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Augmented Workforce: Empowering People, Transforming Manufacturing

WHITE PAPER

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Foreword

The Fourth Industrial Revolution is transforming the relationship between technology and human beings.

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Although technology is an important pillar of organizations' competitiveness, people remain essential on shop floors and will continue to be so in the future. Manufacturing is more than a sum of subtasks that can simply be taken over by robots; people are needed to take charge not only of developing groundbreaking products but also of controlling, troubleshooting and executing complex operations.

To remain competitive in today's increasingly complex manufacturing landscape, companies need to move beyond an automation narrative and consider the empowering role of augmentation. This involves placing the workforce at the centre of discussions, creating a more accessible and inclusive work environment, increasing employees' well-being and fostering human connection and collaboration.

This white paper illustrates how augmentation technologies assist the workforce and amplify human abilities to enable a future of industrial work that is not only more productive but also more accessible, inclusive and sustainable. Ultimately, manufacturing and value chains need to shape what Klaus Schwab, Founder and Executive Chairman of the World Economic Forum, calls "a future that works for all by putting people first, empowering them and constantly reminding ourselves that all of these new technologies are first and foremost tools made by people for people".[1]

Executive summary

Leveraging augmentation technology to empower people to thrive in manufacturing.

Augmentation technology, which includes diverse technologies such as virtual reality, computer vision and exoskeletons (see Table 1), provides opportunities to develop a human-centric vision of manufacturing – to the benefit of both businesses and their employees.

This white paper on the implementation of augmentation technology – which presents the findings of 35 high-impact use cases and interviews with more than 100 senior executives – illuminates the opportunities for effective application of this technology in manufacturing and the benefits that accrue.

It reveals that augmentation technologies can benefit both businesses and employees by:

1. Increasing the efficiency and effectiveness of industrial operations
2. Unlocking innovation and developing new solutions
3. Enabling employees to acquire new skills and knowledge
4. Creating a more accessible and inclusive work environment
5. Increasing workers' well-being and employees' safety
6. Supporting human connection and collaboration

Manufacturing organizations that successfully implement augmentation technology typically move through three phases: the concept phase, the pilot phase and the scaling phase.

In the concept phase, two approaches are discernible: 1) a technology-driven approach through which a company begins the augmentation journey by selecting a promising technology from a range of emerging solutions; 2) a value-driven approach that begins with an assessment of the industrial challenge(s) that a company wishes to overcome and continues by mapping technologies against the challenge(s) to identify the best fit and solution.

In the pilot phase, the focus is on assessing the extent to which the technology selected provides a basis for success in practice.

Finally, in the scaling phase, the emphasis shifts from core assessment to the execution and evaluation of the implementation strategy. In the process of scaling, the technology will be applied in multiple use cases and application scenarios.

The potential of augmentation technology to provide benefits to employees in manufacturing cannot be fully achieved by organizations acting in isolation. Collaboration is required, between businesses (including small and medium-sized enterprises) and also between a broader range of stakeholders, including government, trade unions and the scientific research community.

Overall, augmentation technology proves most productive as part of a human-centric approach. While technology is needed to solve problems, people remain essential on future shop floors to decide which problems to solve.

Below: @anon-tae/
Gettyimages

1 The challenges of technological change in manufacturing

People remain integral contributors in industry. There needs to be a sense of complementarity between people and technology.

The Fourth Industrial Revolution, whose fields of innovation include the industrial internet of things (IIoT), artificial intelligence (AI) and the development of cyber-physical systems, is transforming the relationship between technology and human beings.[2] The exponential development of technology is undeniably exciting: it has the potential to unlock efficiency, productivity, sustainability and growth at scale. Yet such developments also give rise to a series of challenges concerning the role and place of human beings.[3]

Challenges include:

– The ever-rising complexity of manufacturing operations requires shop floors to continually adapt to the introduction of new technologies, machines, processes and production environments.[4]

– As manufacturing increasingly adapts emerging technologies, a gap is emerging between the demand for and supply of science, technology, engineering and mathematics (STEM) skills, which are required to cope with the new pace of innovation.[5]

– Labour shortages are growing, as an ageing workforce gradually retires and younger generations tend to eschew manufacturing jobs because of a perception that they are dangerous, tedious and unhealthy.[6]

One source of solutions to these problems may lie in the further automation of work. Yet assigning the execution of production tasks to fully autonomous systems is not always effective or even feasible.[7] In fact, however paradoxical it may seem, the more that advanced manufacturing technologies are integrated into factories, the more important the role of humans becomes.[8] While technology is needed to solve problems, humans are required to understand which problems to solve and which approaches are best suited to solve them.[9]

The findings of this work – reported in sections 2 and 3 – reveal an important sense of complementarity, in which technology and human factors are combined to work together.

According to this account, the development of a human-centric culture that places human beings at the core of manufacturing operations is crucial. Moreover, manufacturers can use advanced manufacturing to empower and support the workforce. Leading players who have already started to do so are achieving productivity gains, while also providing significant benefit to their employees, who feel more engaged and satisfied.[10]

This white paper presents a new narrative that focuses on augmentation technology as a source of multiple benefits to manufacturers and their workforces. It does so by:

– Showcasing how leading companies are benefiting from using advanced manufacturing technology to engage and support their employees (Section 2)

