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White Paper

A New Era of Manufacturing in the Fourth Industrial Revolution: $7 Billion of Possibilities Uncovered in Michigan

In collaboration with Accenture Strategy and Automation Alley

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Contents

Foreword

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Manufacturing has long been a pillar of economic prosperity. Today, with the rapid pace of technological advancement, industry dynamics are changing. Manufacturers are navigating an evolving competitive landscape as agile new players enter the market and disrupt traditional supply chains. In parallel, consumers are changing in the digital age, demanding personalized products and services. Meanwhile, increased resource constraints are placing added pressure on manufacturers to innovate to remain competitive and achieve sustainable growth.

Throughout the ages, industrial revolutions have disrupted manufacturing systems by introducing new methods of production. A new era of manufacturing is emerging in which the digital, physical and biological technologies of the Fourth Industrial Revolution present an unprecedented opportunity to transform the manufacturing industry, simultaneously driving profitability and sustainability. These goals are no longer mutually exclusive – Fourth Industrial Revolution technologies can both result in enhanced competitiveness and have a positive impact on the Sustainable Development Goals.

Recent years have seen Michigan's economy grow consistently, with its manufacturing industry a main driver of this economic prosperity. The automotive sector has long been a cornerstone of Michigan's economy, and to date remains the largest sector in its manufacturing industry. Given Michigan's history of innovation in manufacturing, the state is well-positioned to reap the benefits of the Fourth Industrial Revolution and lead the way for the future of production globally.

This White Paper identifies the Fourth Industrial Revolution technologies with the greatest potential to affect Michigan's production systems while delivering an annual opportunity worth $7 billion to the state by driving competitiveness and creating sustainable growth in its automotive sector. But the automotive industry's $7 billion case is just the beginning for Michigan. As more industries adopt these technologies, the potential value-add to the state will only grow.

Here, we outline a way forward to transition this potential into a reality for the people of Michigan. The study's findings are intended to inspire multistakeholder collaborations that seize the opportunity presented by the Fourth Industrial Revolution, and drive on-the-ground action in accelerating the shift to more competitive and sustainable production systems.

Executive summary

Manufacturing makes a critical contribution to the global economy (15.6% of global GDP);[1] however, its environmental footprint is also significant. The Accelerating Sustainable Production project builds collaborations between governments and businesses to drive the competitiveness of their production systems and achieve sustainable growth by implementing Fourth Industrial Revolution technologies.

The first phase of the project identified 40 Fourth Industrial Revolution technologies with the potential to transform four manufacturing industries (electronics; automotive; food and beverage; textiles, apparel and footwear). The second, and current, phase brings the global insights and findings to the regional level in order to identify opportunities and areas for progress. The first regional study focused on the state of Andhra Pradesh, India, while this study examines the US state of Michigan, with a particular focus on its automotive sector.

Interviews with industry experts and secondary research established the industrial context for this sector. The Accelerating Sustainable Production framework was then used to identify the most significant emerging technologies for Michigan's automotive sector and quantify the potential value that each technology can add to the economy, society and environment in the state. Finally, these benefits were mapped to the United Nations Sustainable Development Goals (SDGs).

Value opportunity for the automotive sector in Michigan

Targeted implementation of the primary Fourth Industrial Revolution technologies can deliver more than $7 billion in annual value by 2022 to Michigan's automotive sector, increasing the state's competitiveness and positively affecting SDGs 3, 8, 12 and 13, among others. Augmented workforces account for $2.6 billion of that value by increasing worker productivity, reducing training costs and streamlining the product design process. Augmented workforces can help bridge Michigan's growing skills gap and create more than 7,000 jobs in the process.

Cobots (collaborative robots) bring $2.1 billion in value by improving workforce productivity and introducing efficiencies to the factory floor. Cobots can handle the "dirty, dull and dangerous" work, reducing accidents in the workplace and freeing up workers to focus on innovation. Improved safety can save an estimated 7,900 worker-days for Michigan's manufacturers. Cobots can diminish the labour cost advantage of many emerging economies, which may help bring some manufacturing jobs back to the US. The onshoring of manufacturing could create 7,300 jobs in 2022.

Smart digital twin technology (the creation of digital replicas of physical assets) presents an annual opportunity of $1.4 billion through increased operational efficiencies and optimized production processes. By running virtual simulations in real time, smart digital twins can enable predictive asset maintenance, allowing manufacturers to identify issues and minimize unscheduled downtime. Smart digital twins can also improve product development and design processes, and create new revenue streams for manufacturers through premiums on cars sold with digital-twin-enabled maintenance services.

Metal 3D printing adds an opportunity for $800 million to the state's automotive sector by reducing material costs, inventory costs and transportation costs. Metal 3D printing enables decentralized manufacturing, where products can be printed on demand, closer to where they are needed; 3D printing also produces lighter components, allowing for vehicle lightweighting that improves fuel efficiency and reduces CO_2 emissions by 370,000 tons. Through mass customization, metal 3D printing can create new revenue opportunities from premiums charged on personalized vehicles.

The way forward

Fourth Industrial Revolution innovations can provide Michigan's manufacturers with a significant competitive advantage, position the state as the global leader for advanced manufacturing and ensure Michigan is prepared for the rapid innovations transforming its industries. These technologies can deliver economic growth while simultaneously benefitting society and the environment.

To accelerate the implementation of Fourth Industrial Revolution technologies, however, Michigan must establish a multistakeholder collaborative ecosystem in the state. Such collaborations can operate in pre-competitive spaces to instigate ecosystem-level changes that no single company could do alone. Bold leadership is required to take a long-term view in strengthening Michigan and its companies' market positions if they are to remain industry leaders. Without a clear strategic vision of what the future looks like and how to get there, organizations will fail to unlock the full value potential of these technologies.

Through the creation of a new Advanced Manufacturing Platform (AMP), hosted by Automation Alley – Michigan's Industry 4.0 knowledge centre – and connected globally through the World Economic Forum, Michigan has the opportunity to separate itself from the pack as the global leader for advanced manufacturing and ensure the state is prepared for the rapid innovations transforming its industries.

