Neural Manufacturing

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Preface

The nature of customer demand, their expectations from products and services, and consumption patterns have been the primary drivers of change for businesses globally, and the manufacturing industry is no exception. Among the multifold changes impacting manufacturing are cross-industry convergence led by demand for seamless omni-channel journey experiences, trends such as personalized frictionless mobility, the rise of technology-centric players focused on agile operations, and innovative ‘phygital’ products and services.

These multi-dimensional changes require manufacturing businesses to rapidly redefine their operating and business models to gain a competitive head start in the race for sustaining market dominance. The digitalization of businesses—products, customer engagement and channels, and enterprise core systems—has placed intense demands on the organization to become intelligent and insight driven.

The future manufacturing enterprises and their ecosystems can be expected to be connected, cognitive, and collaborative to demonstrate resilience, adaptability, and purpose-driven behaviors. The role of a strongly networked partner ecosystem that will work collaboratively towards this purpose becomes extremely critical. It requires intelligent decision-making capabilities to be embedded in the entire network, especially at the edges. TCS defines this future enterprise capability set as ‘Neural Manufacturing’, where the value chains will be responsive, adaptive, and resilient. Technology will play a key role in building the future enterprise, whereby businesses will redefine their operations, services, products, and customer experiences.

In keeping with our futuristic thinking on enterprises increasingly demonstrating neural behaviors to stay competitive, we bring to you this special edition of the Journal of Innovation and Transformation. Exclusive white papers address the capabilities that enterprises need to invest in to become future ready.

I welcome you to be a partner with TCS Neural Manufacturing in the exciting journey to the evolving new manufacturing world order!

Sreenivasa Chakravarti
Vice President and Head
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Introduction: Building the Future, the Neural Way

The new manufacturing order will see dominant players, or market leaders, demonstrate unique resilience and adaptability by restructuring and reorganizing their businesses and technology architectures. Drawing parallels from the human biological system, TCS has defined this new order under a ‘Neural Manufacturing’ framework.

In the 2020 edition of the Journal of Innovation and Transformation, we recreate the manufacturing industry’s evolution, in which we articulate its potential future state of ‘being neural’. We also examine how neural traits and behaviors play out across the manufacturing value chain, including manufacturing operations, supply chains, and one of the early adapters - the automotive industry.

As each industry adapts to this new paradigm, we explore how an information and decision fabric can stitch the vast data generated from products and assets in use, enterprise operations, and customer context into contextual intelligence and cognitive behavior.

Embracing the new manufacturing order will require an upskilling of the workforce. Developing the right neural skills will provide enterprises competitive advantage. Underpinning this shift to neural operating models is technology, which serves as an enabler for growth and transformation.

**Neural Traits of the Future Manufacturing Enterprise**

Neural traits operating synergistically help firms bring forth necessary business behaviors to create exponential business value.

As illustrated in Figure 1, each trait, either in isolation or in conjunction with other traits, has the potential to bring about desired changes in business processes in one or several functions across the manufacturing value chain or for the complete enterprise.

**Business outcomes, achieved through these neural traits, can be multifold such as the following:**

1. Instilling ‘Sense-Perceive-Act’ behaviors across business processes in the manufacturing value chain can help firms respond in an agile manner, thereby providing them competitive advantage. For instance, continuous monitoring of any demand changes will help any manufacturer’s procurement function be proactive in planning for supplies in the right mix, while collaboratively sharing this insight in real time with their supplier networks to help them cater to these demand patterns.
2. Improving decision-making capabilities of a manufacturing firm by gaining visibility into end-to-end process execution, monitoring patterns, and recommending actions to avert process failures, thus establishing a strong cognitive command center.

3. Bringing together a distributed network of partners who connect across customer touchpoints to enable contextual and autonomous client engagement opportunities for mutual value creation.

Technology – The Backbone of Neural Behaviors

For Neural Manufacturing to manifest, firms need to zoom in on the right confluence of emerging cloud-enabled scalable technologies and platforms such as internet of things (IoT), artificial intelligence (AI), machine learning (ML), automation, and interactive marketing among others, as illustrated in Figure 2.

Technology serves as a lynchpin to achieve the above-mentioned business behaviors and outcomes, and will play a key enabling role through the following:

1. Foundational digital infrastructure that forms the adaptive digital core for the enterprise. This includes cloud infrastructure, information fabric, connectivity as 5G, AI workbench, blockchain infrastructure, IoT platforms, and workplace collaboration tools.

2. Capabilities developed through the application of emerging technologies on value chain functions. These capabilities leverage the digital core to create integrated but differentiated services. Interactive marketing, digital commerce, process automation,
Industry 4.0 applications, predictive and diagnostic applications, and real-time track and trace are examples of technologies that help manufacturing firms become adept in their functioning within the value chain and partner ecosystem.

Manufacturers would be at varying levels of maturity in their technology architectures. Depending on their business priorities and their present state of technology adoption, manufacturers will benefit from embracing neural thinking across their enterprise and in their networks of partners. With such a neural thinking in place, TCS foresees manufacturing enterprises as achieving certain business outcomes - gaining competitive advantage by building an adaptive product and services mix, enhancing end-customer connect to gain mindshare and lifetime value, creating resilience in supply chains for products and services, and differentiating themselves through efficient processes and agile operations.

About the Author

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Gaining power from data, ecosystems, and digital technologies

Transform products, services, and business models to sustain competitive advantage.

Disruption is the new normal. Business models need to adapt to the pace of change and become more resilient to overcome future disruptions. To chart a new course, enterprises have to manage the pandemic's present impact, then take action to recover, and finally lay out a roadmap to build resilience to tackle future disruptions. To do this, enterprises will need to:

- Adaptability: Leverage ecosystems and form strong collaboration networks.
- Resilience: Leverage Ecosystems and Form Strong Collaboration Networks.
- Technology: The lynchpin through which enterprises can define their - Business, Customer experiences, Product or service behaviors.