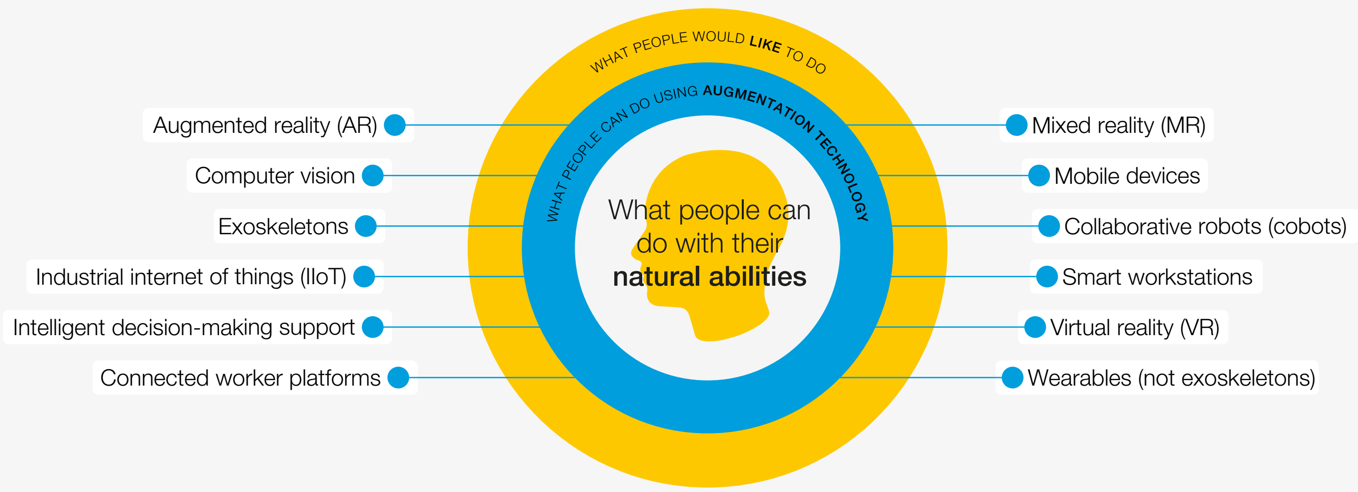
– Outlining the development path towards unlocking the full potential of augmentation technology at scale (Section 3)

– Specifying the ways in which collaboration between stakeholders can help to fully unlock the potential of both technology and people (Section 4)

BOX 1 | **What is augmentation?**

Within the context of this white paper, the term "augmentation" refers to the use of technologies to simultaneously support people's empowerment and engagement, increase productivity and drive excellence across operations and business processes. It aims to realize the most effective ways to support or amplify human abilities with technology (Figure 1).[11]

FIGURE 1 **Purpose of augmentation technology: putting people first**



Source: Moencks et al., "Augmented Workforce Canvas: A Management Tool for Guiding Human-Centric, Value-Driven Human-Technology Integration in Industry", Computers & Industrial Engineering, 107803, 2021

Technology can be used to augment human capabilities and skills in a variety of ways: from problem-solving to work execution, data analytics, physical capacities, learning, communication or decision-making.[12]

Table 1 displays the range of types of augmentation technology.

TABLE 1 **Overview of augmentation technologies**

Augmented reality (AR) Enhanced version of the physical world achieved by digital visual elements, sound or other stimuli	**Computer vision** Area of artificial intelligence (AI) that enables systems to derive information from images, videos and other visual input	**Exoskeletons** External anatomical feature that supports and protects an operator's body during physical tasks
Industrial internet of thing (IIoT) Application of connected sensors and other devices to machinery and processes in industrial settings	**Intelligent decision-making support** System that helps facilitate decision-making, judgements and courses of action based on data	**Connected worker platforms** Digital tool designed for operators to improve communication and control in industrial settings
Mixed reality (MR) Merging of real and virtual worlds to generate environments in which physical and digital objects coexist and interact	**Mobile devices** Portable, electronic equipment that can connect to the internet	**Collaborative robots (cobots)** Machines capable of carrying out a complex series of actions semi-automatically in collaboration with operators
Smart workstations An area in which industrial work is carried out supported by technological means, e.g. task guidance	**Virtual reality (VR)** Computer-generated, immersive simulation of a three-dimensional image or environment	**Wearables (not exoskeletons)** Electronic devices that can be worn as accessories, e.g. embedded in protective work clothing

Below: @recep-bg/ Gettyimages

2 Opportunities and benefits of augmentation technology

Enabling a future of industrial work that is not only more productive but also more accessible, empowering and sustainable.

This section showcases the ways in which innovation involving augmentation technology can be harnessed with a human-centric perspective to the benefit of both organizations and their workforces.

The findings are based on what has already been achieved by some advanced companies. They emerged from a review of 35 high-impact use cases from across eight industry sectors, which were selected based on their maturity levels: 65% of cases involved more than 500 daily users of augmentation technology each and 43% had been scaled over at least three geographies. Taken together, the use cases present a broadly positive picture: 20% succeeded in becoming operational in five weeks to three months; a further 35% did so within a year. On average, the return on investment (ROI) proved positive within three years.

Presented below are six benefits of augmenting technology for the workforce. Each is illustrated by a use case, with 22 additional cases detailed in the appendix.

Benefit 1/6 Enabling employees to acquire new skills and knowledge

Augmentation technologies offer an opportunity to enable lifelong learning and development of employees. For example, applications such as augmented reality (AR) and virtual reality (VR) training, mobile learning or smart workstations can enhance both on-the-job and off-the-job learning. In this consultation, businesses reported gains in training effectiveness, compared to in-person training, of up to 80%, as well as cost savings and gains in scalability.

Use case: Gemba's walk – scaling cross-hierarchical learning

FIGURE 2 **Immersive lean production training**

Source: Gemba – The Leadership Network

One application of augmentation technology is as a training tool powered by an immersive, virtual learning platform, used to make learning faster, more agile, more individualized and more entertaining.

