The Roadmap to the Five Levels of Manufacturing Automation

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Author Bio

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As the manager of Makino's VMC and EDM turnkey and automation proposals, John Bradford brings decades of experience in the development and implementation of complex automation systems for the tool, die and mold market. His nearly three decades of experience in manufacturing includes a diverse background of roles from being a toolmaker to leading Makino's micromachining research and development team.

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Evolution of Tool and Die Automation

Manufacturing automation is transforming the tool and die shop floor. As technology advances and is integrated with Big Data, the Internet of Things (IoT), Virtual Reality (VR) and Artificial Intelligence (AI) the industry is seeing a new area of automation where software and machinery are increasingly more capable, and the manufacturing value stream is evolving.

Automation is being implemented at varying levels depending on the industries served and the products being produced. However, looking at the full manufacturing process there are many key areas where automation is currently being applied, including CNC machining, maintenance, material movement, scheduling, management and administration. In the future, automation will link nearly all tool and die shop functions from design through production.
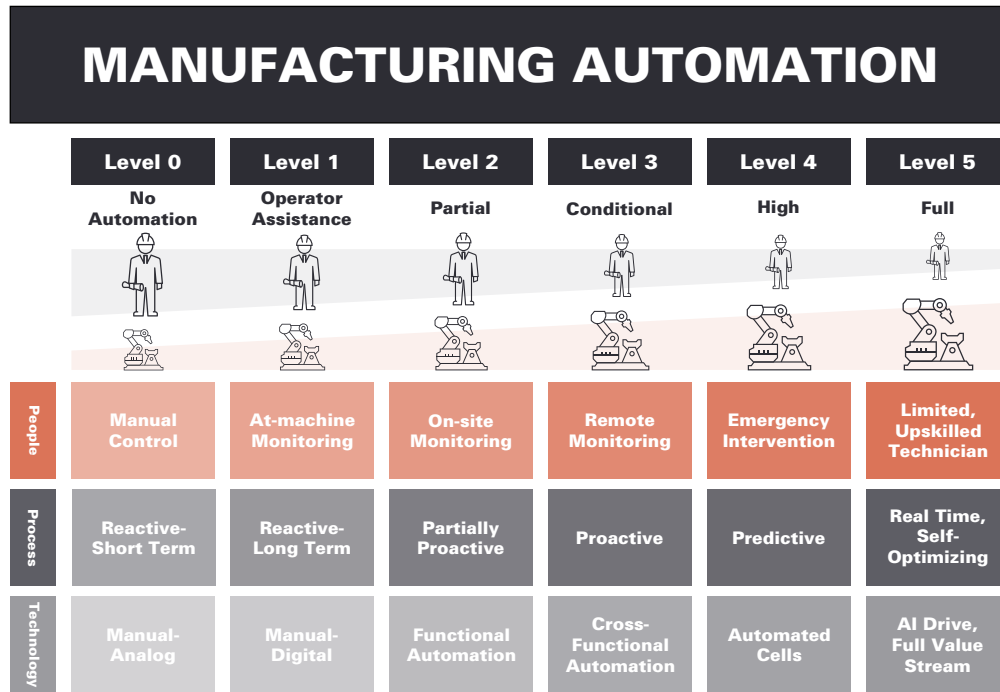
Benefits of Automation

Automation across the shop can deliver a number of benefits that will help companies gain a competitive advantage.

- **Increased Capacity** – As automation is added to the shop floor, companies can increase effective production time, while reducing machine down time resulting in improved utilization rates, while at the same time increasing throughput. This open capacity also will apply upstream to design and engineering and downstream to tool assembly.

- **Improved Quality** – Automated systems and process provide better accuracy and consistency then manual or operator assisted solutions and as a result delivers a higher level of quality across every tool developed.

- **Reduced Cost** – By optimizing machine use time, improving shop floor processes and leveraging predictive machine maintenance, shops are able reduce the overall cost for making a tool.

