Humans Plus Technology

Global Youth Insights on the Future of Work

Edited by

Nancy W. Gleason

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Finally, I am grateful to the United Arab Emirates and the wonderful people who live here. The UAE is a place that dares to both imagine and create the future. Living and working here has given me the space to think boldly and create a sustainable future that leverages the best of humanity.

Nancy W. Gleason
April 2025

Foreword

It is a privilege to introduce Dr. Nancy W. Gleason, a distinguished scholar and leader whose insights into the intersection of technology and human potential have influenced the way we understand the future of work. As a Professor of Practice in Political Science, and Executive Director of the Hilary Ballon Center for Teaching and Learning at NYU Abu Dhabi, Nancy has dedicated her career to exploring the impact of emerging technologies on education, workforce development, and societal progress. Furthermore, she has shared her passion for addressing disruption with her students, and with me! As a colleague at NYU Abu Dhabi I have been able to witness firsthand her impact.

Having the privilege of working closely with Nancy, I have witnessed her dedication and commitment to fostering a deep understanding of how technological advancements, such as generative AI and automation, are reshaping the skills demanded in today's workplace. She has trained hundreds of staff and students, given public talks on these issues around the world, and captivated audiences in her writing. Her insights into the ways in which advanced technologies yield task automation, and reshape professional skills demanded in the workplace are not only timely but also critical to preparing our societies for the future. It has been exciting to watch her expose the need for adaptation within our organization, across the Gulf, and beyond. It is fascinating to watch her change how people see the world and understand their place in it. This book offers a chance for us all to see how she has mentored global youth to come to understand how specific

technologies can change the specific tasks we perform in the workplace.

Humans Plus Technology is a culmination of Nancy's vision and her keen skills as an educator. She teaches an innovative course in NYU Abu Dhabi's signature Core Curriculum titled the *Future of Work*. The course design and assignments reflect the real world while instilling in students new ways of knowing and being. Nancy has worked closely with her students over the past 15 years to facilitate their critical evaluation of the fourth industrial revolution. She genuinely wants them to thrive with the tools they gain in being able to think and write about these disruptions. This volume brings together youth voices from the UAE to Jamaica to New Zealand and back again. Young people are at the forefront of these changes, providing fresh perspectives on how technologies such as Smart Tattoos, Brain Computer Interface Chips, and Exoskeletons extend human capability. Here her students demonstrate their ability to not only detail how the tasks we perform are changing but also how we can grapple with shifts in ethical norms. This book is a testament to Nancy's belief in the importance of including the voices of those who will shape the future—young professionals from around the world who are entering the workforce at a time of unprecedented disruption.

As you read through the chapters of *Humans Plus Technology*, I encourage you to reflect on the implications of the ideas presented and to think about how we, as a global community, can work together to create a future that is both technologically advanced and deeply human. This book is not just a roadmap for the future; it is a call to action for all of us to engage with these critical issues

and to play an active role in both imagining new jobs - as these contributors have done - and valuing what is human in new ways.

It is my sincere hope that this collection of essays will inspire you as much as it has inspired me, and that it will serve as a valuable resource for scholars, practitioners, and anyone with an interest in the dynamic relationship between humans, technology, and work.

Sincerely,
Lolowa AlMarzooqi

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January 2025

Chapter 1
Tasks, Technology, and the Future of Work

By Nancy W. Gleason

Abstract: *The Fourth Industrial Revolution is not only transforming industries but also redefining what it means to work. This revolution in technology represents the automation of cognitive tasks and is happening at a pace and scale distinct from past technological shifts. While the rise of AI-enabled technologies, robotics, quantum computing, additive manufacturing, virtual reality and other advanced technologies brings potential for unprecedented productivity and innovation, it also presents disruptions across virtually every sector of work. We are entering an era where lifelong learning and information literacy are no longer optional; they are the key antidotes to the threat of technological unemployment. In this book, youth from around the world explore how specific job types and the very tasks workers perform are being reshaped by cutting-edge technologies like brain-computer interfaces (BCIs), autonomous vehicles, AI-driven decision-making, and quantum computing. As these technologies evolve, it's critical to prepare for ongoing disruption and the necessary workplace cultural shifts that are required. By bringing in global youth perspectives, we tap into their ability to envision the future of work differently from older generations, who may have more established views tied to traditional models of employment. Each chapter offers a deep dive into specific technologies and their implications of changing tasks in specific jobs. Chapters explore applications from how BCIs are altering*

the skill sets demanded of medical practitioners, the way exoskeletons are redefining military roles, or how automation is changing fields like scientific research and truck driving. The book also warns of the risks of deskilling, especially when employees become overly dependent on algorithms or AL-enabled platforms.