Tier 1 automotive supplier Aptiv has 175,000 employees, with 135,000 people working in manufacturing. The workforce needs to be continuously trained and upskilled in "lean production".

With in-person training, this would require the recruitment and deployment of more than 400 high-quality instructors – a daunting prospect. Instead, Edward O'Brien, Aptiv's Global Operational Excellence Leader, decided in 2019 to procure the services of technology-mediated learning provider Gemba.

The aim was to create large-scale, cross-hierarchical, immersive learning journeys tailored to the needs of the workforce (Figure 2).

More than 7,800 employees were trained in first courses alone. Using Gemba's immersive learning platform, as well as state-of-the art hardware (Oculus Quest 2, Microsoft HoloLens 2), enabled Aptiv to "convey knowledge at a much higher depth and breadth, with an 80% higher efficiency compared to real-world training", according to O'Brien.

The major benefit of using such scalable technology is the removal of skills gaps on a mass scale.

> **In many businesses, there is no additional secret apart from an empowered workforce executing the right strategy faster than anybody else. Large-scale, real-time, location-independent reskilling is going to be the biggest competitive advantage in any industry. Here, immersive VR learning can be a catalyst.**
>
> Nathan Robinson, Founder and Chief Executive Officer, Gemba

Benefit 2/6

Creating a more accessible and inclusive work environment

One use of augmentation technology is to reduce the entry barriers to jobs. In particular, eyeware or projection-based AR technologies can increase the range of tasks and jobs accessible to new employees, with gains in terms of flexibility, productivity and equity, as well as enabling the integration of people with disabilities in shop-floor activities.

Use case: a guiding light – encouraging shop-floor accessibility

FIGURE 3 **Projection-based AR operator guidance**

Source: LightGuide

Mariasteen is a non-profit work integration social enterprise located in Belgium. The organization provides diverse services, including metalworking, assembly, packaging and individual and group secondments. It employs more than 900 personnel, of whom upwards of 750 are disadvantaged employees or people with specific requirements.

The organization's coaches who support these employees faced challenges in creating accessible work instructions. Their instructions were proving unsuitable as the formal language used often presented a challenge for people with cognitive disabilities.

In order to make shop-floor work more accessible, Mariasteen engaged a technology provider, LightGuide. Workstations with projection-based AR were developed (Figure 3), with the aim of providing accessible work instructions. In this way, visual information concerning the location and spatial references for the placement of parts could be projected directly onto the workstation.

Though the need to create the AR work instructions from legacy work instructions represented a challenge, subsequent training using the technology proved successful: quality increased to almost 100%. An important lesson was that the use of inclusive and assistive technology, whether assisting employees cognitively or physically with cobots, can make work accessible to a greater range of staff. The benefits are both economic and social, providing an opportunity for employees to experience greater autonomy and economic participation, while also enabling an expansion of the workforce.

> **We need to design shop floors that are accessible to all people who want to contribute. Assistance systems can help us by decreasing cognitive loads, language barriers and so much more.**
>
> Paul Ryznar, Chief Executive Officer, LightGuide

Benefit 3/6 Increasing employees' well-being and improving their safety

Many manufacturing jobs can be physically demanding. Tasks such as heavy lifting may present health and safety risks for the workforce. One application of augmentation technology – for example, using exoskeletons or cobots – aims to protect employees' health, enabling them to remain safely in their preferred jobs for longer, regardless of age.

Use case: lifting the weight off operators' shoulders

FIGURE 4 **Exoskeletons helping operators in logistics**

Source: Ottobock

DB Schenker is a globally operating air, land, sea freight and contract logistics organization. The company decided to create a more ergonomic, healthier workplace for its workforce.

The focus was on the handling, loading and unloading of non-standardized goods into and from trucks and shipping containers. The organization sought a scalable tool to empower its workforce while allowing its financial department to match the effects of increased employee well-being with productivity gains in the accounts. In collaboration with Ottobock Bionic Exoskeletons and MotionMiners, it decided to deploy exoskeletons capable of lifting 23 metric tons per employee per working week, relieving operators from the strain of doing so.

> **Our analyses showed that – on average – a worker bends 1,300 times while lifting 11 metrics tons per shift. […] That is the equivalent of one heavy transporter on each employee's spine per week. We had to change that.**
>
> Sönke Rössing, Head, Ottobock Bionic Exoskeletons

The initiative resulted in an immediate posture improvement of 30–40% during work execution. By improving handling times, the augmentation technology enables people to take more breaks throughout the shifts, thereby reducing fatigue. Because the technology was considered relatively unknown, cross-hierarchical expectation management formed a key part of the implementation, involving operators, workers' organizations and top management.

Throughout the roll-out, operators were supported by experts in ergonomics and technology, helping them to adjust to the technology. Key lessons included:

– Augmentation technology such as exoskeletons must always be fitted to the requirements of each individual.

– Enthusiastic employees can subsequently be engaged as adoption champions.

Benefit 4/6 Increasing the efficiency and effectiveness of industrial operations

Among the multitude of benefits that augmentation technology can provide are the contributions it can make to machine diagnostics, inspection performance, data capture and information management through technologies such as wearables, mobile and smart devices, intelligent decision-making support and connected worker platforms.

Use case: stay on watch – wearable, cross-hierarchical communication

FIGURE 5 **A notification manager, empowering operators to stay on top of things**

Source: Siemens

How can an employee keep on top of operations and maintain an overview of the status of multiple machines, regardless of location? Faced with the challenge of monitoring machines that cannot be connected to the IIOT, a Siemens maintenance technician began to explore the possibility of intercepting the signals from the machines' status light systems, bringing the information together in one place. Picking up on the employee's idea, Siemens, as a global industrial manufacturer, developed an intelligent, wearable human-to-X communication and coordination application for smartwatches.

