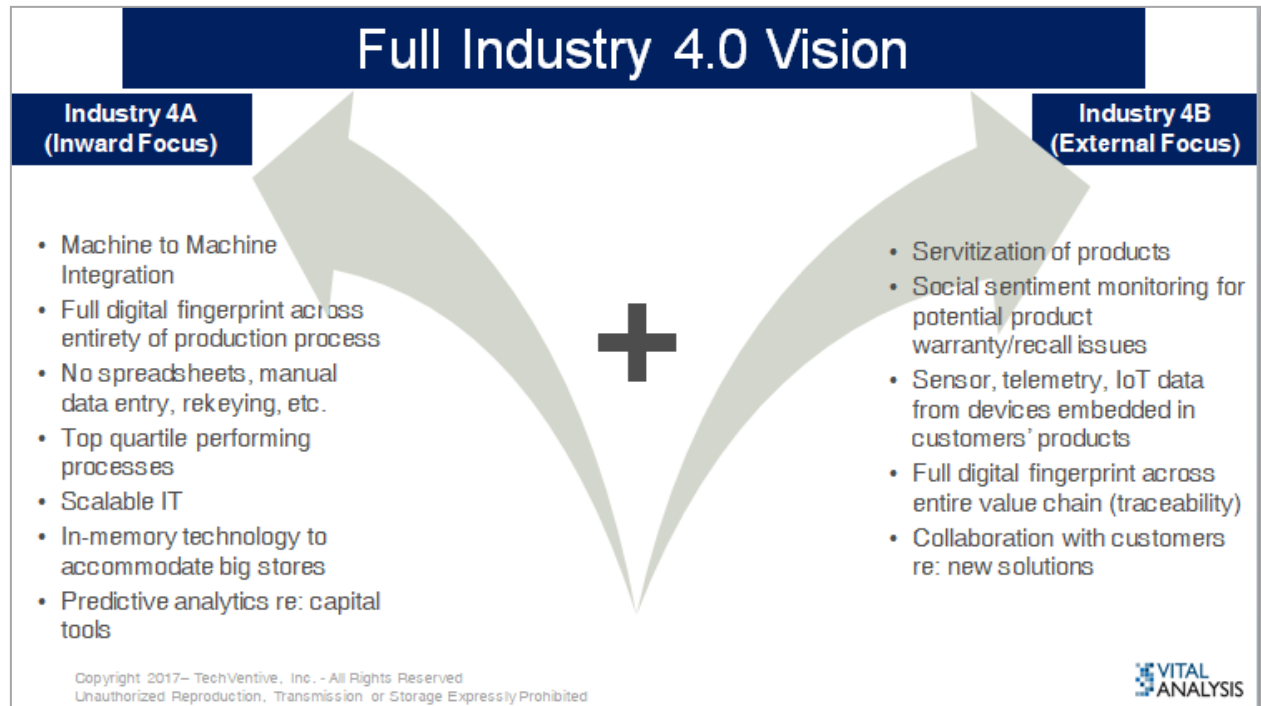
Path(s) to Industry 4.0

While many companies aspire to an Industry 4.0 environment, they may have to first deal with their dysfunctionality, poor plant layouts, and antiquated or sub-optimal systems before jumping into a more digital existence. And though boards of directors and investors may want this new digital future, the reality may be that past sins must be addressed first before this is achievable.

> *"…it is not possible to start a company today without data at its core"*
> Source: Global Finance, December 2017, pg. 20

Some companies we've spoken with are designing a *smart factory* or *factory of the future* to prototype and socialize the way work will get done in other parts of the firm. It's actually a great idea as it helps people see the future of work and the products they make. That insight can help go a long way to increasing buy-in, identifying potential issues early, and speeding up the rollout of Industry 4.0 capabilities.

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[13] https://www.mckinsey.com/global-themes/americas/making-it-in-america-revitalizing-us-manufacturing?cid=other-eml-alt-mgi-mgi-oth-1711

In interviews and in visits with manufacturers we looked at how companies will achieve a more digital, more Industry 4.0 existence. What we observed is that Industry 4.0 should be viewed in two distinct streams:
- An *inward* facing digital future where machines, systems, and people within the four walls of the enterprise are connected in real time to one another and insights are continuously mined within this data. **(Industry 4A)**
- An *outward* digital existence for the products and services a manufacturer produces. **(Industry 4B)**

Industry 4A

In the Industry 4A world, manufacturers should be doing the following:
- Connecting capital machines one to another
- Using an MES to record the movement and changes of every component, every material, etc. by each worker or machine that touches it
- Creating real-time data capture and analytic environments. Data capture occurs via scanners, smart glasses, touch screens, etc.
- Eliminating 99.9% of spreadsheets and data latency – you can't meet traceability, governmental, and other requirements if you don't have this info at your fingertips
- Tracking movement of items, raw materials, interim components, final products, etc. across the entire value chain from supplier to customer
- Understand anomalies within the new data

- Using new digital-enabled tools to rapidly develop prototypes, assess feasibility of new products, pioneer new manufacturing methods, create net-new products and speed up delivery and quality of its goods

The scope of a 4A change program can be daunting. Going from an environment with lots of paper, spreadsheets, and manual interventions to one where machines, algorithms, etc. are automatically recording time, cost, parts used, etc. is a huge change. When big data utilities are monitoring equipment performance in real time, scheduling repairs/replenishment, altering production schedules, dispatching workers, etc., it can cause anxiety with workers that used to perform these functions previously.