This multistakeholder platform will encourage and accelerate the implementation of Fourth Industrial Revolution technologies in Michigan while developing the workforce of the future. This platform has the potential to have an impact on existing public-private partnerships, drive the competitive advantage of individual companies and simultaneously position Michigan as a beacon of innovation and methodology for advanced manufacturing across the globe.

Chapter 1: The future of the automotive sector and industrial context in Michigan

Michigan is now booming following a remarkable comeback from the financial crisis of 2007–08. The Great Lakes state ranks first for job creation in the Midwest region and is the US's seventh fastest growing economy, with unemployment falling to record lows.[2] The manufacturing industry is a major driver of Michigan's economy. Manufacturers in Michigan account for 19% of the state's total output, employing 14% of the workforce.[3] Michigan ranks first in the nation in high-tech manufacturing employment and has created the most manufacturing jobs in the country since 2010.

Manufacturing has the largest multiplier effect on people and businesses of any industry economy in the US. Every $1 spent in manufacturing generates $1.81 in additional economic activity, and for every worker in manufacturing, four employees are hired elsewhere.[4]

Michigan is the birthplace of the modern automotive industry. It is where Henry Ford innovated modern mass-production techniques, including the first moving assembly line in the early 20th century. Today, the automotive industry is Michigan's leading manufacturing sector, making up more than 40% of the state's total manufacturing output.[5] Home to 20% of US car manufacturing jobs,[6] Michigan currently manufactures more cars and trucks than any other state, representing 23% of total US automotive production[7] – with more than 2 million vehicles produced each year.[8]

While the state's economy and manufacturing system are recovering after the economic crisis, sustainability has become a growing concern. Some 67% of respondents of the Healthy People–Healthy Planet Poll, led by Michigan State University's Health and Risk Communication Center, said the environment should take priority, even at the risk of curbing economic growth.[9]

The state ranks 10th in the 50 US states in terms of total CO_2 emissions.[10] No state has more water coverage (by percentage of total area) than Michigan. However, the state has faced several sustainability crises that required urgent action from the public sector.

Trends in the automotive industry

The automotive industry is now facing unprecedented disruption. Technological advances in both manufacturing and mobility are transforming the automotive landscape, requiring new and incumbent players alike to innovate rapidly to remain competitive. Important trends affecting how automotive companies operate include the changing expectations of digital consumers, the emergence of smart manufacturing enabled by the industrial internet of things (IIoT) and data analytics, the rise of connected and autonomous vehicles (CAVs), and sustainability. These trends are fundamentally changing the way vehicles are produced, with a car becoming a connected asset that has its own digital environment. Automotive companies need to transform into, and collaborate with, technology companies to remain competitive as they produce the next generation of vehicles.

Consumers are also rapidly evolving, and organizations must learn to adapt quickly to stay relevant. Consumers don't just want to buy a product; they are looking for a complete user-centric experience. As such, successful firms must shift from selling products to providing services and experiences. Consumers increasingly expect personalized interactions, and, through the sharing economy, are substituting ownership for access.

The IIoT is proving to be the most transformative force for manufacturers across all sectors. Combined with the power of data analytics, IIoT can enable the application of other technologies, giving manufacturers unprecedented visibility of operations and driving efficiencies while enabling new business models.

The impact of autonomous vehicle technology has the potential to revolutionize the way people move and travel. Autonomous vehicles will grant almost everyone access to mobility – including seniors and people with mental, physical or visual impairments whose access is limited by current technology. While widespread commercialization of self-driving cars is years away, manufacturers across the value chain understand its huge value potential and are increasingly pursuing initiatives and forging partnerships to make it a reality.

Sustainability has become a prime concern for manufacturers and vehicle users. Producing a car is a resource-intensive process. Vehicle production involves a significant volume of materials – with an average of 900 kilograms (1,984 pounds) of steel[11] and 350 kilograms (772 pounds) of plastic per vehicle.[12] Production processes also generate a significant eco-footprint through intense water consumption and GHG emissions – an estimated 148,000 litres (39,000 gallons) of water are used to produce one car,[13] and the production process accounts for 20–47% of the life-cycle vehicle emissions for internal combustion engines and battery electric vehicles, respectively.[14] As improvements in fuel economy reduce emissions in the use-phase of vehicles through lightweighting and the proliferation of hybrid and electric vehicles, the emissions from the production phase is an increased area of focus and scrutiny.

But embracing sustainability and green principles is no longer a mere marketing tool: CO_2 emissions from manufacturing, a growing demand for electric and hybrid vehicles and new consumption patterns are all emerging challenges that automotive manufacturers will need to meet.

Automotive in Michigan – an ecosystem ripe for accelerating

Forbes called Michigan the "Silicon Valley of Mobility Tech".[15] But what makes a place an innovation hub? What are the requirements for innovation? According to the National Governors Association, there are four components of an innovative place: expertise, interaction, diversity and application.[16]

– Expertise: new discoveries, insights and ideas arise when smart people have the resources they need to succeed. Michigan is home to the University Research Corridor (URC), an alliance between the University of Michigan, Michigan State University and Wayne State University. The URC conducted $2.3 billion in research in 2016 and graduated 35,000 students.[17] Michigan's Automation Alley publishes an annual Technology in Industry report, featuring seven leading Michigan universities and colleges and corporate insight from a number of industry stakeholders, providing a comprehensive look into several technology sectors. Michigan is a research-and-development hub for the automotive industry, with 76% of the industry's total R&D investment in the US going through Michigan.[18] R&D professionals represent 3.5 times the national average.[19]

– Interaction: an environment that encourages multistakeholder collaboration is needed for the exchange of ideas to drive progress and change. The Michigan Economic Development Corporation (MEDC) created technology business accelerators called SmartZones[20] (Automation Alley is one of 20 SmartZones in Michigan) to connect industry, academia and government, and fuel growth. MEDC also launched the PlanetM initiative,[21] a partnership of mobility organizations, educational institutions, research and development, and government agencies working together to deploy mobility technologies of the future. PlanetM facilitates industry connections, connecting mobility-focused start-ups, companies and investors to Michigan's extensive automotive industry network. MEDC established the PlanetM Landing Zone,[22] a subsidized space in Detroit to serve as a mobility hub for start-ups and attract global tech disruptors.