> **For us, augmentation implies working together to examine employees' individual needs and address respective needs with fit-for-purpose, accepted technology, ultimately promoting a more human-centric production in a digital enterprise.**
>
> Cedrik Neike, Member of the Managing Board, Siemens

Because externally available products did not adhere to the organization's cybersecurity standards, the team decided to build their own application. A prime implementation challenge was to develop a solution that neither employed external services nor connected to the internet. The aim was that employees should be able to directly contact the colleagues who can best support them when they have a problem, without reporting to supervisors or technicians first. Siemens found that employees feel empowered by using state-of-the-art communication technology and having the ability to contact engineers directly without needing to notify supervisors.

Benefit 5/6 Unlocking innovation and developing new solutions

One use of augmentation technology is to help employees suggest ways to improve production systems. This can be achieved with intelligent decision-making systems, connected worker platforms, smart workstations and computer vision.

Use case: cross-hierarchical augmentation and innovation

FIGURE 6 **Connected worker platform allowing operators to suggest improvements**

Source: Schneider Electric

Schneider Electric is a multinational company providing energy, automation and digital solutions. The company wished to identify opportunities to further improve its operations. To this end, it developed a digital system for capturing ideas to contribute to continuous improvement across its shop floors. The system enables operators to suggest ways to improve the production process. Issues raised by operators will be discussed with supervisors, who then commit to an action date for the issue to be addressed. If the issue is not sufficiently addressed at this stage, the connected worker platform automatically escalates it to the next level in the business's hierarchy.

The company found that the digital tool was broadly accepted among its front-line workforce. After the initial challenge of training employees in using the tool, the main difficulty lay in establishing the interaction between different IT layers (notably the industrial-oriented and business-oriented networks).

In addition, although the platform has certainly led to improvements in production processes, it has proved challenging to quantify the resulting gains in efficiency, quality, ergonomics and safety.

The key lessons were:

- Digital technology can help to empower the workforce and facilitate continuous improvement activities.
- Augmentation technologies can help to eliminate non-value-adding tasks on shop floors, thereby removing distractions from core activities.

> **Oftentimes, the greatest ideas for improvement, innovation and optimization originate from the people working on the shop floor. Augmentation should amplify the operator's voice … and leverage the insights of everyone to shape better work, and to remove the fear of being replaced by technology.**
>
> Laure Collin, Senior Vice-President, Human Resources Global Supply Chain, Schneider Electric

Benefit 6/6

Supporting human connection and collaboration, overcoming travel restrictions

A further advantage of augmentation technology is that it can help employees to collaborate successfully and to feel connected with each other, even when they are working apart.

This is particularly the case for AR and VR technologies that enable remote assistance, ad hoc expert feedback or spatial annotations.

Use case: seeing through the pandemic – AR for operational resilience

FIGURE 7 **AR for enabling remote expert collaboration**

Source: Microsoft

Schaeffler is a global automotive and industrial supplier. In this case its aim was to improve operations, communication and collaboration across 75 plants worldwide. Its objectives included: 1) the reduction of the company's carbon footprint occasioned by frequent travel; 2) creating connection between global experts and onsite teams; and 3) preserving functional excellence during the COVID-19 pandemic. The company decided to use Microsoft's remote assistance software on the HoloLens 2 (Figure 7). A key enabler of effective adoption was the technology provider's global distribution and support network, but a second turned out to be the impact of the COVID-19 pandemic, which accelerated a change in mindset, encouraged by the need to rethink processes of communication and collaboration. This facilitated remote collaboration on tasks that were previously considered unacceptable for remote execution.

The major challenges in implementation tended to be technical; cultural change and technology acceptance played only a minor role. The organization sought a globally scalable solution that could be maintained via mobile device management systems. At the same time, all applications needed to adhere to the organization's data protection and cybersecurity standards. When Schaeffler started to pioneer these technologies, only a few medical studies were available to guide them in the ergonomic handling of the devices. In addition, the company found that the requisite hardware and software had only just started to be characterized as enterprise-ready for advanced manufacturing contexts. As the company worked to overcome such challenges, more flexible, real-time collaboration became possible. As an outcome, machine downtimes were reduced, the ad hoc availability of experts increased, the experts' time spent travelling decreased and their work-life balance improved.

> **We've built a safe, sustainable and cost-effective way to support our facilities, our colleagues and our planet, all while making daily business easier.**
>
> Tobias Moser, Vice-President and Head of Operations, IT and Digitalization – Solutions and Services, Schaeffler

Key lessons included:

– The development of a rapid, agile decision-making process accelerated the organization's adoption of augmentation technology and allowed scaling at a rate previously thought unfeasible.

– Gaining user acceptance was identified as the key element of Schaeffler's augmentation journey.

Below: @gorodenkoff/ Gettyimages

3 Implementation: a journey of three phases

Start with a challenge to be addressed. Next evaluate a solution on a small scale. Then unlock the value-added of augmentation on a large scale.

A successful augmentation journey typically comprises three phases

3.1 Conceptualizing | 3.2 Piloting | 3.3 Scaling

3.1 The concept phase

Two approaches may be distinguished: 1) technology-driven; and 2) value-driven.[13]

1. With the **technology-driven approach**, the manufacturing company begins by identifying emerging technologies. Then it defines the challenges that exist in the value chain. Next, it pilots the technology in order to assess its applicability. Finally, it integrates the technology into its workflows, scaling it up in the production process.
2. With the **value-driven approach**, the company begins with an assessment of the industrial challenge(s) that it wishes to overcome. The assessment starts from a neutral view of the technology available and its potential role. This includes a consideration of specific goals and objectives. The company then maps the challenge(s) faced against the technologies and identifies the best technology fit. During the pilot phase, the selected technology is tested for: 1) its suitability in daily operations; and 2) its ability to add value. If the technology passes the pilot stage, it is then integrated into the company's operations.