To design a new course, enterprises have to manage the pandemic's present impact, then take action to recover, and finally lay out a roadmap to build resilience to tackle future disruptions.

Infographic: The Evolution of Future Manufacturing Enterprises – A Neural Manufacturing perspective.
Autonomous Vehicle Validation in the Neural Manufacturing Era

The increased demand for a high degree of autonomy and connected capabilities is impelling automotive companies to increase their research and development (R&D) spend and build collaborative ecosystems to rapidly develop safe and reliable autonomous vehicles. It is the reason why product development for connected, autonomous, shared, and electric (CASE) vehicles are increasingly shifting from the traditional V-development strategy to an agile way of development. An agile approach helps automotive firms deploy vehicles in iterative deep learning techniques, facilitate model training, and validate autonomous algorithms.

Usually, deploying autonomous vehicles (AV) safely requires extensive physical testing for vehicle validation. COVID-19 has not only disrupted supply chains but also exacerbated the need to avoid physical testing. The focus is shifting towards contactless services.
and use of simulation for validation, wherever possible. In fact, many leading AV start-ups and technology players such as Uber, Cruise, and Argo have suspended their physical testing to meet pandemic-safety regulatory norms.

Neural Manufacturing advocates that technologies will improve the connected and collaborative nature of working, and intelligence in processes, services, and products will drive the creation of purpose-driven ecosystems. In the automotive sector too, intelligence in processes, services and products has been on the rise.

As every aspect of vehicle design, development, and delivery is undergoing significant change due to the impact of technologies and its adoption, let us zoom in on vehicle validation capabilities of automotive companies. Though most automotive companies possess simulation-enabled validation capabilities, they lack methodology and the processes to maximize testing coverage across every permutation and combination of test cases.

**Simulation validation in AV testing**

By adopting simulation-based mechanisms, automotive firms become large repositories of data. To better harness the petabytes of data, automotive firms can leverage Neural Manufacturing—inspired by biological systems where the key function is to sense, perceive, and act—to develop neural capabilities to become connected, cognitive, and collaborative entities. Intelligent artificial intelligence (AI) and machine learning-based (ML) decision-making capabilities such as simulation-based testing that optimize and identify true edge cases, will allow firms to demonstrate resilience, adaptability, and purpose-driven outcomes.

A typical drive session of AV development collects data from a plethora of sensors including cameras, lidar, radar, a control area network (CAN) bus, and global positioning systems (GPS), amounting to approximately 30 terabytes of data per day. This data is used to train autonomous driving algorithms and models on perception, path planning, and decision making. However, as automotive firms cannot test drive vehicles, capture training data, and test autonomous algorithms physically, they are turning to simulation-based mechanisms enabled by agile product development to accelerate the AV development process. This requires identifying the scenario, categorizing the test case, and defining the edge case. This can be time consuming and is most often left to the imagination of the test engineer. In addition, validating every possible permutation and combination of test cases can lead to millions of unwanted and unrealistic scenarios that do not accurately test the AV algorithm. It is, therefore, crucial to generate test scenarios and cases where the software is likely to fail, which are also known as edge cases.
With simulation, firms can design additional test scenarios by varying environmental parameters such as adding glare, rain, or snow, or by adding new agents such as obstacles, pedestrians, animals, and speed. This allows engineers to test AV algorithms across various new scenarios, without the need for physically re-creating them. In fact, organizations can leverage more than 100 million miles of driving data already captured to easily create billions of miles of such synthetic data and validate the algorithms. Ideating these agent and parameter combinations is the key to harnessing the value of simulation-based validation.

An often-overlooked aspect of autonomous vehicle validation is passenger comfort, where simulation testing of certain scenarios and test cases can identify potential passenger comfort issues, for example, around acceleration and sudden braking.

While simulation cannot entirely replace physical validation or mimic the physical world completely, it can minimize the need for extensive physical testing. Taking an architected and optimized data approach can help companies enable simulation at scale.

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Ensuring Business Resilience in the Neural Era through Supply Chain Visibility

Misconceptions about business resilience abound. A popular view held among professionals in manufacturing, even those in supply chain, is that business resilience can be achieved through add-on tools. One reason for this belief is that the alternative requires rethinking operations entirely, which is erroneously linked to potentially higher costs. Resilience is defined as the ability to recover from an adverse situation, and while its association with risk management is valid, it need not be a costly burden. Moreover, one needs to consider costs over a period of time, and not at a point of time.

This point of view seeks to address these concerns by examining how building resilience in supply chain visibility can lead to cost savings and qualitative benefits, particularly for process industries. Neural Manufacturing, which is a framework to help enterprises become connected, smart, cognitive, agile and collaborative, can amplify this visibility in many ways.
What shrouds supply chain visibility in process industries

Process industries face supply chain disruptions of a higher magnitude due to external shocks such as COVID-19, trade wars, and bottlenecks arising due to natural disasters. That's because their high-asset specificity increases the lead time to throttle production up or down. Moreover, many sub-segments such as chemicals are unable to meet demand volatility, and typically are more susceptible to geo-political risks since many are made from oil and distillates. Operational complexities are further increasing because of large product portfolios, changing customer expectations, frequent mergers and acquisitions, and greater customization in the form of multiple grades catering to fragmented end markets. Process industries typically lack the agility to respond to any change due to ageing infrastructure in manufacturing facilities that limits process control automation, thereby hindering radical process re-engineering. Changeovers could be costly and impact productivity since any material produced during a cutover could fall out of specifications (glass manufacturing, for instance). In industries such as food and beverage (F&B) and personal care, it is all the more essential to monitor and trace quality and origin of the ingredients used (levels of impurity, environmental conditions, and temperature), as they directly deal with end consumers. Moreover, the lack of supply chain visibility makes it challenging to comply with the varied and ever-evolving health and safety regulations while transporting hazardous materials.