Think of the way your production operations will work at the end of your 4A journey. Newer technologies and techniques may mean that simulation tools will have digital twins of your capital equipment available virtually. New analytics will detect upcoming issues and engineers can diagnose these virtually and from afar. These tools should save fortunes in re-work, reduce downtime, and eliminate scrap. Your entire production process can be digitally modelled and tested prior to the expenditure of one dollar in your actual shop floor.

But, none of the above is possible if your firm is stuck in an Industry 3.0 world.

Industry 4B

The key objective from a 4B program is to create long-term sustainability and prosperity for the company. The recent adage "*Data is the new oil*" speaks to the importance of having data and products together, not just products. When data and products are combined, companies can create new value propositions for the customers. This is the driver behind the servitization of products. It's why railroads no longer buy locomotives but instead consume power-as-a-service. Customers just don't want a product anymore; they want to consume the product as a service. In short, customers want a manufacturer that is proactive. Manufacturers should monitor the usage and performance of the products they sell and recommend preventative measures to their customers.

In the Industry 4B world:
- Customers and sales professionals should be able to model new products, co-innovate products and solutions, and share in the data that sensor-enabled products create.
- Customers should be able to submit orders, drawings, etc. digitally and have them machine-ready at the manufacturer in seconds, if desired.
- Great cost tracking, traceability, etc. should allow audits to happen virtually and in minutes, not days or months.
- Manufacturers will have digitally connected supply chains that provide real-time data on parts, costs, deliveries, etc. This information is used as a key input to production planning systems, forecasts, etc.
- Beyond the digital supply chain, a digital value chain should connect the manufacturer with its customers to monitor product usage, product performance, potential recalls, etc.

- Sensors will generate tons of new information from the products being sold. The best manufacturers will have subject matter experts, quants, statisticians, and more reviewing the information to understand which anomalies warrant further review and/or action.
- Blockchain technologies may be used to maintain the integrity of the supply chain and prevent counterfeit goods from entering it.

Some manufacturers told us that they make components or subassemblies that go into larger goods sold by an OEM. As such, they didn't feel a need to get into the Industry 4B world. We pushed back on that assumption as it didn't jibe with our market knowledge. For one of those manufacturers, we discussed how they could be monitoring social sentiment data to see if end customers were experiencing issues with the OEM's product and did any of those issues relate to their components. We also discussed numerous other Industry 4.0B use cases that more manufacturers should consider but aren't today. In fairness, these manufacturers have a huge change effort in front of them just to get to Industry 4A, and the 4B initiatives will have to come later.

During our interviews, we noted that the path to an Industry 4.0 existence may follow this common trajectory:
1) Get older operations/facilities to a process excellent state
2) Bring Industry 4A capabilities online for all processes, technology, and capital equipment within the four walls of the enterprise
3) Then, launch Industry 4B capabilities for externally facing constituents

Your Next Year's Plan

To remain competitively relevant, manufacturers have no choice but to evolve and adapt. And while few find change to be fun, it is, nonetheless, necessary. Once you accept this, the next step is to create the conditions for change.

We believe the following are your most immediate action items regarding strategy and leadership:

- **Become aware** – You can't really change, effectively, if you don't survey the possibilities out there. Don't be surprised if the vendors that brought you Industry 3.0 technologies (e.g., your existing on-premises ERP vendor) aren't really ready for the Industry 4.0 world. In all likelihood, you'll need to find new ideas, process designs, and suppliers for this digital journey. Where do you get these ideas? Get out from behind the desk and catch trade shows, tour other firms' plants, and engage with newer technology vendors.
- **Fight incrementalism** – Many of the changes your firm must make will be big. Yet the organization may have decades of experience, a culture of taking little steps, and lots of muscle memory. While these may be good for some things, major transformation initiatives will require the setting aside of old beliefs, limitations, processes, etc. Think big and encourage others in your firm to do likewise.
- **Refocus your R&D** – If typical, your R&D group has been singularly attentive to creating solutions for customers. Get them involved in redefining and redesigning your firm. What ideas and vision can they bring to the table?
- **Develop the BOM for future skills** – Your firm is probably hip-deep with Industry 3.0 skills, but it may not have the analytic, big data, algorithmic, in-memory, cloud, etc. skills it needs for a more digitally relevant future. What's the new bill of materials for your workforce? Where will you get this workforce, and how will you train/transition your current workforce?
- **Understand the consequences of going slow (or not at all)** – Inertia (i.e., a body at rest remains at rest) is something that must be addressed. Prepare a competitive assessment of your manufacturing sector, and determine your vulnerability. And, don't forget about new entrants (e.g., Google/Alphabet, Apple, Amazon, etc.) who bring new business models to competitive spaces. Did anyone ever think Elon Musk and Jeff Bezos would get into the aerospace business? Going slow may be a luxury you really can't afford.
- **Create the sunset plan for EVERYTHING**! – What's the best used-by date for every facility, tool, skillset, product, etc. in your firm? Are you developing plans to have the replacement in place before these expiration dates hit? While the tax code may let you depreciate a manufacturing plant over a 35-year timeframe, will you be making these products in 35 years? Change is accelerating, and the smart people get ahead of the changes.