The future of work is being dramatically reshaped by technologies of the fourth industrial revolution (4IR). In the early 2020s generative AI dominated the news as it transformed tasks across various industries. Adoption latency caused by fear of job loss and a lack of digital literacy slowed cultural shifts in the early years of generative AI. However, integration of AI is not simply about replacing human workers but about how workers can leverage both hard and soft technology to enhance productivity and decision-making. A 2023 study from Harvard Business School highlights that consultants using an early version of generative AI, completed 12.2% more tasks on average, executed tasks 25.1% faster, and produced results of 40% higher quality compared to their counterparts without AI assistance.[1] Similarly, Cui *et al* found the impacts of AI on programmer productivity in Fortune 100 firms increased completed tasks by 26.08%.[2] Melissa Valetnien of Stanford University's Human-Centered Artificial Intelligence

[1] Dell'Acqua, Fabrizio, McFowland, Edward, Mollick, Ethan R. et al. , Navigating the Jagged Technological Frontier: Field Experimental Evidence of the Effects of AI on Knowledge Worker Productivity and Quality (September 15, 2023). Harvard Business School Technology & Operations Mgt. Unit Working Paper No. 24-013.

[2] Cui, Zheyuan and Demirer, Mert and Jaffe, Sonia and Musolff, Leon and Peng, Sida and Salz, Tobias, The Effects of Generative AI on High Skilled Work: Evidence from Three Field Experiments with Software Developers (September 03, 2024). Available at SSRN: https://ssrn.com/abstract=4945566 or http://dx.doi.org/10.2139/ssrn.4945566

Center explains that the result in the workplace is that the nature of expertise is changing.[3] The fourth industrial revolution is a story of "humans plus technology" where we automate pattern-based work and perform new complex tasks in collaboration with software and hardware. This indicates that AI doesn't just augment human labor but reshapes how tasks are performed, leading to both efficiency gains and higher-quality outcomes when employees are properly trained to think with the tool. The human plus technology combination, often referred to as "humans in the loop" in reference to AI, is a key feature of optimizing technology in the workplace. And the future of work is not only about AI.

Change is the new constant. As Mustafa Suleyman, former CEO of Inflection AI, and CEO of Microsoft AI in 2024, noted, we are on the cusp of exponential advancements in AI, with models expected to be 100x times larger in just three years.[4] CEOs of AI-enabled tech companies have been hyping the inevitability of artificial general intelligence as they seek greater amounts of capital investment. Exaggeration was part of the game in the early 2020s. And the inevitability of the momentum to produce intelligence different from humans is questioned by AI leaders like Professor Yann LeCun of New York University. Nonetheless, the scale of the workplace shifts that are underway demand a proactive approach to talent development. The ability to adapt to the rapid pace of change will define success in the future workforce. To ensure

[3] Melissa Valentine (Feb 21, 2023), https://hai.stanford.edu/news/melissa-valentine-understanding-how-companies-best-incorporate-machine-learning

[4] Mustafa Suleyman and Michael Bhaskar, *The Coming Wave: Technology, Power, and the Twenty-first Century's Greatest Dilemma.* New York, Penguin Random House, 2024

humans are treated with dignity and respect in the workplace, we need to get this transition right.

One of the most profound impacts technologies of the fourth industrial revolution are having is on how tasks are conceptualized and executed. Advancements like brain-computer interfaces (BCIs) are beginning to enable enhanced human capabilities. Initial applications are for people with quadriplegia and medical conditions that restrict movement. But, as the website of Nueralink- a pioneer in BCI impacts - explains, the intention is to create this technology for all types of humans to access,

> "Create a generalized brain interface to restore autonomy to those with unmet medical needs today and unlock human potential tomorrow."[5]

Tasks currently thought of as uniquely human might soon be assisted or even executed by AI-enabled hardware advancements. Similarly, Jensen Huang argued in January 2025 at the Consumer Electronics Summit that as Agentic AI is deployed in the workplace (through NVidia's technology called NeMo) IT departments will be the Human Resources of AI Agents. What that means is, AI Agents become employees. And physical AI will soon be changing how we exist in the world and what we spend our days with. Agentic AI and Physical AI will entirely shift work flows, processes, and client needs. The optimistic view is that these technologies could unlock human potential in ways we have yet to fully grasp, particularly for those with unmet medical needs.