Enhancing supply chain visibility: Five key pillars

Building transparency into supply chain networks can help organizations address the above-mentioned challenges and account for volatile, uncertain, complex, and ambiguous (VUCA) factors. A connected, smart, collaborative, agile, and cognitive, or neural, approach (Figure 1) can help firms in process manufacturing enhance their supply chain visibility, as described in the five pillars below:

- A connected network of systems to provide visibility into inventory at all levels spread across global locations.
- A smart system to dynamically optimize distribution planning considering multiple factors such as maximum capacity utilization based on demand, service levels, and reducing the overall cost of operations.
- Business agility to respond to uncertainties such as supplier network disruption, shift in global demand, or logistical challenges.
- Collaboration between different business processes and external stakeholders such as suppliers to facilitate the exchange of information at different levels and hierarchies which will remove the bottlenecks.
- Cognitive supply chain capabilities to sense the market demand and trends at an early stage and drive production planning accordingly.
Building resilience with neural supply chain networks

Having a resilient business structure reduces variability and earnings sensitivity to external shocks. It empowers industries to sustain through a crisis like COVID-19 and achieve competitive edge over the long term. End-to-end visibility in supply chain synchronizes all activities and facilitates comprehensive understanding of operations at all levels. By creating neural supply chain networks, organizations can build systems that provide sufficient early warnings to sense shifts in demand, logistical challenges, and risks from suppliers to enhance business agility. By deriving actionable insights through improved quality of signals, an organization can be better prepared to face any external shocks, drive operational efficiency, and ensure greater supply chain responsiveness.

For instance, a leading chemical manufacturer leveraged process mining and data analytics to identify the root causes for its delayed shipments. By gaining end-to-end supply chain visibility, they were able to improve business resilience and realized over $25 million worth of opportunities for value improvement by reducing multiple order changes and delivery delays.

In another case, a process manufacturing firm derived actionable insights by linking all data points and analyzing them to address customer satisfaction issues for one of its key customers. The company was able to cater to niche segments, improve the on-time-in-full (OTIF) metric from 75% to 92%, and improve schedule adherence from 70% to nearly 97% for their key customer.
Neural networks pave the way for futuristic supply chains

In today’s VUCA world, rising complexities, increasing external factors, and inconsistencies in supply and demand make it difficult for the existing IT landscape to provide real-time actionable insights. Although many organizations have invested heavily in enterprise resource planning (ERP) and other IT systems, they still struggle to be proactive in addressing issues and mitigating risks. Bringing intelligence and cognition into processes and systems are crucial to having a proactive and predictive business process. Technology is thelynchpin in such cases where machine learning (ML) and artificial intelligence (AI) can lend neural traits to the business function. Neural networks can provide organizations with the right tools to predict potential problems and in some cases take preventive steps automatically. Using different predictive algorithms, a deep learning neural network can be effective in many areas (Figure 2).

![Figure 2: Applications of a neural network](image-url)
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Rewiring Core Competence in Manufacturing

Traditional manufacturing strategies revolved around excellence and scale, and IT enablement served the purpose strongly. In the 80s and 90s, enterprise resource planning (ERP), manufacturing execution systems (MES), product lifecycle management (PLM), and customer relationship management (CRM) were key to establishing controls and processes. Their increasing maturity in the last decade helped organizations to scale and globalize.

The focus of modern-day manufacturing has shifted to mass customization, products bundled with services, and as a consequence the focus of core competence is now on flexibility, agility, and resilience. The latter has gained far more prominence with black swan events like COVID-19. The tryst to standardize and avoid costly custom developments in enterprise systems has made manufacturers lose their core competence of continuous micro innovations, business reimagination, and enterprise agility that build...
resilience. Standardization has also hindered collaborative decision making across the organization, aligned to strategy and objectives.

This paper examines how firms can rebuild their core competence to develop agility in decision making based on the tenets of digitalization, connectedness, ecosystem collaboration, and cognition. This has been defined by TCS as the next big core competency – Neural Manufacturing.

Chasing organizational core competence

An organization’s success lies in having the right strategy and diligently executing it. The manufacturing industry traditionally has hinged on three elements to define its strategy – product innovation leadership, cost leadership, and customer experience leadership (and proximity) to awe the customer.

The product leadership focuses on extending a state-of-the-art, innovative, and feature-rich product. A cost leadership approach focuses on cost minimization across the value chain, and some organizations believe in keeping the customer happy through continuous and impressive engagement. For instance, in the automotive industry, BMW’s primary strategy centers around product leadership, whereas Kia Motors follows the cost leadership model. BMW looks into the far future of mobility and focuses on sustainability and CASE mobility under the innovation umbrella. In 2017, they created a vision of the next 100 years in mobility and re-energized their innovation agenda. Organizations in view of market opportunities also make a conscious shift in their strategy and primary focus. For instance, Kia Motors turned the 2008 economic crisis into an opportunity for a brand makeover. At that time, it operated in a market where customers were knowledgeable and demanded efficient and technology-enabled vehicles. It shared platforms with Hyundai and clubbed cost leadership with product innovation leadership. Today, the company has again repeated the approach by turning the rising demand in electric and connected cars into an opportunity, with a complete focus on electric and mobility solutions. Its 2020 strategy focuses on premium electric vehicles and developing a new specialized Electric - Global Modular Platform (E-GMP). This marks a clear and complete shift in the firm’s strategic element - to product innovation leadership.

Every organization needs all three elements but strategically focuses on one of them. This consistent focus over time has helped manufacturers develop specific capabilities that are not easy to replicate and are the source of organizational core competence. It becomes not just a strength in a certain function but the ability of the entire organization – from the board room to the shop floor associate, aligning decisions, big or small to a firm’s core strategy.