– Diversity: ideas improve only when they are openly discussed by a mix of people from a variety of backgrounds and fields. Michigan is home to a high concentration of original equipment manufacturers (OEMs), suppliers and academic institutions, and is actively attracting the world's leading technology companies to shape the future of mobility. One example is the American Center for Mobility (ACM),[23] a joint initiative between the state, academia and business. The ACM is a 2 square-kilometre (0.8 square-mile) testing facility designed to accelerate the safe deployment of CAVs. Its unique partnership model allows firms to invest in ACM and has attracted companies such as Ford, Toyota, AT&T (as the exclusive network provider), Microsoft (as the exclusive data infrastructure and cloud provider) and Siemens (which has provided its simulation and test solutions).

– Application: the proof of the true value of any idea lies in its application and commercialization. The state is investing in infrastructure and facilities to support the deployment of next-generation mobility initiatives. The Michigan Department of Transportation (MDOT), GM, Ford and the University of Michigan have created a series of connected freeways and arterials in southeast Michigan[24] to test methods for vehicles to communicate with nearby infrastructure, as well as other vehicles, in order for traffic to move along more smoothly, prevent crashes and improve safety. It is the first state in the nation to legalize self-driving vehicles, including ride-sharing services, on public roads.

Michigan has always been at the epicentre of automotive innovation and, today, it has all the components of an innovation hub for mobility. It is the leading state in mobility-related patents, with more than 2,500 awarded over the past five years. The state also has one of the fastest-growing venture capital communities and ranks first in the research spending-to-venture capital ratio in the US.[25]

However, challenges still lie ahead. Automotive innovation was born in Michigan, and its automotive companies were early adopters of robotics and automation. As a result, these companies have massive legacy systems and infrastructure in place that need to be integrated with emerging technologies if they are to upgrade to a truly digital factory floor – the factory of the future. Another challenge is the growing concern of Michigan manufacturers about talent shortages and skills gaps in the workforce. With the rapid pace of technological change, it is difficult for workers to keep up with the relevant skills needed as manufacturing evolves. There is also a need to attract younger generations to manufacturing and change their perception of the industry.

Michigan has succeeded in reinventing itself and has seen a wave of economic prosperity over the past decade. However, the automotive industry is experiencing rapid transformation. This leaves Michigan industry leaders facing a complex question: How can the state adapt to the Fourth Industrial Revolution and adopt the most relevant technologies at speed and scale to lead the transformation of the car industry, increase the state's regional and global competitiveness and achieve sustainable growth?

Chapter 2: Fourth Industrial Revolution technologies to drive competitiveness and sustainable growth in automotive manufacturing in Michigan

The Fourth Industrial Revolution is creating new realities for the manufacturing industry. Innovation in digital, physical and biological technologies can enhance production systems and connect manufacturers more closely to their supply chains and consumers, enabling feedback loops to improve products and shorten time-to-market. These technologies can transform the core of a business and enable new business models that deliver sustainable economic growth.

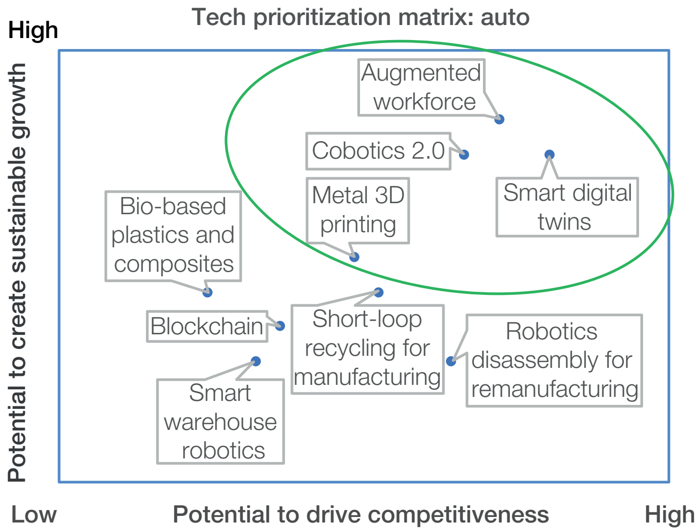
It is sometimes assumed that economic growth happens at the expense of society and the environment – a sentiment backed by history. The link between economic growth, CO_2 emissions and resource use is very strong: 1% growth in world GDP results in 0.5% increase in CO_2 emissions and 0.4% increase in resource consumption. However, the Fourth Industrial Revolution presents an unprecedented opportunity to decouple this relationship by driving economic growth and competitiveness while simultaneously enhancing the benefits to society and the environment. The implementation of Fourth Industrial Revolution technologies unlocks real economic value for manufacturers and increases the well-being of society at large.

As innovation continues to disrupt manufacturing and mobility, one thing is clear: The future of the automotive industry is more sustainable than ever. Major automotive OEMs are making bold commitments for a more sustainable future. For example, GM has linked its business strategy to its sustainability strategy with a vision for personal mobility in a world with zero crashes, zero emissions and zero congestion. As a part of this strategy, GM has committed to using 100% renewable energy in its operations by 2050.[26] GM has already realized $5 million in cost savings in its transition to renewables and expects to realize greater savings as the company scales renewables globally.[27] In addition, vehicle lightweighting is a high priority for automotive manufacturers looking to improve fuel-efficiency standards and meet the evolving demands of increasingly electrified vehicle platforms. Typically, a 10% reduction in vehicle weight can lead to a nearly equivalent improvement in fuel economy.[28] Manufacturers are further encouraged to reduce the weight of their vehicles due to consumer preferences for the savings associated with increased fuel efficiency. Moreover, pressure to reduce costs is creating upstream sustainability incentives for suppliers to automotive manufacturers, with energy use being a top priority.