We also recommend these action items regarding technology:

- **Assess runway -** Older technologies and their purveyors may have been key ingredients to your prior market successes. But some of these may have already had their best days while newer solutions or vendors have a lot more runway in front of them. Do NOT get nostalgic. If people speak of an old technology like a worn, well-broken-in pair of shoes, it's time to seek true love elsewhere.
- **Reward new business to worthy providers and dump bad actors -** Remember 10-15 years ago when your technology sales professional told you that your firm was their most strategic customer? Today, some of these older vendors are aggressively auditing or suing their own customers: a behavior that strategic partners avoid. Don't reward these bad actors with new business – kick them to the curb!
- **Get out of the data center/utility computing business –** For many IT shops, much of their labor cost goes into patching, maintaining and application software, and the systems software and hardware it runs on. Unfortunately, this prevents IT team members from developing competitive advantage capabilities for the company. Utilize cloud solutions wherever practical.
- **Plan for unconstrained technology –** For decades, no one had enough disk storage, throughput, processor speed, etc. nor could they afford what they really wanted. The age of constrained technology is essentially over as new devices (e.g., IoT sensors, smartphones, scanners, video cameras, etc.) are generating massive amounts of digital exhaust. Look for public cloud platforms and infrastructure services that support a big data, dark data, etc. world and not just an old, internal transaction processing world we've known for years.
- **Upgrade your technology skills –** Manufacturers are using virtual reality headsets, drones, video, and scores more tools that need experts with skills in machine learning, social sciences, statistics, algorithms and much more to tease out great business outcomes. If COBOL is still king in your IT shop's skillset, you've got a problem.
- **Redefine what a "*Strategic Technology Vendor*" is** – Great CIOs know which vendors and solutions are key to the success of the firm and which ones peddle commodity offerings. Twenty years ago, your office automation suite provider may have been designated a strategic vendor, but should they be designated one today? What technologies and vendors should be strategic in an Industry 4.0 world?

Closing Thoughts

To move to an Industry 4.0 future, the work that manufacturers must complete will vary. Some will need to repair their physical plant, integrate machine tools, replace technologies, and more. While that sounds obvious, **the exact path** will vary significantly from one firm to another. The variability will occur because of many past investment decisions. Firms with long histories of incremental changes, stingy capital budgets, incomplete initiatives, patchwork systems, old technologies, and broken processes (with lots of manual, low/no-value added activities) will be the hardest to change and have the longest change journeys.

Industry 4.0 initiatives need to be prioritized so that firms can optimize internal resources as well as external users. A path that only considers internal factors may yield many huge benefits but even larger external opportunities may go unrealized.

One of the most sobering thoughts may be this: *while manufacturers are transitioning to a new, more digitally driven future, many of the technologies they'll need will be new, too*. Technology buyers will be confronted with:
- Old solutions that vendors are trying to pass off as modernized
- New solutions with little track record
- New, immature solutions that require additional development by vendors
- New kinds of data (e.g., dark data, big data, unstructured data, etc.)
- New computing architectures
- New integration challenges
- Etc.

These Industry 4.0 initiatives will affect most every aspect of a firm. They clearly are NOT just a technology initiative. Material changes in the workforce will be required for some firms. Processes must be substantially altered, too. Even core business functions like sales, customer service, public relations, quality management, etc. must be reimagined and redesigned.

The curious but nonetheless dramatic journey to Industry 4.0 will be different than any prior one your company has undertaken. Are you ready for it?

About Vital Analysis

Vital Analysis is a very different kind of technology research organization. We are the intersection set where exceptional technology market knowledge meets the executive suite. Where other 'analysts' replay vendor press releases, we give you the:

- Impact new technologies will have on your business.
- Reasons why you should care about specific emerging solutions.
- Business justifications why you may want specific solutions.

Vital Analysis was carved out of TechVentive, Inc. in 2007 as a new, but related, business. As designed, Vital Analysis is the publishing, research and analytical arm of that company.
Our reach, like our blog readership, is truly global. We've consulted with top technology executives across the globe and have been briefed by technology providers from virtually every corner of the planet.

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