- **Skilled Trade Gap** – As companies automate they will require fewer employees to manufacture tools due to the efficiencies gained and the ability for the machines to run operator free. However, it is important to note, that the skills set of those integrating and managing the automation will be different than today's traditional tooling skills.

- **Reduced Lead Time** – With equipment and machinery running closer to 24/7 on the right pieces and parts with fewer errors, the required slack time in the design and build process will shrink resulting in a lead time advantage.

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MANUFACTURING AUTOMATION

	Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
	No Automation	Operator Assistance	Partial	Conditional	High	Full
People	Manual Control	At-machine Monitoring	On-site Monitoring	Remote Monitoring	Emergency Intervention	Limited, Upskilled Technician
Process	Reactive-Short Term	Reactive-Long Term	Partially Proactive	Proactive	Predictive	Real Time, Self-Optimizing
Technology	Manual-Analog	Manual-Digital	Functional Automation	Cross-Functional Automation	Automated Cells	AI Drive, Full Value Stream

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Five Levels of Manufacturing Automation

Manufacturing consultants, Harbour Results, Inc., has developed a scale outlining Five Levels of Manufacturing Automation. Each Level is categorized by the criteria needed in three key implementation areas - people, process and technology. Today, there are tool and die shops operating at Level 0 through Level 3. Some of the most sophisticated shops are approaching Level 4 automation, while Level 5 is a future state just now becoming achievable. With today's technology and the adoption of AI, cloud computing and other advancements it will become a reality soon.

To better understand where automation could most profitably be applied to improve performance, shop leadership should conduct an audit to understand where they are currently positioned on the scale; keeping in mind that to successfully attain the Automation Level all three categories must be achieved.

Evaluating a shop's operations along the Levels of Automation Scale can help determine the appropriate implementation strategy to deliver long-term success. Wherever a company is on the scale, it is essential to focus on value creation. To move along the scale a company will need to undergo a number of transformational steps. To achieve higher levels of automation a facility must be digitally connected through a single network. In other words, everything within a shop must talk to each other. Additionally, the shop must be connected to external audiences, such as machine manufacturers, to optimize automation performance.

By reviewing the feasibility and benefits of the transformational steps with a clear eye on the change management requirements to accomplish it, shops will be able to prioritize what must be addressed first to ensure an investment in automation will deliver the expected impact for the company.

Implementing Automation

To be competitive in the tool and die industry it is no longer an option to avoid automation. Shops of all sizes must determine the best Automation level and implementation strategy to remain competitive across the manufacturing

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marketplace. Will this transition occur overnight? The answer is no but that doesn't mean many North American tool shops are not actively working trying to move themselves left to right on the automation continuum.

In order to effectively implement automation, it is critical that a company look at its facility holistically before investing. Selecting the right equipment or software is only part of the equation. The three key areas that need to be considered when automating a shop are people, process and technology. Manufacturing automation will not be successful if leadership only focuses on one area. All three need to be in alignment to receive the greatest benefit.

People
It is important to understand the skill sets that are needed to implement automation and to determine if they currently reside within the company. If not, decisions need to be made on training current employees and/or hiring new talent. It is a frequent misconception that the goal of automation is to replace people as they are a critical factor to executing automation at all levels within the shop. Automation should drive an ability to do more with less, but the issue is employees will need to have far different skills and capabilities than today's workforce. The bottom-line when we look at people is the focus is more competency needs and less capacity needs.

Process
Adjusting and updating current manufacturing processes will be critical to optimizing the benefits of automation. If a shop only changes technology and not the process in which the software and machines are utilized efficiencies will be lost. For example, as the level of automation increases there will be machine to machine and machine to man interface which will require new processes and methods to manage and monitor.

Additionally, the process for collecting data will be significantly different. By data we mean the type, amount, value, accuracy and speed of it. The "datification" effect will result in a transition from utilizing historical data to real-time self-

intelligence. So instead of looking backwards, we are being provided the right information at the right time for the right purpose.

Technology
Identifying the right technology for a company is determined by many factors based on the established automation strategy. From budget to competency to available I/T support systems, companies need to ensure that its systems, sub-systems and culture are aligned to successfully integrate the technology.