For Michigan to continue as a global leader in the automotive industry and be a pioneer in the future of mobility, there needs to be a clear understanding of which Fourth Industrial Revolution technologies have the highest potential to drive competitiveness and sustainable growth.

With support from Automation Alley, a non-profit manufacturing and technology business association that serves as the state's Industry 4.0 knowledge centre, the primary stakeholders in Michigan were interviewed, including leaders from business, academia and state government. After interview analysis and secondary research, four technologies were prioritized based on their potential to drive competitiveness and create sustainable growth in Michigan's automotive sector (see Appendix for the detailed prioritization framework).

Figure 1: Technology prioritization matrix: automotive sector



Source: Accenture Strategy

The following technologies were identified:

– **Augmented workforce** schemes equip employees with additional technological insights through virtual interventions such as augmented reality (AR) and virtual reality (VR). In Michigan's automotive sector, AR can bridge the growing skills gap that has led to a shortage of skilled workers – a major concern for manufacturers in the state. The fast pace of technological change means there is a continuous need to train and retrain workers. AR is a cost-effective way of building technological resilience, offering on-demand guidance overlaid on tasks already being performed. It boosts worker productivity from its initial use, even without prior training; some manufacturers report performance improvements of more than 30%. AR also enables real-time communication with remote experts – raising performance levels while reducing costs.

Volvo is equipping production-line workers with augmented-reality wearables. They enable workers to digitally view assembly-line instructions in real time while working. Work instructions, associated technical drawings and video footage recorded by the last person who completed the procedure can be viewed on Microsoft's HoloLens. The initiative has led to increased productivity and output.[29]

- **Cobotics 2.0 (collaborative robots)** are designed to work alongside humans. They can learn multiple tasks to assist workers on the factory floor. Cobots can help bring manufacturing back to the US by diminishing the labour-cost advantage of emerging economies. Michigan has the largest automotive manufacturing workforce in the United States, but it has been diminished by outsourcing and automation. Robot–human teams are 85% more productive than either robots or humans alone.[30] Cobots increase job satisfaction – and safety – as they can handle the "dirty, dull, difficult and dangerous" work, freeing up human workers to innovate. This helps attract and retain workers, as the perception of manufacturing jobs improves.

  PSA Group is using cobots to increase its factory performance while reducing costs and improving worker ergonomics. This has resulted in costs savings of 2–8 euros ($2.25–9) per car – an initial saving of up to 1.6 million euros ($1.8 million). PSA Group has had no failures in more than 200,000 cars produced.[31]

- **Smart digital twin** technology creates digital replicas of physical assets, processes and systems, enabling near real-time updates and digital asset representations created by sensors deployed in machines. Michigan has the largest number of robots of any state in the nation and its automotive industry is highly automated. Preventing losses from production downtime is critical. With smart digital twins, predictive asset maintenance minimizes unscheduled downtime. Moreover, as the use of data and software grows, digital twin technology plays an increasingly important part in the design and development process.

  Maserati partnered with Siemens to upgrade and modernize the mass production of two of its models. By implementing Siemens' digital twin solution, Maserati was able to virtually create, simulate and test the cars manufactured, reducing the number of prototypes. This reduced development time by 30% and cut time-to-market from 30 months to 16 months.[32]

- **Metal 3D printing** fabricates components, building them by sequentially adding layers of material. Michigan's "Big Three" – Ford, GM and FCA – all have 3D-printing initiatives in place, but the technology is not yet mature enough to produce at scale. However, Michigan's industrial landscape of OEMs, suppliers and the University Research Corridor encourages innovation and collaboration, giving the state a competitive advantage in the race to scale metal 3D printing. The University of Michigan's Smart and Sustainable Research Lab has already developed a software algorithm to speed up 3D printing, which could theoretically make production more feasible at scale. 3D printing can reduce material costs by up to 90% and supports aggressive vehicle lightweighting[33] – a top priority for auto manufacturers wanting to produce fuel-efficient vehicles.

  GM partnered with software company Autodesk to introduce the next generation of lightweighting, pairing AI-powered generative-design software technology with 3D printing. It has produced a stainless-steel seat bracket that is 40% lighter and 20% stronger than the original part. This proof-of-concept consolidates eight different components into one 3D-printed part.[34]

The true transformative impact of these technologies can be realized only when they are deployed together. While each of the technologies on its own will significantly improve the operations of manufacturers, combining them can take manufacturers to the next level: The sum is greater than the parts. For instance, the smart digital twin of an asset can alert a worker equipped with an AR device of a maintenance issue in real time, allowing workers to act almost instantly to minimize machine downtime. While designing and developing a 3D-printed part, AR can allow designers to quickly alter and visualize new concepts, and smart digital twins can be used to run virtual simulations and optimize the digital product, dramatically reducing development time and cost.

Chapter 3: The value opportunity of the Fourth Industrial Revolution for Michigan's automotive sector

The implementation of the top four technologies identified can create more than $7 billion in annual value for the automotive sector in Michigan by 2022. These technologies can drive efficiency in manufacturers' existing production systems, enabling cost savings throughout the value chain while positively affecting revenue as a result of increased throughput. In addition to improving the competitiveness of manufacturers' current operations, the technologies can open additional channels for revenue from new products and services rendered to consumers and generate incremental revenue from premiums for customized, high-quality products, all while reducing resource use and emissions.

Fourth Industrial Revolution technologies can fuel competitiveness and sustainable growth in the automotive sector and position Michigan as a global leader in advanced manufacturing. The United Nations Sustainable Development Goals (SDGs) are a vital strategic goal for many manufacturers in Michigan, with Ford, GM and FCA all publicly stating their commitment and reporting on progress in meeting the goals.[35] As demands for transparency and corporate social and environmental responsibility increase, companies need to integrate the SDGs into their manufacturing strategies and actively influence them. The implementation of the four selected technologies in Michigan can help realize some of the SDGs, including:

– Goal 3: Good health and well-being – through increased safety in the workplace

– Goal 8: Decent work and economic growth – through higher levels of efficiency

– Goal 12: Responsible consumption and production – through reduced material consumption

– Goal 13: Climate action – through reduced greenhouse-gas emissions

The technologies can also create shared value for society as a whole, by addressing critical social and environmental challenges. The deployment of these innovations can create high-skilled jobs in the US market, help upskill workers and improve safety and quality of life. Moreover, these technologies will reduce CO_2 emissions, fuel consumption and material use.