In general, the value-driven approach has proven the more effective, as it starts with a focus on what value can be generated for employees. It can facilitate the exploitation of off-the-shelf technologies, avoiding prolonged pilot stages in the process, while always keeping employees at the centre.

> **Conversations used to focus primarily around technology. Now, the focus of these conversations is shifting to what value is possible, and what challenges can be solved with augmented reality.**
>
> Mike Campbell, Executive Vice-President, PTC

3.2 The pilot phase

In the second phase – the pilot – the focus is on assessing the extent to which the use case selected provides a basis for success in practice. Does the technology perform as anticipated?

Because a pilot is typically conducted at small scale, it needs to be borne in mind that not all the anticipated benefits of a full-scale solution can yet be demonstrated. Rather, the focus needs to lie on learning and development through reiteration.

A number of considerations should be examined before the project can progress to the scaling phase. To what extent is the business's IT infrastructure equipped to provide global support if the technology were to be adopted? What cost-benefit method should be applied? Critically, human considerations lie at the centre of the assessment process. To what extent does the use case align with the goals of the workforce and the organization? Is the use case appropriate to the culture and mindset of the workforce? Do the staff possess the necessary digital literacy?

> **Our strategy on augmentation? Purpose first. Technology follows. Corporate culture is key. Iterative improvements beat postponed perfection.**
>
> Jay Lee, Vice-Chairman, Foxconn

Lessons learned (phases 1 and 2)

1. End users are key: operators know best where processes can be enhanced, so they need to be engaged early in the planning process.

2. There must be trust in the adaptability of the workforce: they often prove more open to trying augmentation technology than expected – and, without an engaged workforce, projects will fail.

3. The process should start with a challenge in mind, rather than with a technology.

4. It is important to start with achievable goals – not necessarily the biggest possible projects.

5. Even if projects can seem slow at the outset, it is important to prepare for the scaling phase (in terms of governance, roll-out plans, etc.).

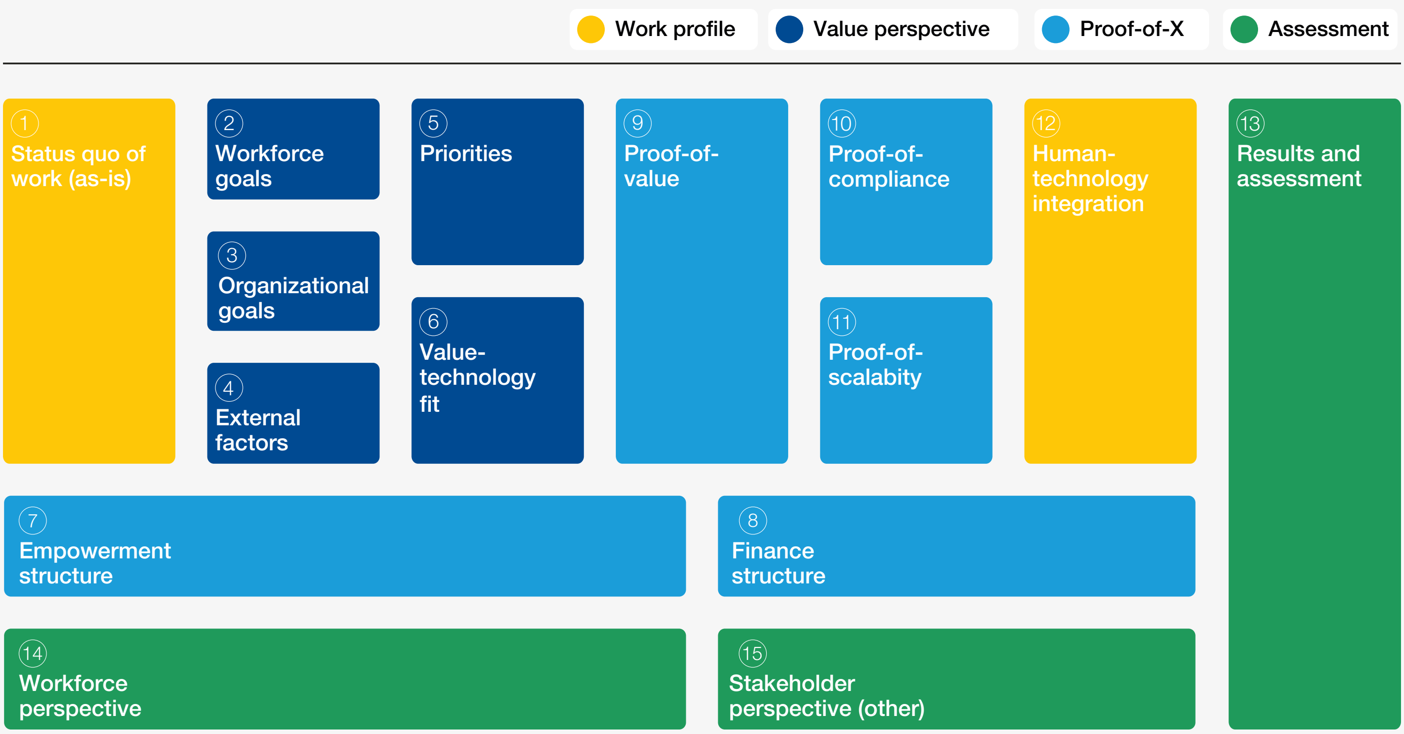
3.3 The scaling phase

In the scaling phase, the emphasis shifts from core assessment to execution and evaluation of a strategy.