Embracing Level 2-3 Automation – Industry 4.0
Industrial automation is expanding rapidly across the manufacturing industry. Industry 4.0 is a term that has been used for years, but many don't understand its potential impact on manufacturing. Industry 4.0 at its essence is combining traditional manufacturing practices with the technological world. This translates to businesses leveraging machine-to-machine (M2M) and industrial internet of things (IIoT) deployments to increase the effectiveness and functionality of industrial automation, improve communication and monitoring and become more predictive.

Through automation companies are developing and integrating new methods, techniques and systems that help to reduce human intervention on the shop floor and, as a result, they are able to maintain or improve quality and efficiency while managing the talent gap. However, the challenge across the tool and die industry is to understand how how do shops move from being reactive (Level 0) to be more predictive (Level 3)?

To better define actions that need to take place to move up the automation scale, it has been broken down into the three key areas of focus – Technology, Process, People

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Industry 4.0 Roadmap - Technology
As we look at integrating Industry 4.0 the first logical place to start is technology. In manufacturing, technology can be broken down into three categories akin to the human body. Like the human body, each is separate and distinct but must work together to function properly.

- **Automation (i.e. Muscles)** – This includes all the machinery, equipment, sensors, robots, etc. All of which needs to be flexible to ensure you can meet the customer's needs and adjust to changes more effectively. The muscles need to be operating at high efficiency to get benefits from Industry 4.0.

- **Connectivity (i.e. Nervous System)** – More and more devices, equipment and systems are being converted from wired and analog to wireless and digital. Standard communication paths and protocols will be required to obtain complete linkage between all equipment and systems.

- **Intelligence (i.e. Brain)** - Ultimately you need to harness information from the whole enterprise to make data-driven and intelligent decisions to operate faster and reduce cost/hours.

- Automation and connectivity focus on establishing linkages between equipment, machines, and computer-based systems for the collection and integration of data. Intelligence is about the processing and analysis of that data.

Before a shop can consider investing in technology for Industry 4.0 it is critical that a company's I/T infrastructure and cybersecurity systems are in place and up-to-date. Once this is in place, the next step to move up the automation scale is upgrading connectivity – I/T drivers, software and sensors need to be able to speak to each other. Shops should purchase technology that meets current standards (MTConnect) and, where necessary, upgrade controllers on key pieces of equipment. Many of the technologies currently being utilized in shops can continue to be leveraged, such as CAD/CAM, Simulation, ERP, Laser Scanning.

However, it is important to fully leverage all the systems' capabilities. Additionally, shops should ensure that new equipment, technology and software is aligned and connected across the shop. And, finally, focus on accessing date across all current systems and partners rather than waiting until new all-in-one systems are implemented.

The best way to increase automation within a shop is by integrating existing and new smaller technology together to optimize the shop floor and be less reliant on shop operators. To operate at Level 2 or Level 3 automation, shops will need to integrate both hardware and technology beginning with a nervous system upgrade and enhancing existing controls on key equipment to support new functionality. This should allow for equipment/machine monitoring technology that provides alerts and real-time data and information about a machine including run-time, number of parts produced, efficiency, estimated time remaining, etc. This same critical equipment can be augmented with a few AI driven templates to move toward more predictive maintenance (e.g. bearings, ball screws, coolant, etc.). In the near term, knowledge of how equipment is running (and for how long) and whether it is healthy provides management an opportunity to better utilize current assets and avoid costly downtime.

These kind of data streams are critical for a manufacturing plant to mature along the automation scale and will enable computer-aided scheduling tools (and eventually AI-driven production schedules) and eventually automated ordering of spare parts through current maintenance systems.

It is important to note that one of the key challenges to integrating new and advanced technology is cost. To be effective business strategies must include detailed plans for capital investment to ensure timely implementation and integration across the shop.