Figure 2: Value impact of the top Fourth Industrial Revolution technologies for Michigan's automotive industry

Technology	Commercial impact	SDG impact	Associated risks
Augmented workforce	$2.6 billion in value through higher output from increased work efficiency and reduced training costs	Number of people that can be skilled due to reduced training time in AR/VR set up is doubled	AR/VR content can overshadow realism and blur real-virtual experiences
Cobotics 2.0	$2.1 billion in value through improved throughput and enhanced labour practices	Save 7,900 worker days (~5%) through reduced safety incidences; 7,300 jobs created by reshoring to US, leading to GDP growth of $355 million	Absence of liability in case of any injuries caused by cobots on the shop floor
Smart digital twins	$1.35 billion in value through cost savings from preventive asset maintenance and reduced product development costs; revenue increase due to premium charged on DT-enabled servicing	Reduction in CO_2 emissions by 620,000 tons due to better maintained cars; 20% reduction in road accidents due to timely defect detection	Lowering labour demand by reduced need for human intervention and making existing hardware skills insufficient
Metal 3D printing	$800 million in value through cost savings due to lean spare-parts inventory and enhanced product premiums due to customizable parts production	Reduction in CO_2 emissions due to lightweighting of vehicles by 370,000 tons	Metal 3D printing releases toxic fumes in the process, which could have adverse effects on workers' health

Source – Accenture Strategy

– **Augmented workforce schemes** can be used in various stages of the vehicle production process, including assembly, maintenance and design. In addition to increasing worker productivity and bridging the growing skills gap, the use of AR can streamline the design process, with concepts being quickly evaluated and altered in real time as they are developed. In Michigan, augmented workforce schemes can help generate more than $2.6 billion in value for the automotive sector through higher output from increased work efficiency (higher OEE) and reduced training and skilling investments. AR technology reduces training time by up to 75%. This allows for a larger number of workers to be trained than when using traditional training methods. Using AR technology can double the number of people to be employed, potentially creating more than 7,000 jobs in Michigan.

  There is a risk that augmented workforce schemes can lead to mental health issues since AR/VR technology blurs the distinction between real and virtual experiences.

– **Cobots** introduce speed, precision and repeatability to manufacturing operations. They are easy to program and set up, flexible and mobile, and can work safely with workers – without needing to be caged off like traditional industrial robots. In 2022, Cobotics has the potential to create more than $2.4 billion in total value for Michigan's automotive players. The human-robot productivity gains possible with cobots can enable manufacturers to increase the number of vehicles produced by 2%. Cobots can also bring greater cost efficiency to the manufacturing process, diminishing the labour cost advantage of emerging economies. This way, existing vehicle imports could be substituted by domestic manufacturing, and the onshoring of manufacturing could result in 7,300 jobs being created in 2022. Michigan's companies can also save an estimated 7,900 worker days by improvements to safety and ergonomics that lead to reduced numbers of workplace safety incidents.

  The ease with which cobots can be programmed may also have a downside – because cobots are easy to set up and program, workers can disable their safety features with relative ease. This can lead to potential injuries on the factory floor.

– **Smart digital twins** drive operational efficiency and can optimize the production process by enabling manufacturers to run real-time simulations, virtually testing and validating various design and production scenarios without interrupting workflow. Smart digital twin technology can help Michigan's companies realize a $1.3 billion value opportunity. This is through cost savings due to predictive asset maintenance that results in reduced asset downtime and associated cost of asset failures in plants, as well as reduced product development costs. In addition, companies can increase revenues through the premiums charged on cars sold with a digital twin-enabled maintenance service comprising digital upgrades and constant monitoring of safety stats. Smart digital twins can lead to higher fuel economy for cars due to improved maintenance, reducing CO_2 emissions by 620,000 tons.

  On the negative side, smart digital twins can reduce labour demand by minimizing the need for human intervention in monitoring equipment and rendering existing hardware skills insufficient.

– **Metal 3D printing** saves energy by eliminating production steps, using substantially less material and producing lighter materials. Metal 3D printing technology has the potential to create more than $800 million in value through cost savings and enhanced product premiums for the automotive sector in Michigan in 2022. The technology can reduce inventory costs by printing production parts on demand. It can also enable decentralized manufacturing – items can be fabricated closer to consumers, reducing transportation costs and emissions. Metal 3D printing also allows for mass customization, providing new revenue opportunities for carmakers who can charge a premium for personalized vehicles. The technology can reduce CO_2 emissions by 370,000 tons due to vehicle lightweighting, which results in improved fuel economy.

  However, metal 3D printing involves use of metal powders that pose combustion risks if handled negligently. There is also concern about the long-term exposure risks of such powders through inhalation as this has not yet been fully studied.

Chapter 4: The path forward

To lead in tomorrow's world of production, Michigan's manufacturers must embrace the Fourth Industrial Revolution. Fourth Industrial Revolution technologies bring a unique opportunity to drive the competitiveness of production systems and achieve sustainable growth. The above findings represent an enormous opportunity to inform targeted policies and technology-implementation efforts with the potential to accelerate the state's successes in the past decade.

There are important considerations for manufacturers in Michigan's automotive sector in implementing Fourth Industrial Revolution technologies. First, bold leadership is required to define a clear strategic vision of the future so that organizations can unlock the full value potential of these technologies. Second, people need to be at the centre of any strategies regarding factories of the future. Given the rapid pace of technological change, there is an imperative need to constantly train and retrain the workforce. Without skilled workers to program and run smart factories, the value of the Fourth Industrial Revolution will not be realized.