In the process of scaling, the technology will be applied in multiple use cases and in multiple application scenarios. Use cases can be highly context-specific, and some of the learning from the pilot phase might not apply in all cases. Evaluation should therefore focus on the extent to which the learning from the pilot stage is still applicable when the technology is scaled. To what extent do assumptions need to be modified?

A number of elements commonly feature in a business's decision-making during the scaling phase. These are identified in Table 2.

FIGURE 8 **Augmented Workforce Canvas – execution framework to scale augmentation technology**



Source: Moencks et al., "Augmented Workforce Canvas: A Management Tool for Guiding Human-Centric, Value-Driven Human-Technology Integration in Industry", Computers & Industrial Engineering, 107803, 2021

With regard to the human factors involved in the scaling phase, four principles emerge:[14]

1. An organization needs to transparently communicate its plans for future technology integration to the workforce. This will require advanced notice, well before any integration activities commence.

2. To ensure the necessary digital literacy, training programmes need to be tailored to the integration of the new technology.

3. A process of participatory design is required. In particular, trade union representatives should have the opportunity to participate in early-stage technology decisions to help shape their design.

4. During the initiation phase of augmentation technology, the organization will need to provide comprehensive adjustment assistance.

Lessons learned (phase 3)

For the scaling phase, our experts offered the following lessons:

1. End users must act as champions for solutions and engage with the continuous improvement process. This is the biggest driver of success.

2. There will be a learning curve – patience and iteration are essential.

3. This does not, however, involve remaining stuck in the pilot phase.

They also provided the following insights on the foundations of long-term success:

- Iteration along a defined approach, including KPIs, is essential.

- The focus must lie on interoperability and integration of the technology throughout operations.

- A digital culture and the sharing of knowledge among employees should be encouraged.

> **We are augmenting people, not replacing them. Obviously, there is some fear of that, but I really don’t know of any technology right now that could fully replace a human. So instead, let’s address questions such as how we can make tools for humans to do their job easier, better.**
>
> Peggy Johnson, Chief Executive Officer, Magic Leap

Below: @fotografixx/ Gettyimages

3.4 Overview

Table 2 provides a summary of the key activities required at each phase of implementation.[15]

TABLE 2

Elements for effectively harnessing and scaling augmentation technology

Concept phase	
Status quo of work	Analysing the current work, task and job profile
Workforce perspective	Placing the perspectives and concerns of the workforce at the centre of all augmentation technology projects
Stakeholder perspective	Integrating other stakeholder groups (e.g. workplace designers, ergonomics experts, instructors, managers)
Goals	Identifying stakeholders' and organizations' goals as well as external factors shaping the future of work
Priorities	Prioritizing goals and external factors. Aligning on the added value to be realized
Value-technology fit	Identifying a technology that promises to realize the required added value
Pilot phase	
Empowerment structure	Ensuring that employees feel confident in employing augmentation technology
Finance structure	Ensuring that monetary resources are available for purchasing the technology, workforce training and maintenance. Calculating the economic viability
Proof-of-value	Exploring how far the augmentation technology can realize the added value on a small scale (e.g. pilot)
Proof-of-compliance	Evaluating the technology for its adherence to regulatory standards and corporate governance
Scaling phase	
Proof-of-scalability	Exploring the technology's potential to be scaled, e.g. across multiple sites, multiple use cases, multiple application scenarios
Augmented workforce	Realizing more engaging, empowering, sustainable work with the tested augmentation technology
Results and assessment	Evaluating how far the augmentation technology benefitted people, the planet and business

Below: @AzmanJaka/ Gettyimages

4

The way forward: stakeholder collaboration

Overcoming challenges and reaping the benefits collectively.

The full beneficial potential of augmentation technology for employees cannot be unlocked by businesses acting in isolation. Collaboration is required – between businesses, including small and medium-sized enterprises (SMEs), but also with a broader range of stakeholders, including government, trade unions and the scientific research community. To shape a human-centric future, a multistakeholder approach is required.

The potential benefits that can accrue from collaboration and the issues that need addressing are as follows:

– Collaboration can help to ensure that the manufacturing sector learns from both effective technologies and observed shortcomings. A major focus for such learning is the recurring question of how to move projects from the pilot to the scaling phase most effectively.

– While much work is being done on increasing productivity, augmentation technology should strive to preserve the employability and dignity of ageing employees or those with disabilities. It is important not only to explore ways of supporting able-bodied employees to perform their tasks better but also to direct attention to means for helping ageing employees or those with disabilities to be included in manufacturing.

– Collaboration between stakeholders can help to ensure that government-funded projects take account of human factors and wider social considerations. To date, a significant amount of state funding has centred on the development of technological prototypes. The risk of such a strategy is that it can inadvertently divert resources away from human-centric initiatives focused on effective implementation in the workplace.

– Stakeholder collaboration with technology providers can help to ensure that development projects dovetail with industry needs. In particular, enterprise technology needs to mesh with manufacturers' digital infrastructures and rigorous operational demands, ensure data privacy, and adhere to labour and technical standards.

– Stakeholder collaboration can help to ensure that industry works within a sufficiently robust legal and cultural framework – in particular, with regard to data protection and privacy measures. More generally, stakeholder collaboration can help to establish a new narrative of innovation based on the notion of complementarity. Automation and augmentation can be framed as providing complementary opportunities; technological development needs to work in tandem with human concerns. It remains the case that, while technology is needed to solve problems, humans are needed to establish which problems to solve.