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Industry 4.0 Roadmap – Process

Currently, many shops are reactive and focused on what needs to be addressed today to meet customer needs with a goal to become more proactive and, ultimately, predictive. Adjusting and updating current manufacturing processes will be critical to optimizing the benefits of automation. Ideally, companies need to put processes in place that align with the new technology.

To be successful process automation needs to occur across the whole value stream – from marketing and sales to quoting and estimating through design and engineering and manufacturing and assembly. It must not be limited to the shop floor. In each of these areas, there are a number of systems, functions and tasks that are used daily to operate the business. When implementing Industry 4.0 it is important that a company looks at it holistically in a system-process hierarchy – system, process, function and tasks. By breaking it down this way, shops can better understand where they can automate a task or, more importantly, a whole system. This is often a missed opportunity during ERP implementations. In many instances, companies look to maintain their current processes and want the ERP system to conform to it. In the process of doing that they often end up having to do "more work" with no discernible benefit (e.g. warehousing, shipping and receiving). A system-level change such as an ERP implementation is supposed to increase automation and minimize transactional repetitive work, not increase it.

Another area of opportunity for almost every shop is CAD and CAM. Software enhancements/upgrades are never-ending, and it is difficult to keep every team member appropriately trained and leveraging new capabilities (see People below). Further, standardization efforts around CAD and CAM have had mixed results, yet this standardization can have a profound impact on automation capabilities. Employing feature-based machining, templates, macros and standard libraries reduces human variation and mitigates errors being introduced to downstream processes, whether those are machines or other people performing value-added tasks.

The operational benefits of a CAD/CAM focus include:

- Reduced programming time through those standardization efforts mentioned above

- Faster machining programs through optimized cutter paths

- More predictable cycle time estimates/scheduling

- Linkage of programs and/or blocks together to increase "lights out" run time

- Use of simulation to more confidently run unattended machining

- Leveraging cutter and probe checking in the programs to improve first-time quality and reduce downstream re-work

Simultaneously, these improvements set the company up for greater and more impactful automation opportunities in the future.

One of the key requirements in implementing Industry 4.0 from a process perspective is data. Today, most shops are gathering some level of data and some are even analyzing it. However, most shops are not using the data to make decisions. This will need to change in order to move up the automation scale. Shops need to be implementing and connecting the right metrics systems to collect, analyze and use the data to drive the business in real-time. Shop data must undergo a transition from being reactive and descriptive "what happened?", "what is the problem?" or "how many?" to more proactive and prescriptive such as "why is this happening?", "what if these trends continue?" or "what will happen next?". The ideal information for every level of the organization would answer the question "what's the best action to take right now to achieve the best result?"

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More proactive use of data and information will require data conversion to the right information with the right purpose at the right time. The first step is choosing a key data stream and automating the acquisition, transportation, and analysis of it. This will allow shops to be more proactive and further leverage the benefits of automation.

Industry 4.0 Roadmap – People
People represent the third area in which companies must address in order to successfully integrate automation across the shop floor. It is critical that the workforce possess the correct skill set that supports the integration and use of new technologies and processes. There are four critical areas shops can focus on to make the necessary transition.

Standardize Work – A shop should conduct time studies and skills mapping to understand the roles and activities of its employees. This data will identify areas to minimize and/or automate transactional and repetitive tasks as well as creating standard work procedures across the company. Finally, this process will create a clear understanding of the current capabilities within the team and identify where skill gaps exist.

Leverage Skilled Trades – As the average age of a tool and die shop employee continues to increase and the number of young people entering the skilled trades job force decreases, a gap has emerged both in competency and capacity. Automation is one tool that can help fill that gap, but it is important to note that the existing skilled trades talent will be an important part of implementing automation. Their knowledge and experience should be leveraged to optimize opportunities to automate on the shop floor. Their knowledge needs to be institutionalized in the organization through standardized work and they are critical in identifying information needed to be a more proactive shop.

Embrace Changing Workforce – As a shop increases automation across its business, it will require a different set of skills. Data analysts or scientists, I/T folks, and engineers are among a few of the positions that may be part of successfully implementing Industry 4.0. Shop owners need to be open to the changing workforce and embrace talent that might not be traditionally part of the tool and die industry.