With many complex systems in place, manufacturers face challenges standardizing data and intelligently collecting information to capture the insights that drive business value. Manufacturers need to evaluate their legacy systems and assess what needs to be done to integrate these systems and transition to the factories of the future. Only then can data analytics transform their production floors into smart factories. Deploying IIoT infrastructure can help modernize and connect legacy equipment. Moreover, with widespread digitalization of operations, it is imperative to have a strong cloud platform and robust cybersecurity infrastructure in place to protect intellectual property and proprietary information as the risk of security breaches increases.

To address the above challenges and technological opportunities, it is essential that Michigan creates an environment that encourages multistakeholder collaboration. The state has already taken measures to create a favourable business environment and promote collaboration between players in the automotive arena. It is imperative to continue to facilitate collaboration as competitive landscapes evolve, with new players changing industry dynamics and challenging incumbents. Partnerships between players throughout industries and sectors drive innovation, as technology increasingly disrupts existing industries and creates new products, services and business models. Underpinning this network, government engagement is necessary to ensure that favourable policies and investment are in place to support advanced manufacturing.

Through the creation of a new Advanced Manufacturing Platform (AMP), hosted by Automation Alley – Michigan's Industry 4.0 knowledge centre – and connected globally through the World Economic Forum, Michigan has the opportunity to position itself as the global leader for advanced manufacturing and ensure the state is prepared for the rapid innovations transforming its industries. While numerous manufacturers in Michigan are already taking steps to adapt to the Fourth Industrial Revolution's innovations – highlighting the agile and innovative spirit that has defined the state's manufacturing industry for decades – no company, organization or entity can single-handedly create an environment that will ensure its future position as a global leader in advanced manufacturing.

This multistakeholder platform has the potential to accelerate the impact of existing public-private partnerships, drive the competitive advantage of individual companies, and simultaneously position Michigan as a beacon of innovation and methodologies for advanced manufacturing across the globe. The new platform will exploit Automation Alley's roadmap for positioning Michigan as the global leader in Fourth Industrial Revolution innovation and adoption in manufacturing.

Chapter 5: Conclusion

The "Shaping the Future of Advanced Manufacturing and Production in Michigan" study set out to identify the Fourth Industrial Revolution technologies with the greatest potential to drive competitiveness and create sustainable growth in the state's automotive sector. This study revealed a potential annual value opportunity of $7 billion by 2022, addressing the main economic, social and environmental challenges in Michigan. The technologies address the principal challenges raised by local stakeholders. An augmented workforce, for example, is a cost-effective method of training the manufacturing workforce and bridging the skills gap. Cobots can offload the "dull, dirty, dangerous" tasks, improving productivity on the factory floor and attracting a younger generation to the manufacturing industry. Importantly, this $7 billion potential is just the beginning for Michigan. As more companies from diverse industries also begin to adopt these technologies, the positive impact on the economy, society and environment will continue to expand on a massive scale.

As the competitive landscape continues to evolve, manufacturers need disruptive business models to achieve higher efficiency levels and unlock new revenue streams. The flexibility to adapt is necessary to keep up with the constant pace of technological change. Through collaboration between players within industries and sectors, and with the support of the public sector to drive policy frameworks that enable progress, Michigan will continue to expand its reputation as the Silicon Valley of mobility tech.

This study's findings are intended to facilitate conversation and enable collaboration between businesses in the automotive sector, government, academia and civil society in order to accelerate the adoption of Fourth Industrial Revolution technologies. The next step is to launch the Advanced Manufacturing Platform for sustained impact, to implement solutions that take advantage of the opportunities identified and overcome challenges for advanced manufacturing in Michigan.

Collaboration and the exchange of knowledge will be the central principles of this platform, which will convene the main stakeholders from the public sector, large corporations, small- and medium-sized enterprises, start-ups and academia. Activities will include:

– **Community-building:** Support the creation of a community of local stakeholders for sustainable manufacturing to facilitate networking, maximizing opportunities for collaboration

– **Knowledge exchange:** Enable the exchange of methodologies and use-cases that can serve as an inspiration for other companies and stakeholders, creating a space for open debate and dissemination of ideas

– **Driving action:** Identification and support for the implementation of high-potential sustainable production projects. Additionally, the incubation of select projects, providing tools and support to ensure success

Appendices

Appendix 1. Scope, methodology and terms

Scope of the study

The Fourth Industrial Revolution technologies for competitiveness and sustainable growth in Michigan study builds on the World Economic Forum's white paper *Driving the Sustainability of Production Systems with Fourth Industrial Revolution Innovation*. This study focused on four industries that were chosen based on the interests of the project community. They were low- and high-tech product-manufacturing industries with high environmental productivity, end-consumer visibility and good potential for further transformation:

- Electronics
- Automotive
- Textiles, apparel and footwear
- Food and beverage

In addition, the *Driving the Sustainability of Production Systems with Fourth Industrial Revolution Innovation* study identified 40 Fourth Industrial Revolution technological developments that could drive competitiveness and sustainable value throughout the value chains of the four focus industries.

Figure 3: Fourth Industrial Revolution technological developments for driving competitiveness and sustainable value

Automotive (9)	Electronics (8)	Food and beverages (11)	Textiles, apparel and footwear (12)
Short-loop recycling	Green electronic materials	Precision agriculture	Precision agriculture
Bio-based plastics and composites	Autonomous disassembly	Advanced bio farming	Biofabricated leather
Robotic disassembly for remanufacturing	Semiconductor fab 4.0	Genome editing	Alternative natural fibres
Cobotics 2.0	Advanced green packaging	Agriculture 5.0	Gene-edited fibre crops
Metal 3D printing	Digital traceability of minerals	Cellular and tissue engineering	Advanced organic wastewater treatment
Blockchain	Advanced electronic design automation	Automated agriculture	Advanced bio farming
Augmented workforce	3D-printed electronics	Advanced organic wastewater treatment	Next gen bio-based polyester
Smart digital twins	Near-dark factories	Supply chain traceability and control	Upcycled textiles
Smart warehousing		Vertical farming	Blockchain for fashion
		3D food printing	Footwear factory 5.0
		Supply-side advanced packaging	Automated sewing
			Nanotech-enhanced fabrics

Source: World Economic Forum and Accenture Strategy, *Driving the Sustainability of Production Systems with Fourth Industrial Revolution Innovation* white paper, January 2018

In Michigan, the automotive industry was selected because of its contribution to the state's GDP, the number of jobs and the historical relevance of the industry to the state.