[2] Marketing Week: Kia's marketing boss on transforming the brand from ‘budget’ to premium; February 5, 2018; https://www.marketingweek.com/kia-transform-brand-budget-premium/
Strategy and core competence go beyond excellence in today’s increasingly volatile, uncertain, complex, and ambiguous (VUCA) world. Elements like the ability to evolve the business model and drive resilience, adaptability, flexibility, and agility have become relevant strategic needs to create core competence. Large-scale technology-driven, favorable disruptions in business operations in the last decade and the current pandemic have accelerated the transformation, and in turn, the success of organizations adopting it. Besides these strengths, an organization needs people traits and capabilities to deal with uncertainty and risk to develop a core competence.

Earlier, core competence in manufacturing meant maximizing certainty and consistency, operational excellence, and continuous improvement. It now includes cost-effective, mass custom manufacturing; flexible production and supply chain; a connected, extended enterprise; and agile decision making. A Neural Manufacturing approach—inspired by biological systems to drive connectivity, collaboration, and digitalization across operations—can help firms imbibe these features to build the future enterprise.

**Why enterprise solutions fall short today**

Organizations earlier depended on scale, standardization, efficiency, and excellence. The focus was on automating both manufacturing processes and business transactions. Scaling them up was easier than tweaking or changing them. They automated tasks, but only in pockets. Over the years, transaction-oriented enterprise systems became and remained the de facto systems of records, which have hindered organizational core competence due to the following:

1. **Enterprise systems capture only the end-result transaction**

   Systems cater to standard processes as well as to the most prominent deviations. For instance, material inspection is followed by acceptance or rejection, or acceptance with some rework. The process flow diagrams typically used to design transactions capture the tasks with all the relevant what-if conditions but fail to identify the thought process behind decisions. Such an incomplete process is then blueprinted into the system design.

2. **Enterprise systems are disconnected from planning**

   In successful organizations, thorough planning precedes any execution across functions. Enterprise systems are focused on execution, be it materials’ procurement, process engineering, quality assessment, or customer connect. Most decisions are made in the planning phase. Any deviations from the plan need on-the-fly decision making or a return to the planned course of execution. Since execution systems are not connected to planning solutions, tracking deviations is difficult. This prevents organizations from learning from actual events to improve planning systems or to micro innovate.

3. **Enterprise systems have standardized and rigid processes**

   The deployment of enterprise systems runs long and usually precedes business process re-engineering (BPR). One of the key objectives of BPR is to create enterprise standards and make the processes watertight. Another challenge is that industry best practices are often disconnected from the organizational
strategy and core competence. Industry best practices have been the most significant reason for deteriorating core competence because it negates all the refined knowledge an organization has gained when executing a process. Enterprise systems are seldom designed with flexibility and agility built into their processes.

4. Costly custom developments and change implementation discourage micro innovations

The high cost of customization of enterprise systems is a deterrent for tweaking the solution and process aligned to the organizational strategy and core competence. A firm’s management is always focused on deploying the standard solution and controlling changes to contain costs. These vanilla solutions, sometimes even agnostic to an industry, are silent killers of organizational core competence.

5. Enterprise system data silos hinder a connected enterprise and value chain

Most enterprise solutions not only end up as systems of records but also become monolith applications with complex data structures and managing them becomes a challenge over time. These data silos make it difficult to easily access relevant data. The industry value chain needs data across systems for establishing correlations and correct causal effect. Lack of real-time data transfer and incorrect decisions due to stale master data are common in enterprise systems.

Clearly, today’s ecosystem demands real-time information, which in itself is a big enabler of right decision making, that can be further improved with analytical insights. Enterprise systems are necessary but are insufficient to quickly evolve business models. The organizations that treated enterprise systems as the means and purpose of their IT strategy and a panacea to all their business problems are realizing that their core competence and innovation capabilities are being eroded. They are reckoning the need to embrace and gain from the advantages of a digital world.

The following section delves into how organizations can regain their core competence and the traits they need to thrive in the new VUCA world.

The four key stages of rewiring core competence

The creation and continuous evolution of organizational core competence involves people and technology. The softer aspects of core competence creation are associated with vision, mission, values, and the culture of empathy, empowerment, and enablement driven by leadership. The other aspects include clarity of purpose, development of the right skills, and technology enablement which are the features of Neural Manufacturing, a framework to understand the future manufacturing enterprise, which is connected, cognitive, and collaborative.

The purpose and daily progress of activities within an organization are met by sequential and parallel decisions. When every individual in an organization is aligned to a common core purpose, business outcomes and, in turn, the outcome are improved in the short and long-term. Manufacturers must be flexible and agile in their ability to change their core
purpose. This change can be achieved by building resilience in their business models with minimum impact or damage.

The Neural Manufacturing framework focuses on creating a connected value chain, sensitive to stimuli from the environment and intelligent enough to know the response and take action in a decentralized but federated manner. All this is possible when an organization is aligned to the purpose articulated by the business model. Organizations can build their core competence in multiple ways; however, the key focus here is enabling decision making through technology, as illustrated in Figure 1. Decision-making and automation mature through the following four stages, all of which are based on the tenets of Neural Manufacturing:

1. **Creation of a digital work bench**

   Developing a digital platform with a role-specific user interface can provide employees (process executors) with data for executing a task. When developing a digital platform, the starting point of collecting data relevant to the activity and associated decision is to provide every user a role-specific interface to execute the task. Besides task execution, it creates metadata association of the related information from the system of records, thought process, and decision drivers from the workflow. Such a digital platform captures both structured and unstructured data and offers a connected and personalized work ecosystem.
for employees, who are the customers within the organization. The platform becomes an extension of the traits of Neural Manufacturing intended for the end customer.