Reinvest in People – In most small- to -mid-sized companies people investment is an area of weakness. However, reinvesting in the existing team can deliver the most value. This includes training on the latest software systems, providing live dashboards and alerts to help them prioritize, creating a succession plan so the right people are in leadership roles and investing in future competencies that will support the team's automation integration activities. If a company does not invest in its people, it will struggle to meet its Industry 4.0 integration goals.

Implementing Industry 4.0 into a business is a challenging task. It requires a business to have a vision and strategy for the transition, which will be guided by shop leadership. Before embarking on significant investment, it is important that a shop ensure the building blocks for implementation are in place and that foundation elements like I/T infrastructure and ERP systems are sound. It is critical that shops are using data to inform the strategy and implementation. And, leadership must have a clear understanding of the business' weakest link – is it technology, process or people – because benefits only accrue as far as the weakest link.

Future of Manufacturing – Level 4 and Beyond
There are many different perspectives on what the future of manufacturing will look like. As technology continues to evolve and advance, some suggest there will be a time when the tool and die industry is fully automated and people will no longer be part of the process. It is true shops will be heavily automated in the future. However, the reality is people will always be part of the equation.

The easiest part of automation is purchasing the right technology. As companies look to increase

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automation across the business it will require several fundamental considerations and an organizational-wide focus on staying digitally mature with a culture of continuous improvement and standardization. The transition to greater levels of automation requires clearly defined processes that have been optimized and dedication to collecting the data and determining the best opportunities for improvement through automation.

The questions shops need to ask themselves is how far do you want to take automation; how will you determine the ROI of your investment; and, what makes sense for your shop? In theory, a shop can automate nearly every aspect of its business but that might not be the path to success for every shop. For some there are obstacles such as budget, skillset or tech readiness that would make automating across the business more challenging or not the right strategic decision.

High Level of Automation - Level 4

Today, there are no shops that have achieved Level 4 automation across the board, but there are shops that have integrated processes and equipment that will be required to be at this level. At Level 4 tool manufacturing will be fully automated. Although design and programming will have evolved (and likely consolidate) people with the right skill sets will be required for these functions and they'll work hand-in-hand with machine learning enabled design and processing applications.

AI-based predictive maintenance, a method for anticipating maintenance requirements in machines on a factory floor by monitoring and analyzing data in real time from the machines, will be commonplace across the facility. Sensors will detect when a piece of equipment requires attention and will alert the appropriate person (internal or equipment provider service center) to complete the job if it cannot self-correct the issue on its own. This will significantly reduce machine downtime and improve the overall efficiency.

It is highly likely that at Level 4 tool and die shop's equipment will be connected to its

customer – the Original Equipment Manufacturer (OEM) – so they can monitor machine performance and automate required engineering changes of the tool. These tool changes will be captured from the OEM and programmed into the manufacturing cell seamlessly avoiding costly rework.

Additionally, tool quality will become automated. Before a tool finishes production, sensors and systems will work together to scan the tool and ensure it aligns exactly with the design. If there are any errors, it will be flagged and sent back to the appropriate piece of equipment to be fixed. This process will drastically reduce and ideally eliminate the need for multiple tryouts and sampling.

To achieve Level 4, shops will be required to transition its workforce to a more highly skilled, technical team. Employees will need to embrace technology and automation and move from manual intervention to programming, monitoring and intervening if there is an issue. These employees will need to be process driven to ensure all production activities are aligned and meet the standards that have been established. The future of manufacturing will no longer fluctuate based on artists who change and adjust based on personal preference, feel and gut intuition. While that kind of tribal knowledge is critical, it will ultimately be integrated into various applications, machines and equipment through AI.

Fully Automated - Level 5

The future state of manufacturing will be fully automated and integrated with the end customer for a complete blurring of the traditional upfront processes that exist today from CAE, simulation, CAD and CAM. Moreover, from design to CAM programming to scheduling to production, every step in the development of a mold or die will be conducted by connected series of applications using hardware (machines, robots, automation, sensor) and software (AI, cloud computing).