The 40 Fourth Industrial Revolution industry developments identified in the *Driving the Sustainability of Production Systems with Fourth Industrial Revolution Innovation* study were considered as the starting point to select the top developments presenting the most significant potential for competitiveness and sustainable growth in Michigan's automotive industry.

Local working group

A local working group in Michigan was formed, in collaboration with Automation Alley, consisting of select local and international companies from the automotive industry. The working group provided consultation and expertise to the project team throughout the study.

Methodology

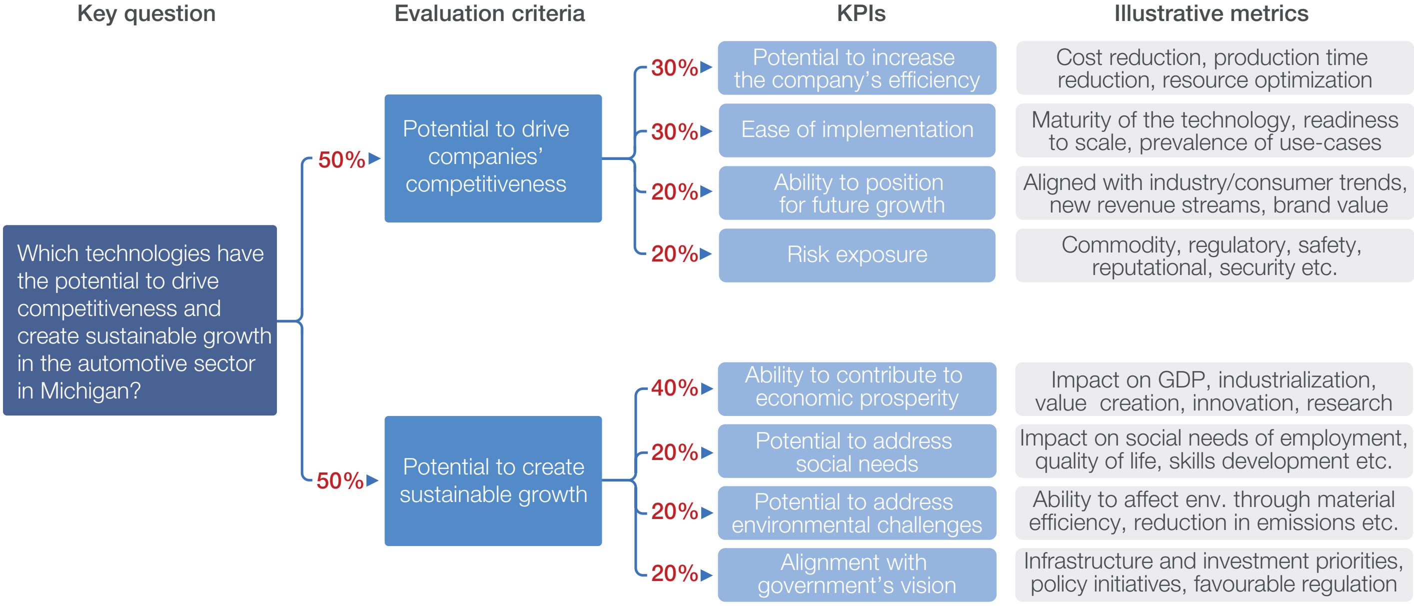
To develop this study, mixed-method research was used, combining two types of analysis: qualitative (i.e. interviews) and quantitative (i.e. data collection, value quantification exercise).

Secondary research and prioritization framework

A technology-prioritization framework was created for a first assessment of the Fourth Industrial Revolution technological developments, to identify those with the most significant potential for competitiveness and sustainable growth in Michigan's automotive industry.

The framework's purpose was twofold: 1) to measure the potential of the impact of Fourth Industrial Revolution developments; and 2) to identify the top four developments with the most significant potential in the state's selected industries.

Figure 4: Technology prioritization framework



Source: Accenture Strategy

Primary and secondary research was conducted to assess the technologies, including interviews with subject-matter experts, identification of case studies and analysis of available public and private data.

This assessment concluded with the preselection of the top four technology developments for the state's automotive industry.

Subject-matter expert interviews

Subject-matter experts from Michigan's automotive sector interviewed by the World Economic Forum, Accenture and Automation Alley validated the top four developments preselected according to the technology prioritization framework criteria. They also helped clarify the relevance of the selected technology developments. One-to-one discussions were conducted with industry experts from relevant manufacturing domains.

Michigan Roundtable

The Michigan Roundtable (Detroit, 13 November 2018) brought together the project team and important companies from Michigan's automotive industry.

The objective of the Michigan Roundtable was to validate the technologies preselected and identify potential opportunities for collaboration to facilitate the implementation of these Fourth Industrial Revolution technologies in the state.

Value quantification exercise

This exercise used the Accelerating Sustainable Production framework developed in the World Economic Forum's *Driving the Sustainability of Production Systems with Four Industrial Revolution Innovation* study.