2. Collection and visualization of data

In this stage, relevant data from multiple systems are brought together. As the workflow progresses, every stakeholder in the loop is provided with the necessary data points relevant for decision making. The final decision taken on each task is also recorded and used for building correlations between parameters and decisions in the next stage of maturity. As the associated metadata is realized, the relevant data from multiple systems of records are made available to every stakeholder in the loop for the task execution. The digital platform collects the information created at each phase of decision making. Data available at such a mature stage reduces the time spent on searching for relevant information.

3. Collaboration – Decision process modelling

Here, analytics models are deployed to automate decision making. The focus is on using the massive data generated from every task executed to gain a collaborative view across functions or roles. This data is then run through analytical models, which churn out system-recommended decisions. This stage is the starting point of decision automation, but the decision still depends on statistical correlations and human validation. Such an adaptive process sets the stage for the next phase—cognitive decision making.

4. Cognition – Advanced analytics tools for prediction and decision recommendation

This is the most mature stage of the decision-making process. AI algorithms are used to identify the correct decision based on a large number of prior human decisions. Such algorithms facilitate experiential learning for the system. The algorithms can also predict decisions, helping simulate the different scenarios even before they occur, and possibly avoid damaging ones. At this stage of maturity, the lead time for decision making is cut down considerably, bringing agility into it. Further, with considerable knowledge generated for every scenario, attending to uncertain decisions are easier and provides flexibility in changing the ecosystem. This combination of agility and flexibility enhances the resilience of manufacturing operations and the organization at large. The quality and alignment of decisions are not limited to an organization but also includes the entire value chain.
The benefits of reimagining core competence

Though difficult to implement, the four stages listed above are extremely rewarding for businesses. Besides automating decision-making processes for routine operational tasks, they can reduce the lead time and improve the accuracy of the task executed.

The success of a decision can be measured through technology, as described below:

- A quantitative measure assesses the number of decisions enabled through decision process re-engineering, the speed of decision making, and the number of failures or damage avoided.
- Qualitative measures identify the comprehensiveness of the parameters in the decision-making model and the accuracy of decisions recommended. The latter part can also be estimated by the impact cost of the decision – either as resulting damage or opportunity lost.

The decision-making and its stage-wise maturity leading to automation can help firms build their core competence, as the entire thought process behind every decision is now retained as organizational knowledge. This knowledge can be extensively used by different stakeholders to arrive at decisions that are aligned to a specific purpose such as efficiency, cost optimization, customer satisfaction, and more. The decisions will be more data and knowledge-driven rather than being dependent on human mistakes and errors. It is also important to note that the data is now not limited to the organization but the entire value chain through data control towers. The vast knowledge generated from a decision that spans the ecosystem can help organizations build resilience and tackle not just unknown and unexpected situations but also equip firms to make decisions in the face of changing priorities and evolving business models. Such a capability will make them flexible, agile, and adaptive to a rapidly changing external world.

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Neural networks with multi-node connectivity hold immense potential for the manufacturing industry, particularly as business resilience and adaptability become key focus areas in the new reality. While the concept of neural networks has existed for long, it is more relevant than ever before in today’s manufacturing business scenario. In light of this, Neural Manufacturing—which draws inspiration from the biological neural system where the unique ability is to sense, perceive, and act—can help enterprises become collaborative, resilient, and adaptive. This can help firms navigate uncertainties in an increasingly volatile, uncertain, complex, and ambiguous, or VUCA, business environment.

This paper discusses the information fabric strategy and insights-driven behaviors that manufacturers should embrace for the neural era, the data handling capabilities required, and their impact on the operating model and design choices.
Understanding the role of data in Neural Manufacturing

Manufacturers deal with humongous data volumes from a multitude of sources such as connected products and the context in which they operate. This includes a variety of data structures, including semi-structured and unstructured data formats. To complicate matters further, data is spread across a variety of systems—on the cloud, on premise, or on hybrid platforms—and data silos abound across systems and business functions. On the other hand, evolving business needs require faster discovery of emerging business problems and opportunities, greater business agility to respond to triggers, and collaboration across organization and ecosystem boundaries while ensuring compliance to data privacy regulations.

Neural Manufacturing is defined as an intensely networked set of partners aligned to a common purpose, where the value chains are responsive, adaptive, and personalized, with intelligence built on the edge of the networks. Together, data abundance and new business priorities are creating a compelling need for manufacturers to embrace Neural Manufacturing which paves the way for next-gen operations.

To understand the sense, perceive, and act basis of Neural Manufacturing, let’s take the example of autonomous vehicles (AVs). The sense aspect for AVs can be sensing objects on the road through object recognition capabilities. The perceive aspect is related to an analysis of the situation which then drives action.

Data is at the core of Neural Manufacturing and underlines its essence across key dimensions, such as:

- **Connected**: Data lays the foundation for a strong network and serves as a basis for creating new business models. Exchange of data is critical for any business to thrive in an ecosystem-driven model. For instance, in a connected car, data (how the car is used, where it is, who is behind the wheel, etc) could be exchanged as a product between partners (insurers, retailers, etc), in turn creating new service-led business opportunities and delivering an overall superior customer experience. According to McKinsey, the overall revenue pool from car data monetization at a global scale might add up to $450-750 billion by 2030.1

- **Automated**: Data-driven machine-first delivery helps manufacturers increase operating efficiencies while improving customer service. Case in point, conversational systems such as chatbots are now being widely used as a first line of response for customer service, with great success.

- **Adaptive**: Adaptive data governance can help manufacturers frame policies and processes for data usage, which are flexible and ensure a culture of collaboration. Thus, enabling data sharing across partners while embedding data security and privacy by design to meet the unique, ever-evolving business needs in the new reality.

- **Personalized**: Contextual data-driven insights can help manufacturers devise personalized customer experience strategies. Case in point: The connected car ecosystem can enable contextualized offers for service campaigns based on usage and predictive part failure.