[5] Nueralink Homepage, (2024) Retrieved from https://neuralink.com/

The chapters in this book detail some of the ways in which this could happen for specific job types. Aside from the hype of what is to come, how can we apply these tasks to specific jobs today? It is not all flashy AI lights and robots who put your groceries away. Much of this is a wonky workplace application that often fails. The purpose of this book is to help us understand how to apply these technologies for efficiencies in the workplace and effectively upskill employees in particular contexts.

A crucial piece of this puzzle is giving space for younger people to weigh in on how they understand this transition to be taking place. Youth are the ones who will perform this work, and they are often left out of discussions on the future of work. Let alone being invited to contribute to the discourse. Global youth perspectives are critical in this conversation for several reasons. Today's youth are the generation that will be most impacted by the Fourth Industrial Revolution. They are the ones entering a workforce radically transformed by advanced technologies like AI, automation, and biotechnology, while coming from education systems built for a different era. Their perspectives offer fresh insights into how these changes are perceived and how they can be navigated. Young people are often the early adopters of new technologies. They are not only the ones shaping new digital behaviors but also the ones who will develop and innovate further upon these tools in the workplace. By bringing in global youth perspectives, we tap into their ability to envision the future of work differently from older generations, who may have more established views tied to traditional models of employment.

Incorporating voices from around the world ensures a diversity of experiences and contexts. These contributors all graduated from

New York University Abu Dhabi and bring their self-awareness to the context of their research and insights. The United Arab Emirates is a significant leader in technological innovation and advanced research. For example in April 2024, a key collaboration was established between Microsoft and G42, an Emirati AI company, that reflected the UAE's leading role in AI innovation. The contributors to this volume are channeling the excitement and energy of UAE leadership in technological innovation as they forecast what the future holds for workplace applications of new technologies. Their perspectives help build a more comprehensive understanding of the future of work, one that is inclusive and responsive to the specific challenges and opportunities in different parts of the world.

The first section of the volume addresses enhanced humans, including pending cyborg possibilities. New technologies such as exoskeletons change human capacity. They expand the limits of current human physical strength. That changes work. Similarly, smart tattoos, which embed vitals on the patient in a hospital, will automate much of the crucial data nurses collect in medical settings. They will be freed up to perform new and different tasks that require upskilling. New technologies will yield cyber-physical systems, bringing new jobs and shifting old ways of working. In these chapters, youth identify specific technologies and break down what skills will be automated, augmented, or made redundant.

The second section of the book addresses existing jobs, and the ways in which familiar job titles will be associated with very different tasks and skills inside them going forward. From driverless vehicles and trucks, to automating scientific research, to

imagining the future of radiology work, the contributors of this section of the book deconstruct work into tasks and explain what new skills humans could perform in this context.

The third section of the book considers new technologies and the new jobs they will inevitably create. Here the contributors review the potential impacts of quantum computing, soft haptics, and Non-Fungible Tokens (NFTs) to create new work. Yes, the explosive technological boom of the fourth industrial revolution will make some work redundant - manufacturing and agriculture are likely to be hit very hard - but new jobs, that demand new skills, will come in the wake. This is not to say the transition will be smooth for those living through it. It is to imagine what is on the other side of this transition. This section offers futures of what new jobs are coming alongside new technologies.

The final chapter is a cautionary tale on deskilling. Contributor Jordan Simpson walks us through the ways in which humans may lose skills that once were the key to their employment. The narrative of this chapter helps us understand not only the shortened shelflife of knowledge in the 2020s, but also the shortened shelflife of skills. It is not always a positive story. Some skills we may want to keep human. This chapter enables us to explore a possible future we may want to avoid or at least prepare for with strategies that are flexible and resilient to deskilling's impact on individuals and expertise.