In this spirit, the World Economic Forum, in collaboration with the University of Cambridge, will continue to provide a platform for organizations in the manufacturing ecosystem to work together to understand and harness the potential of technology-augmented work for a more supportive, engaging, productive, people-centric and inclusive manufacturing and production ecosystem. This will allow stakeholders to share further insights and learn why and where to effectively employ augmentation technologies across production ecosystems. Further information is available here.

Below: @NicoElNino/ Gettyimages

Appendix

TABLE 3 **Industrial use cases for the augmented workforce (self-reported impact data)**

Organization	Challenge	Solution	Impact	Augmented capabilities
Aptiv x Gemba	**Transforming** the organizational culture with a new lean production approach Limited expert resources available to **deliver high-quality training across 125 factories** and more than 20 office areas	Training **7,868** (2021) employees via **VR** to enable Aptiv's organizational transformation and deliver **cross-hierarchical** learning offerings (plan for 2022: more than 100,000 trainings)	Savings: $2 million ▲ Workforce satisfaction ▲ Work-life balance of instructors ▲	People development Upskilling Lifelong learning
DB Schenker x Ottobock	Improving workplace ergonomics: on average, each logistics operator bends 1,300 times and lifts a weight of **11 metric tons** per shift	Lifting 6 metric tons (in sum) off the logistics operator's spine per day by employing state-of-the-art upper-body **exoskeletons**	ROI: 350% (after five years) ▲ Quality: +50% ▲ Ergonomics rating: +300% ▲ Daily physical load -6 metric tons ▼	Ergonomics Data-capturing
Dow	Overcoming communication gaps, travel restrictions and speed of business issues associated with placing expertise in the right location at the right time in continuous manufacturing environments	Applying **augmented reality** (eyeware), wearables and mobile devices to reduce rework, enhance operator collaboration, reduce repair time, improve customer collaboration and enhance training	Travel reduction ▼ Reduced time to repair ▼ Remote troubleshooting/ mentoring/training ▼	Decision-making Task guidance Remote expert support
Ford Otosan	Improving the way operators receive assembly instructions, assigning operators to suitable processes considering health and ergonomics training, enhancing the quality control at the end point of the assembly line, and increasing end-to-end production traceability	Co-developed within a cross-hierarchical digital factory project, operators assigned to suitable jobs receive **wearable devices** to improve decision-making processes. Operators receive assembly instructions and vehicle information dynamically through wearables	Production traceability ▲ Time to job assignment ▲ Quality ▲ Health and safety ▲	Ad hoc feedback Information management Workforce management

TABLE 3 **Industrial use cases for the augmented workforce (self-reported impact data)**

Organization	Challenge	Solution	Impact	Augmented capabilities
Foxconn	Workforce **training** is time-consuming and costly Traditional **paper-based operation** instruction is **inefficient** and does not have real-time feedback	Deployed an AI-assisted, **projection-based AR** system that can provide digital instructions in the right place and at the right time, which informs the operator in case of failures	Training cost: -70%▼ Training efficiency: +70%▲ Product quality: +100%▲ Workforce effectiveness▲	Knowledge management Task guidance
GAP x ProGlove	**Increasing distribution capacity to grow and accommodate rising e-commerce and retail store demand with existing human resources**	Increased micro-efficiency by deploying ergonomic, **wearable scanning** solutions (scanning gloves), enabling employees to work seamlessly and hands-free	Efficiency gain: +20%▲	Data-capturing Ad hoc problem-solving
Grupo Bimbo x Parsable	Realizing an agile implementation of standardized **safety** programme components in a **multilingual environment to create a safer environment for workers**	Using a connected worker software-as-a-service (**SaaS**) **platform** for digitizing standard operating procedures on the shop floor and deploying: 1) safety incident investigations; and 2) safety observations across multiple countries and languages	Decreased safety incidences ▼ Increased training effectiveness ▲ Improved time effectiveness ▲	Knowledge management Information management
Henkel	Eliminating non-value-adding tasks, such as **converting standard operating procedures** from paper to digital formats and merging different information flows into a single source Transforming workflows and making the organization's **knowledge centre** available to all operators	The Connected Worker programme expands workers' capabilities by providing an **end-to-end information flow** where data is collected, digested and enhanced, and delivered back to the people on the shop floor, using **mobile devices** and **desktop computers**	Cost: -40%▼ Equipment efficiency: +40%▲ Reduction of redundant workflows▼ Real-time information exchange▲	Data-capturing Decision-making Task guidance

TABLE 3 **Industrial use cases for the augmented workforce (self-reported impact data)**

Organization	Challenge	Solution	Impact	Augmented capabilities
Howden Compressors x PTC	Due to social distancing and travel restrictions caused by COVID-19, it became apparent there was a requirement and broader opportunity to support customers directly with troubleshooting and support services instead of sending a technician on site	Implementing an augmented reality **remote assistance** solution with **handheld devices** When a problem emerges, the customer can troubleshoot issues in real time via shared video, audio and spatial annotations from the support team	Increased customer satisfaction ▲ Increased workforce effectiveness ▲ Reduced travel costs ▼	Ad hoc feedback Communication Decision-making
Jabil x Magic Leap	**Onboarding** new employees on the assembly line with a minimal overhead while allowing for **individual learning** experiences, especially differing learning paces	Compared to paper-based training, an **AR** (eyeware) training achieved faster training outcomes with lower overheads	Time-to-onboard ▼ Learning curve ▲	Task guidance
Johnson & Johnson	Providing operators and technicians with easy access to all relevant and **most up-to-date standard operating procedures**, forms and technical documents in one place, in a digital format and at the actual point of use	Employing standard software and QR codes, an assistive platform provides access to **accelerated content retrieval capabilities** that helps the worker perform tasks more efficiently	Reduced downtime ▼ Information retrieval time ▼ Increase in end-user competency ▲	Task guidance Data-capturing Information management
Mariasteen x LightGuide	Creating more **accessible work instructions** for 900-plus employees, of whom more than 750 are disadvantaged workers or people with a disability	Deployed collaborative robots and **projection-based AR** to provide visual work instructions for assembly that are easy to understand and follow Work instructions were **co-authored** by the operators to ensure a high degree of usability	Accessibility ▲ Quality defects: 0% ▼ Training effectiveness: +100% ▲ Operator well-being (empowerment/skills mastery) ▲	Training Task guidance