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**Cognitive:** Analysis of sensor data can help manufacturers perceive and respond to stimuli. For instance, in agriculture, data from various sensors can sense external stimuli (soil parameters, temperature, etc), and application of artificial intelligence (AI)-based algorithms based on this data can improve crop yield and drive precision agriculture by recommending the exact quantities of irrigation, fertilizers, etc. required.

**Resilient:** Data transparency and end-to-end visibility across the supply chain can help manufacturers build a supply chain control tower driving operational resilience, enabling actions to preempt and fix potential bottlenecks, thereby eliminating downtime.

**Intelligent:** Real-time continuous insights from data across the value chain can help manufacturers deliver on the promise of a connected intelligent enterprise with a strong digital backbone.

### Implementing the right data and analytics strategy for Neural Manufacturing

In the neural era, the data and analytics strategy should be driven by the value proposition of key stakeholders such as customers, employees, ecosystem partners, and business stakeholders.

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**Figure 1:** The value proposition for key manufacturing stakeholders
Customers expect a seamless experience across all interactions and touchpoints, and for manufacturers this presents an opportunity to push the boundaries and add greater value. For instance, the connected car has now become a new channel of engagement for original equipment manufacturers (OEMs) and customer interaction is no longer limited to the driving experience. It has extended to the services offered by the connected car ecosystem such as entertainment (car play), service and maintenance, and safety and security. Take the case of BMW Connected Drive—it offers an array of services and apps, from entertainment to security and everything in between, that elevates the overall experience.² By 2035, Deloitte predicts that most of the new vehicles sold across developed countries will have V2X functionality i.e. vehicle to everything connectivity.³ Consumers’ willingness to pay for high connectivity levels and receiving access to on-the-way services and updates, such as traffic congestion and nearby parking, are driving the growth of the V2X market.

On the other hand employees and business stakeholders demand that information be available to them anytime, anywhere and on any device to allow for agile responses with automated workflows and approvals. Sales and marketing teams need, not just a 360-degree view of customers, but also holistic supply chain visibility to get insights into inventory. The aftermarket holds huge untapped potential for manufacturers and the right pricing strategy is crucial to harness it. An average industrial or automotive company generates 10% of its revenue and more than 40% of its profit from spare parts sales.⁴ Leveraging AI algorithms for optimized parts pricing from segment level to individual parts, sales teams can ensure the optimized price to meet their goals and maximize their returns.

Thriving in today’s ecosystem-driven world requires manufacturers to implement a well-networked structure with value chain partners to promote secure data sharing. For instance, polamide supplier Domo and polymer manufacturer Covestro are collaborating with Dutch technology start-up Circularise to create a system for tracking plastics using blockchain technology.⁵ The goal of the partnership is to create an open standard for sharing data about where resins or materials originate — these insights can help the plastics industry move towards circular production models to increase the use of recycled content and decrease the use of virgin plastic. The result is a winning proposition for all ecosystem partners as it paves the way for OEMs, and brand owners meet their sustainability targets and strengthen brand positioning. Another such example is Cargill Corporation which connects farmers to markets, and customers to sustainable nutrition solutions by enhancing transparency in the global food value chains.⁶ Why does that matter? Because 59% of global consumers are interested in learning where their food comes from and how it is made. For brands, having traceability means they can be confident of the integrity of the ingredients they buy and that further enables them to tell compelling food origin stories that resonate with end consumers.

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² BMW Connected Drive; https://connecteddrive.bmwusa.com/app/index.html#/portal
⁵ GreenBiz; Domo, Covestro, BASF are testing blockchain for tracing plastics; April 6, 2020; https://www.greenbiz.com/article/domo-covestro-bASF-are-testing-blockchain-tracing-plastics
Adapting data handling capabilities for the neural era: Best practices

Manufacturers need to rethink their data handling and storage practices to be able to thrive in the neural era. Static and predefined data models are designed to solve known problems where the metadata is known, and hence, they largely focus on how data needs to be stored. The neural era, on the other hand, needs agile data models to actively manage a new class of metadata that is generated by connected assets, and be able to dynamically connect, optimize, and automate data integration processes. The data may not be in a structured format and may include semi-structured or unstructured data such as images or videos. For instance, the connected car as a data model is an agile model designed on how the metadata will be accessed to drive the evolving V2X use cases in the connected car ecosystem.

Similarly, data processing capabilities also need to be designed based on the business need. For example, critical decisions such as emergency machine shut down when certain threshold parameters are exceeded will require data processing capabilities at the edge to ensure low latency. On the other hand, other use cases such as customized insurance plans for connected fleets may be processed better on the cloud as it will require insurers to also collate data from various sources such as telematics devices, driver behavior, open-source data (maps, weather, terrain, and operational systems), customer relationship management (CRM), policy management systems, and other transactional systems to create customized insurance plans.

Neural Manufacturing will also require companies to overhaul their current data visualization capabilities to go beyond interactive dashboards and reports. New-age data visualization tools need to be self-explorative, accommodate business users, drive data discovery combining unstructured data, and support visual queries. Dashboards must evolve from alerting and scheduling to self-heal and inform-based capabilities. Leveraging AI-driven automation capabilities, manufacturers can enable a paradigm shift from monitor-and-alert driven reactive operations to predict-and-avert driven proactive operations, wherein faults can be prevented from happening with great accuracy. Engine maker Rolls-Royce, for instance, uses nanobots for predictive maintenance and inspection, allowing for superior engine servicing and inspection.7

Neural Manufacturing will see players increasingly adopt AI for automation and adaptive data governance. Systems need to be designed keeping in mind how data will be used and how it will be secured, all while ensuring privacy by design in order to lawfully process the data. In the connected car example, the OEMs need to address the challenge of using data without violating compliance to the General Data Protection Regulation (GDPR) and other geo-specific data privacy regulations.8 As recognition of the volume and commercial value of connected car data grows, ecosystem partners and regulatory bodies will tread a fine balance between maintaining data privacy and consent management, without jeopardising the commercial value of data.