In sum, the future of work is humans plus technology, and we can learn a lot from youth on how they anticipate work-place augmentation of tasks. This will require a delicate balance between embracing technological advancements and maintaining personal

well-being and ethical standards. The disruption brought on by the fourth industrial revolution is not something to fear but an opportunity to create more meaningful and productive work. We can do this if we are organized. The key to navigating this future lies in supporting employees in their upskilling journey. As the technologies of the fourth industrial revolution merge to shift what it means to be human, employers need to foster work environments that reward continuous learning, adaptability, and a willingness to integrate technology into our professional and personal lives. The fourth industrial revolution is here. This book offers forecasts of how we will need to adapt and thrive in this new humans+technology world.

Part One

Enhanced Humans

Chapter 2
Wearable Machines in Construction

By Samantha Lau

Abstract: *In some parts of the world, the construction industry struggles with labor and skills shortages compounded by an aging workforce and a dearth of young talent. Exoskeletons, a wearable device that enhances physical abilities, are considered one of the most promising technological solutions to the construction industry's chronic labor inefficiencies. A key benefit of exoskeleton technology is that these wearable devices can make the workplace safer for employees even as pressure to increase production grows, a development that could help mitigate future labor shortages. But despite their potential, exoskeletons haven't been widely adopted by the building trades and there remain technical, economic, and ethical challenges that must be overcome. This chapter will examine the potential benefits of wearable tech to the construction industry and discuss the role that the technology can play in reducing labor shortages in the decades to come.*

In recent decades, growth in the construction industry has stagnated. A February 2017 report[1] by McKinsey Global Institute found that during the previous 20 years, the global construction industry grew by a paltry 1% annually, compared to the

[1] "Reinventing construction: A route to higher productivity."

manufacturing industry (3.6%) and the total world economy (2.8%)[2] during the same time period.

The poor growth is the result of numerous factors, but chief among them are labor and skills shortages compounded by an ageing workforce and a dearth of young talent in some parts of the world.[3] The problems are global, and covid-19 exacerbated challenges.. For instance, in Canada, a quarter of the construction workforce is forecasted to retire between 2018 and 2027, which is predicted to leave a 42,000-worker-sized hole in the industry's labor force.[4] In 2017, the United States suffered a shortage of 200,000 construction workers.[5] Similarly, the 2018 Turner and Townsend International Construction market survey found severe construction skills shortages in Malaysia, Colombia, and Indonesia, among other nations.[6] The industry also suffers from high injury and accident rates, which is a further drain on the workforce.[7] In Australia, Safe Work reported that work-related musculoskeletal disorders (WMSDs) are "the leading work health and safety problem, both in frequency and cost," with 76% of injuries and 60% of the serious claims between 2009-2010 and 2013-2014 being related to MSDs.[8] Globally, WMSDs rank third out of the top 25 diseases by global burden.[9] Such a high incidence of injury results in high turnover

[2] Barbosa et al., "Improving Construction Productivity."
[3] Bogue, "Prospects for Robots," 1.
[4] Burke, "The Future is Now."
[5] See note 2.
[6] Brown, "Construction's Skill Shortage."
[7] See note 2.
[8] EPC Media Group, "Health and Safety."
[9] Howard et al., "Industrial Exoskeletons," 202.

rates and greatly exacerbates the industry's existing labor shortages.[10]

Amid such an outlook, digital technologies offer opportunities for strengthening the sector's labor capacity.[11] This recommendation is particularly pertinent given the industry's reputation for being slow to adopt digital technology when compared to other sectors.[12] Exoskeletons are considered one of the most promising technological solutions to the construction's chronic labor inefficiencies. Defined by ASTM International as any "wearable device that augments, enables, assists, and/or enhances physical activity through mechanical interaction with the body,"[13] exoskeletons have been touted as one of the emerging technologies destined to revolutionize the way physical labor and work is performed.[14]

In particular, exoskeletons hold countless benefits for construction trades. For instance, these wearable devices have strong potential to make work for employees safer and more efficient, which in turn can mitigate labor shortages and increase productivity for the industry. But despite their potential, exoskeletons have not yet been widely adopted by the industry. There remain technical, economic, and ethical challenges raised by academics, employers, and employees. Thus, given the magnitude of their potential benefits and the solvability of the barriers to their adoption,

[10] EPC Media Group, "Health and Safety."
[11] Barbosa et al., "Improving Construction Productivity."
[12] Delgado et al., "Robotics and Automated Systems," 1; Bogue, "Prospects for Robots," 5.
[13] Howard et al., "Industrial Exoskeletons," 201.
[14] Goode, "Future of Physical Labor."

exoskeletons are a desirable form of technological intervention in the construction workplace and should be adopted in the industry.