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Imagine a fully automated cell run by robots that converts a block of steel into a finished product with no manual intervention. All purchased components are then delivered just-in-time to the work cell requiring them. The assembly labor teams will work in an augmented reality environment, use industrial exoskeletons for greater safety and strength while working side-by-side with robots to dramatically increase productivity.

The critical factor in achieving this level of automation is the introduction and growth of artificial intelligence (AI). AI will allow shops to achieve complex capabilities by enabling equipment and robots to analyze data and learn through environmental awareness and advanced cognitive programming. With the ability to learn and adapt, shops will not only be able to develop different tools within the same cell, but they will also be able to rely on technology for scheduling and correcting any errors to achieve the highest level of quality while maintaining the highest levels of efficiency with very little manual intervention.

Additionally, predictive maintenance is taken a step further. Machines and equipment will self-diagnose and once they determine work is required, a task-based (ro)bot will be dispatched autonomously to address the issue. These same autonomous robots will address many of the auxiliary features that are currently done manually or semi-automated such as removing chips.

This level of automation will require fewer and more highly skilled employees. In fact, many of the skill sets that will be required have not been clearly defined today but will evolve as technology evolves. Additionally, it will be critical that companies continue to train teams as the introduction of new, yet to be discovered, technology becomes mainstream in manufacturing.

Ultimately, increased automation will eliminate the biggest issues that create challenges across manufacturing, including variability in quality and timing.

Challenges to Achieve High Levels of Automation

Although automation solves many of the issue's shops are dealing with today, it is not easy to successfully navigate this roadmap. To achieve Level 4 and Level 5 automation there are a number of challenges:

- **Infrastructure** – There is a minimum level of IT infrastructure a facility must have to implement and integrate the required technology. A company must continue to upgrade its infrastructure as it increases the levels of automation to accommodate advanced systems and optimize the capabilities of each new application.

- **Cost** – At some point, the cost of automation will outweigh the benefits. Shops will need to develop a CapEx investment strategy that allocate dollars for investment that makes sense. In addition to investing in new equipment, costs will be associated with developing the IT infrastructure, implementing cybersecurity systems, securing and integrating advanced software solutions and employee training.

- **Entrenched Business Models** – Shops need to be willing to review their current business model and determine how it needs to change to accommodate the future. This could include collaborative partnerships with suppliers, competitors and customers including new sourcing agreements with component suppliers or even the machine/equipment manufacturers. Today's business model will likely not work as the industry evolves, so top performers are already addressing the need for change and developing the best course of action to successfully adopt automation.

- **People** – Opinions, skill sets, traditions will need to evolve to successfully integrate automation. People will always be needed but the type of person and amount of people will change drastically. As a shop transitions and integrates automation, people will need to

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adopt a new mindset – from each mold/die is unique to it is a standardized process. Additionally, more people with IT, software and programming experience will be required. In short, tooling companies and their skilled tradesman that work for them need to stop thinking of themselves as "artists" treating each tool as a unique work of art but more so as scientists who follow a prescribed path and process yielding consistent predictable outcomes.

• **New Processes** – If leadership isn't open to changing current processes such as spotting or handwork, the shop will not be able to survive. There are many other processes that are currently common amongst the tool and die industry that will need to evolve or be eliminated altogether to achieve success.

It is hard to imagine what lies beyond Level 5. Technology is evolving quickly, and new and unique business models arise every day. However, one thing is clear, automation is here, and it is not going to go away. Shops that are

not considering how automation can be integrated into their business will not survive. It will be required for shops to be competitive in the future.

That said, there is not one clear path. There is no "yellow brick road" to follow. It is important that businesses understand where their shop currently stands as it relates to automation and developing a sound strategy and action plan for integration. No two shops will do it the same, but it will be incredibly important for shops to consider all three facets of the business – Technology, Process and People – to successfully move through the automation roadmap.