7 RT Insights; How Rolls-Royce Uses Nanobots for Predictive Maintenance; August 22, 2018; https://www.rtinsights.com/the-nanobots-crawling-into-an-engine-system-near-you/
8 IT Pro Portal; GDPR meets the connected car; January 14, 2019; https://www.itproportal.com/features/gdpr-meets-the-connected-car/
Going forward, the infrastructure required to support Neural Manufacturing ecosystems will be powered by edge-enabled architectures and innovative open data platforms and technologies to drive greater transparency and trust in the system.

**Key building blocks to becoming Neural**

Harnessing data abundance to create neural behaviors would require the enterprise to work on key building blocks:

- **Information fabric** - Build an information fabric which elegantly stitches together the multiple data silos that may lie across different systems and business units to create a unified business view of the data.

- **Data life cycle management** – Create a comprehensive framework to set the foundation of data to serve manufacturing business needs. This framework should account for the special needs of connected products and assets such as data privacy concerns, and regulations across geographies.

- **Consent management** – Embed consent management policies to ensure compliance to data privacy regulations for personally identifiable data. This is will require an understanding of data regulations and its implications across geographies, such as the GDPR in Europe, California Consumer Privacy Act (CCPA) in North America, and Personal Data Protection Bill, in India.

- **AI / ML workbench** – Develop an analytics platform to rapidly build and deploy AI/ML solutions with prebuilt libraries and models adapted to a firm’s business needs.

- **Data monetization** – Democratize data within the enterprise to create opportunities to cross sell / up sell to increase revenue, or to derive efficiencies and reduce costs. Sharing data across value chain and ecosystem partners creates new data-driven services with direct monetization of data.

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**Figure 2: Key building blocks to becoming Neural**
Reimagining the manufacturing operating model

Traditional centralized or decentralized operating models will not suffice in the era of Neural Manufacturing as hybrid, flexible operating models that encourage collaboration and allow for agile responses are the need of the hour. The future will require manufacturers to break out of their comfort zones and build a strong foundation for sharing resources, and driving collaboration and innovation across ecosystem partners, including competitors. The value will reside in finding synergies and harnessing the abundance across the value chain. Design thinking will play a key role in helping manufacturers reimagine the future operating model by not just tackling problem solving but also unlocking new business opportunities.

About the Author

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Geeta Rohra is an Industry Advisor and leads the digital practice in the Manufacturing Business Unit at TCS. She develops digital business strategies for global manufacturing enterprises. She brings over two decades of experience in developing innovative domain-specific solutions and leverages TCS’ platforms, assets and new-age digital technologies for driving digital initiatives for the group.
Enterprise Neural Skills: Building the Future Manufacturing Workforce

The past decade has seen multiple changes in the demographics and skill profile of manufacturing workforce. As a first priority, the ageing workforce in several of the industries has led to a focus on knowledge management and retention. Next wave saw the emergence of ‘co-bots’ as manufacturing enterprises invested heavily in technologies such as automation, robotics, and artificial intelligence, changing the fundamental nature of business operations. And more recently, the ‘distancing’ enforced by the COVID-19 pandemic pushed the enterprises into extensive usage of virtual collaborative tools, and even remote operations, wherever possible.

Our research and analysis leads us to believe that many, if not all, of these changes are irreversible. In fact, in the TCS paper ‘Neural Manufacturing’ we have postulated that the new manufacturing order will see a different set of leaders – those who have mastered
the application of contemporary digital technology. An increasing number of organizations will embed cognitive capabilities and machine-first thinking into business operations and collaborate with an expanding partner ecosystem. There will be emphasis on developing soft skills and creativity along with an agile and design-critical mindset, besides the core engineering, planning, and management skills.

This paper describes how building neural skills and capabilities will help modern manufacturing companies transform into highly automated intelligent enterprises which will drive exponential value for all stakeholders.

The Evolution of Manufacturing into Neural

Digitalization has significantly impacted all industries, including manufacturing. Cyber-physical systems are rapidly going mainstream in manufacturing operations. The rise of emerging technologies has blurred the lines not just between the physical and digital spheres but also the biological one, leading to the emergence of what we term as ‘neural’ manufacturing - an intensely networked set of partners aligned to a common purpose. These partners and the entire manufacturing ecosystem operate within a value chain that is adaptive, automated, and personalized, with intelligence built on the edge of the networks.

As the industry shifts to a neural way of working, the capabilities of the workforce will be driven by two critical elements – demographics and technology adoption.

The rise of millennials as the largest generation in the workforce and COVID-19 are two key factors driving technology adoption in manufacturing. Digest this - by 2050, one-fourth of the population in Europe and North America will be 65 years or above. Even emerging economies such as China will see their favorable demographic dividend hit a trough. Demographic changes over the last few decades are likely to reach a point where more millennials will be in decision-making roles. Millennials as decision makers and a younger workforce are likely to further accelerate the technology adoption by manufacturing companies.

At the same time, pandemic-induced lockdowns and other limitations have forced companies to accelerate the adoption of drones, digital twins, artificial intelligence (AI), and autonomous technologies (Figure 1). Manufacturers who were previously reluctant to make technology investments to intensify their efforts towards catching up with more technologically advanced peers.

[1] United Nations; Global Issues - Ageing; [2] The International Monetary Fund; The Long, Good Life: Demographics and Economic Well-Being; March 2020; [3] CNBC; 28% of millennials are managers now—Here are 5 ways they’re changing the office; March 6, 2019;
Amid all these changes, the skills gap is already starting to show. In recent years, manufacturers, especially in the developed economies, have reported thousands of vacant positions primarily attributed to the growing skills gap. Manufacturers who do not plan their future human capital needs are likely to find it difficult to remain relevant. To adapt to the neural era, modern manufacturing companies will need to build capabilities in completely new areas such as automation, cyber-security, analytics & AI, computing, and material science, to name a few.