This chapter will examine the potential benefits of wearable tech to the construction industry and discuss the role that the technology can play in reducing labor shortages.

Rise of the Robots: Benefits of Exoskeletons as Colleagues in the Construction Industry

Exoskeletons were designed for use in medicine to aid gait rehabilitation and in the military to enhance soldiers' physical capabilities. It has only been in the last decade that companies have begun producing exoskeletons for industry, such as in factory or construction settings.[15] The first industrial exoskeletons entered the market in 2015 and now many – if not most – of the biggest players in the exoskeleton market – such as Ekso Bionics, suitX, and Lockheed Martin – produce exoskeletons for industrial use.[16]

An industrial exoskeleton serves two basic functions: to "reduce ergonomics issues"[17] in workers and to "amplify human performance."[18] To achieve these ends, exoskeletons provide bodyweight support and/or stabilization, offset weights,[19] help wearers to maintain proper posture and form,[20] and enhance grip strength,[21] amongst many other features. The results of receiving

[15] Kara, "New Systems, Improved Technologies."
[16] EduExo, "A Brief History."; Meticulous Research, "Top 10 Companies."
[17] Owen-Hill, "A Beginners Guide."
[18] Shein, "Exoskeletons Today."
[19] Kara, "New Systems, Improved Technologies."
[20] ManagePlaces, "Exoskeletons in Construction."
[21] Kara, "New Systems, Improved Technologies."; Burke, "The Future is Now."

physical support from exoskeletons for wearers are thus increased endurance, increased speed of task completion, and reduced risk of injury from stress or accidents.

In a construction-specific context, these outcomes are exemplified through a task a construction worker might typically perform – the removal of tiles using a motorized chipper. When performing this task, the worker experiences physical stress from the tool's violent vibrations and from exertion required to hold the tool against the wall. After using the chipper for 10-15 minutes, the worker will have to rest for 15-20 minutes, so that more time is spent resting than actually working.[22] With an exoskeleton's stabilization support and weight-offsetting capabilities, this stress can be eliminated so that the worker "never tires or loses their grip."[23] Given that some of the tools in the trade weigh upwards of 28 kilograms,[24] exoskeletons such as the Guardian XO by Sarcos Robotics — designed to allow wearers to lift and carry up to 90 kilograms for eight hours without exertion — could greatly benefit workers by providing physical support, which in turn can increase working speed, endurance, and overall productivity.

Indeed, Mandy Rennehan, founder of the Ontario-based construction company Freshco, has reported that two of her workers wearing exoskeletons were able to complete a bathroom tile-chipping task that would usually take three workers four days in just half the time and with "90 percent less fatigue."[25] Similarly, trials by exoskeleton company suitX have shown that workers

[22] Burke, "The Future is Now."
[23] See note 21.
[24] See note 21.
[25] Burke, "The Future is Now."

wearing a shoulderX model finished grinding and buffing tasks in just one day instead of two.[26] An exoskeleton-supported worker is not only able to work faster, but also has increased endurance. In another of suitX's trials, workers supported by the backX model saw a 40% increase in endurance. Workers themselves have also supported these claims, with one reporting, "My energy level is so much higher when I go home after wearing the vest all day."[27]

Exoskeletons also help lower the rate of accidents and stress. The increased motor control afforded by an exoskeleton reduces injury from accidents related to heavy object use in dangerous or physically intensive tasks (such as in the example above).[28] In the long-term, exoskeletons can protect workers' muscles and joints, alleviating cumulative stress[29] and reducing the incidence of WMSDs.[30] Reduced fatigue throughout the day affords workers "more energy for their off hours"[31] and lower injury rates results in less time taken off work. This is turn may increase workers' job satisfaction, thus boosting their motivation and performance.