TABLE 3 **Industrial use cases for the augmented workforce (self-reported impact data)**

Organization	Challenge	Solution	Impact	Augmented capabilities
MESS – Turkish Employers Association of Metal Industries	Ensuring operations reliability, quality and traceability for product variants with **varying cycle times**	Deploying a **smart workstation** with **projection-based AR**, hand-tracking and smart screwdriver control, including ad hoc **feedback** for assembly guidance The worker is **guided** by standard operating instructions and **warnings** on a screen at the workstation	Quality: +80%▲ Training effectiveness: +40%▲ Safety incidents: -20%▼	Task guidance Ad hoc feedback Individualized workflows
Outset Medical x Tulip	Introducing a novel medical device in a new greenfield assembly facility within six months while **documenting** each step for **compliance purposes**	A cloud-based manufacturing and **documentation system** allowed engineers and operators to **self-develop** more than 90 apps guiding and tracking the assembly process step by step System visualizes the full production and ensures that **compliance** is met	Remote operations visibility ▲ Real-time feedback ▲ Quality/adherence to compliance: 100% ▲	Compliance and regular certification Upskilling and expert development Ad hoc problem-solving
Schaeffler x Microsoft	Decreasing machine downtime, reducing travel time and increasing **expert availability** across a global factory network; COVID-19 disruption mitigation	Front-line workers collaborate remotely with experts using hands-free video calls including spatial annotations with **wearable AR headsets** when needed	Experts' work-life balance▲ Expert availability▲ Productivity▲ Machine downtimes ▼	Ad hoc feedback and problem-solving Communication
Schneider Electric	Empowering the front-line workforce to **eliminate non-value-adding operator tasks** and helping the business to improve output and efficiency	Deployed a **digital idea and short interval management system** where operators can enter their pain points, improvement suggestions and innovative ideas. Accountability is ensured by **escalating** issues to **top managemen**t if not addressed properly	Employee engagement +20%▲ Near-miss safety reporting improvement +40%▲	Communication Decision-making Information management
Schneider Electric	Providing operators with tools to improve the **management of asset downtimes**, troubleshooting and breakdowns	A **connected worker platform** serves as an augmented operator adviser, which helps front-line workers to exchange real-time information with technicians in case an equipment error occurs	Machine uptime improvement: +30%▲ Travel cost reduction: -10%▼	Communication Data-capturing Decision-making

TABLE 3 **Industrial use cases for the augmented workforce (self-reported impact data)**

Organization	Challenge	Solution	Impact	Augmented capabilities
Siemens	Ensuring that product groups with **many variants** are assembled correctly Lifting the **cognitive load** from the operator to decrease stress during assembly	Deployed smart workstations with desktop-based work instructions integrated with **projection-based AR**, provides ad hoc **feedback** Integrated **smart interlocking** functions to release products only after correct assembly	Mental load/stress level ▼ Quality: 100% ▲ Process assurance: 100% ▲	Task guidance Visualization Ad hoc feedback
Siemens	Improved **coordination of technicians' resources** **Prioritizing** downtimes of machines that are **too old to be connected to the industrial IoT** Ensuring more effective **cross-functional communication**	Connected **machines' status light systems**, bringing together all information in one place. Developed an **X-to-X communication app** for **smart watches**. Front-line operators **exchange cross-hierarchical information**	Time-to-react ▲ Efficiency of information exchange ▲ Digital mind shift ▲ Self-efficacy ▲	Ad hoc feedback Cross-hierarchical communication Task guidance
Stanley Black & Decker	Improving the way workers can **learn** how to adequately perform job tasks autonomously in plants and distribution centres **Overcoming traditional training limitations** (poor quality, time-consuming, wasteful)	Used an **AI-powered video learning platform** to capture, index, translate and transfer knowledge to organization's operations and manufacturing workforce, resulting in significantly accelerated **speed-to-competency** for new learners	Reduction in training time: 50% ▼ Performance improvement: 25% ▲ Savings in time spent creating content: 90% ▲	Task guidance Training People development
Volkswagen	Effectively and flexibly **training** operators who had previously assembled vehicles with combustion engines in assembling **electric vehicles**	Employing head-mounted **AR** headsets to **train** front-line workers on demand for **new products** in less time	Learning effectiveness ▲ Time-to-productivity ▼ Organizational transformation ▲	Task guidance Training People development
Volvo x PTC	Improving inspection accuracy challenges as product **complexity** and unique **configurations** increase in volume and rate of change	Using **AR**, operators can recall the most up-to-date configurations in 3D to ease the burden of sorting through stacks of paper, creating gains in productivity, quality control and overall process efficiency	Training effectiveness ▲ Production flexibility ▲ Search time ▼	Decision-making Information management Task guidance

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