The adoption of technology is driven not only by the advancements, but the scalability, user-friendliness and cost affordability. Coupled with the above, the abundance of data which can be harnessed and synthesized for the entire value chain from product design to customer experience has led to a surge in business capabilities.

The Skills-Scape Under Neural Manufacturing

The advancements in computing and electronics in the 1970s led to the emergence of new manufacturing skills in the areas of embedded systems, programming, and communication. New interdisciplinary skills such as mechatronics (a combination of mechanics and electronics) guided the development of robotics, which automated production. Though the initial focus was on design of systems to manage complex operations, the capabilities have rapidly seen ‘democratization’, and now touching daily operations, thanks to the art of possible demonstrated technology companies from adjacent industries such as Amazon.

As manufacturers continued to focus on operational efficiencies, they began to widely adopt manufacturing execution systems (MES), supervisory control and data acquisition systems (SCADA), material requirements planning (MRP) and enterprise resource planning.

(ERP) software along with tools to improve product data and lifecycle management, logistics, supply chain management, and more. As the tool adoption increased, manufacturing companies combined core engineering skills with software skills (Figure 2).

The advancements in software shaped the rapid evolution of manufacturing in the latter part of the third industrial revolution. The emergence of the Fourth Industrial Revolution, or Industry 4.0, in the last decade led to a confluence of technologies such as IoT, AI, big data, cloud computing, and advanced robotics in the industry. This technological maturity has now pushed manufacturers to develop skills for a neural era.

As manufacturers in the neural era look for connected, collaborative, and cognitive capabilities to cater to the demands of operating in purpose-driven ecosystems, next-gen manufacturing jobs are more likely to require higher-order cognitive and soft skills (Figure 3). New roles will emerge due to the new division of labor among humans, machines, and algorithms. Along with technical skills like programming and app development, there will also be strong demand for skills that computers can't easily master such as creative thinking, problem-solving, and negotiating.

Neural skills will drive a radical change across manufacturing technology areas, a confluence of which will lead to exponential industry transformation.

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[5] World Economic Forum; The digital skills gap is widening fast. Here’s how to bridge it; March 12, 2019; https://www.weforum.org/agenda/2019/03/the-digital-skills-gap-is-widening-fast-heres-how-to-bridge-it/
Every manufacturer would not need every capability outlined here. A lot will be driven by the enterprise strategy, choice of business and operating models and nature of ecosystem partnerships. As has been the case with all strategic interventions over the years, it is necessary for manufacturers to build only the core ‘neural’ capabilities which will provide them the sustainable competitive advantage, while they leverage the ecosystem for the rest. In the paper ‘Neural Manufacturing’ we have called this out as the ‘New Manufacturing Order’.

Closing the Skills Gap

Just as technology is turning the industry on its head, millions of people are leaving manufacturing jobs. More than 2.6 million baby boomers are expected to retire in the next decade, many of them in management positions. The manufacturing industry has to work hard to attract younger generation workforce due to the overall negative perception of the industry.

A survey conducted by The Manufacturing Institute found that 2.4 million jobs in the US will remain vacant by 2028. A report in the Wall Street Journal states that labor shortage is a major concern for countries in the European Union, which in turn has constricted industrial production in 17% of companies in the region. Thankfully, manufacturers are aware of the impact of the skills gap and are taking steps to close it. The survey mentioned above further


found that nearly 80% of manufacturers have increased their workforce training efforts to combat the skills gap. In 2019, firms spent over $26 billion on training programs for new and existing employees. Manufacturers are making such programs more effective by using extended reality (XR) tools. For instance, augmented reality applications can supplement trainee coaching with expert technical information. In addition to workforce training, XR technologies can help the existing workforce retain knowledge and ensure smooth knowledge transition.

Going forward, candidates’ ability to demonstrate practical skills will be critical in addition to domain knowledge. Employers will prefer candidates with foundational knowledge of digital technologies in addition to the core skills. Some advanced skillsets may remain specialist, while others may quickly become intermediate or even foundational as firms adopt more complex technologies. For example, as quantum computing becomes more mainstream in the future, substantial changes are bound to happen in current technologies such as cloud computing[9]. As a result, newer computing skills or combinatorial skills which can leverage such advanced technologies such as Quantum Machine Learning[10] will become specialist while some current skills around cloud or machine learning could become intermediate in the future.

Making Manufacturing Future-Ready

As the demand for neural skills increases, it is clear that future manufacturing transformation must start with a workforce transformation. Manufacturers having a workforce with multidisciplinary skills will have a competitive edge in the neural age. However, manufacturing companies will need to revamp their existing organizational processes, systems, tools, and structure to build capabilities that will help them grow in the future.

In terms of processes, systems, and tools, the focus should be on agile product/service development, harnessing abundance of data, working in ecosystems, open innovation, defined roles for human workers and robots, industrial hygiene, and occupational health.

On the structure aspect, manufacturers would need to drive changes to their organizational culture to encourage collaboration with ecosystem partners, build centers of excellence to scale capabilities, and create cross-functional teams.

Neural manufacturing will not be limited to implementing new technologies; it would require a shift in attitude and culture. Neural skill development will be a critical element driving the success of manufacturing organizations as they transition to become truly connected enterprises in every sense.


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About TCS Manufacturing

In the Manufacturing industry, TCS partners with leading enterprises across the world, in the automotive, aerospace & defense, continuous manufacturing & chemical, industrial machinery and agriculture industries, helping them pursue their growth and transformation agenda with its industry-leading Neural Manufacturing framework.

For further details on TCS Manufacturing, please visit: https://www.tcs.com/manufacturing

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