Figure 5: Framework for analysing value at stake for individual production technology developments

Level 1 Value levers	**Level 2 Value levers**	**Level 3 Value levers**
Value addition	Operating profits (from incremental revenues)	Improved yield/volume, higher premium
	Costs saving	Reduced costs (including direct/indirect costs)
Value migration	Revenue shift	Revenues (form new/substitued products, services, technology solutions etc.)
Customer benefits	Time savings	Improved access (due to better connectivity, reduced congestion, improved access)
	Cost savings	Reduced prices
	Quality benefits	Increased health benefits (sustainable products/services)
Labour	Job opportunities	Increased net job (due to direct/indirect job creations), improved employability (due to upskilling initiatives)
	Income growth	Improved salaries (due to high-skill jobs, improved revenues etc.)
	Working conditions	Reduced job-related injuries and fatalities
Society	Health and safety	Reduced mortality rate attribuable to basic living conditions (air ambiance, water sanitation etc.), reduced mortality from accident-realated injuries
	Quality of life	Improved access to basic amenities, reduced inequalities (gender, income etc.)
Environment	Emissions to air	Reduced GHG emissions and particulate matter
	Water use	Improved water usage (water use efficiency, recycling etc.), improved water discharge
	Land use	Improved land use
	Material use (inculding waste management)	Improved material usage (use of renewable inputs, circular models, recycling etc.), reduced waste generation (including hazardous waste)

Note: Levels 1, 2 and 3 indicate different levels of value levers
Source: World Economic Forum and Accenture Strategy, *Driving the Sustainability of Production Systems with Fourth Industrial Revolution Innovation* white paper, January 2018

The framework was applied to each of the top-four technological developments identified. The value levers with the potential to create the highest impact were selected for each and quantified to ascertain their commercial effect as well as their social and environmental impact. The assumptions and resulting numbers that formed the basis of the quantitative analysis were gathered through primary inputs from industry experts and secondary research and were validated by the local working-group members in the final call.

Figure 6: Overview of the Fourth Industrial Revolution technological developments evaluated for the Michigan automotive sector

Development	Brief overview
Short-loop recycling for manufacturing	Short loops, in which all recycling processes remain in the automotive sector, are set up to recover and recycle materials for (re)manufacturing, using multiple partnerships enabled by digital platforms and geo-proximity. Current examples of short loops include those set up to recycle raw materials such as steel, copper, textiles and plastics, keeping them in the local automotive industry as much as possible.
Bio-based plastics and composites	Heavier metal and other plastic components are replaced with engineering-grade biopolymers and/or lighter natural-fibre-reinforced plastics created partially or wholly by using plant feedstock. For example, structures can use flax fibres and bio-epoxy resin intermingled with carbon fibres in hybrid composites, which are lighter, cheaper and more environmentally sustainable than conventional polymers. These materials and parts are suitable for multiple vehicle systems, including power-train applications.
Cobotics 2.0	A cobotic system includes a cobot and a human collaborating to achieve higher productivity and also to protect human workers from potentially hazardous jobs (those with a higher incidence of accidents). A lighter-weight, mobile plug-and-play generation of robots is arriving on the factory floor to collaborate safely with human workers thanks to advances in sensor and vision technology, and computing power.
Metal 3D printing	A shift towards metal-printing will allow more flexibility in general and application-specific materials. Applications in the car industry are characterized by the broad adoption of additives for production tooling, spare and custom parts and increased industrial uptake of print components for end products. Building objects from the bottom up and using materials only when needed reduces waste, enables weight reduction and has a cost advantage, especially when using materials such as titanium and nickel-alloy steels.
Smart digital twins	The digital twin paradigm enables manufacturers to operate factories efficiently and gain timely insights into product performance through the convergence of existing digital twin technology with the industrial internet of things and machine-learning technologies, providing near real-time updates and digital asset representation created by sensors deployed in the machines.
Blockchain	Blockchain is a distributed ledger technology that enables the creation of an immutable record of transactions to share with multiple participants in a business network. In the automobile sector, blockchain technology could enable all stakeholders to trace the origin of spare parts and components back through every step in the supply chain, as well as in reverse logistics applications to enable remanufacturing and recycling.
Augmented workforce	The use of augmented reality (AR) tech in various stages of the vehicle production process can support complex assembly, machine maintenance, expert support needs and quality assurance processes in the automotive industry. It is a collaborative tool that facilitates automation on the shop floor, enables productivity gains, increases resource efficiency and drives health-and-safety improvements.
Robotics disassembly for remanufacturing	Robots are widely used in automotive manufacturing but not in remanufacturing, particularly at the critical stage of disassembly. Advances in this sphere could mean that end-of-life product disassembly for remanufacture will become easier, faster and more cost-effective, driving efficient resource use and enabling the circular economy in the industry.
Smart warehouse robotics	Advances in autonomous mobile robotics (AMR) technology make it easier for robots to be used in warehouses, where they support high volumes of small, multiline orders, often in collaboration with warehouse workers. This leads to productivity gains and fewer accidents and injuries among workers, while providing opportunities for skills development and retraining. Current research is focusing on incorporating machine learning into AMR solutions.

Source: World Economic Forum and Accenture Strategy, *Driving the Sustainability of Production Systems with Fourth Industrial Revolution Innovation* white paper, January 2018

Appendix 2. Important terms and definitions

Production: The full spectrum of value-adding activities in the cradle-to-factory-gate part of a given industry value chain (excluding those assumed to be out of scope for this analysis).

Sustainable growth: The manufacturing of products and product inputs, and the creation of related services, which respond to consumer and market needs and bring a better quality of life.

Fourth Industrial Revolution sustainable production development: A set of digital, physical and/or biological Fourth Industrial Revolution technologies converging to change manufacturing inputs, processes and outputs. They enable new business models with the potential to increase value creation across the triple bottom line (economic, social and environmental).

Appendix 3: Working group (convened in collaboration with Accenture and Automation Alley)

ABB US	Accenture US	AFL-CIO Industrial Union Council
Altair	Automation Alley	Ascent Aerospace
BorgWarner	Bosch Rexroth	Brose
CAR	DEGC	DENSO International America, Inc
Desktop Metal	Dow Chemical	Fanuc
FCA Group – Fiat Chrysler Automobiles	Flex-N-Gate	Ford Motor Company
Fori Automation	General Dynamics Land Systems	GS3
Hilite	Hirotec America	Joyson Safety Systems
Kelly Services	LIFT	Macomb County
Mahindra	Michigan Economic Development Corporation	Microsoft
NLB Corporation	OPS Solutions, LLC	Park Corporation
Pratt & Miller Engineering and Fabrication Inc.	RCO Engineering	Siemens
Soft Robotics	Stanley Black & Decker	Sundberg Ferar
Tata Technologies	University of Michigan	Vickers Engineering

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