Large scale integration of exoskeletons into construction trades would produce profound benefits for the industry. The increased speed and endurance of exoskeleton-supported workers would increase the quantity and quality of output per day per worker, thereby lifting the industry's productivity levels. Reduced strain and the consequent injury and accident rates may reduce staff

[26] Kazerooni, "Exoskeletons Lend Muscle."
[27] Goode, "Future of Physical Labor."
[28] See note 25.
[29] EPC Media Group, "Health and Safety."
[30] See note 28.
[31] See note 24.

turnovers,[32] and help to address the industry's labor shortage by allowing older workers to remain in the workforce longer.[33] This labor shortage might also be mitigated by attracting younger people into the industry using the appeal of new technology, which, according to some construction employers, makes the job "more attractive."[34] Exoskeletons might even draw women into the industry who "may have thought they didn't have the strength to keep up with men at the jobsite."[35] given that exoskeleton support will make natural strength disparities irrelevant.[36]

Barriers to Adoption

While exoskeletons promise revolutionary benefits for worker safety and could help address the construction industry's labor shortages and stagnant productivity levels, there remain various technical, economic, and ethical concerns that bar exoskeletons from being smoothly integrated into the industry. Academics have questioned the validity of claims regarding exoskeletons' ability to reduce injury rates given the dearth of current research into their effectiveness in real-world construction environments. Howard et al. argue 2020 that while there is indeed great potential for exoskeletons to reduce WMSDs in construction, more research is needed before adoption can become widespread. Of the limited research that does demonstrate net benefits of exoskeleton use,

[32] Kara, "New Systems, Improved Technologies."; EPC Media Group, "Health and Safety."
[33] ManagePlaces, "Exoskeletons in Construction."; Kara, "New Systems, Improved Technologies."; Delgado et al., "Robotics and Automated Systems," 3; Burke, "The Future is Now."
[34] EPC Media Group, "Health and Safety."; Burke, "The Future is Now."
[35] Burke, "The Future is Now."
[36] ManagePlaces, "Exoskeletons in Construction."; Burke, "The Future is Now."

most studies have involved too few participants for the findings to be compelling.[37] Howard et al. argue that not only is exoskeletons' injury-reduction potential "inflated," but there also remains unaddressed risks for wearers that run counter to their purpose in the first place.

For instance, potential risks for workers, according to the US Consumer Product Safety Commission, include increased muscle strain, skin irritation or chemical burns from battery leaks, thermal burns, increased chest pressure, postural strains, increased cardiovascular demand, pressure wounds or compressed nerves from prolonged use, and mobility restriction, which may impede workers' ability to avoid falling objects.

Howard et al. also highlight the transference of risk that may occur when exoskeletons are worn. Because exoskeleton-supported workers may be able to hold tools for longer without taking rests, the duration of their exposure to other risks – such as vibration, noise, and toxins – may increase.

Employers have also expressed reluctance to promote widespread industrial use. In a study conducted by Delgado et al. 2019, it was found that contractor-side economic factors constituted the primary barrier to adoption of robotics in the industry.[38] Similarly, a report by Research and Markets lists "high procurement cost associated with exoskeletons" as one of the main challenges currently obstructing exoskeleton market growth[39] (devices range from USD $5,000 up to as much as $80,000, depending on

[37] Howard et al., "Industrial Exoskeletons," 202.
[38] Delgado et al., "Robotics and Automated Systems," 7.
[39] Research and Markets, "Global Exoskeleton Industry."

exoskeleton models.[40] It is not only the exoskeleton itself that requires high upfront payment, but also the additional set-up costs, which cover "installation, accessories, maintenance, spare parts, [and] training."[41]

Additionally, employers report technical concerns with the suitability of exoskeletons in construction work environments. Issues with weight, range of motion, and tool compatibility are the most common, and statements from companies who have purchased or trialed exoskeleton models report that exoskeleton-wearing workers found it difficult to wear safety harnesses and tool belts, both of which are essential to the trade.[42] Existing research even highlights that weight and bulk issues should be addressed by using lighter and more compact actuators and batteries in development.[43]

Perhaps most significantly, construction workers themselves are hesitant. As Maurice et al. argue, proof of the safety and productivity benefits that such technologies might bring into the workforce are "not sufficient to ensure [their] smooth and successful deployment" (2018 p.131). Lack of consideration of ethical and social implications for workers may not only lead to a lack of use, but could even "generate additional stress, hence defeating their initial purpose of improving working conditions."[44] In their paper, which was published in the proceedings of the IEEE Workshop on Advanced Robotics and its

[40] Burke, "The Future is Now."; Goode, "Future of Physical Labor."; Shein, "Exoskeletons Today."
[41] Delgado et al, 9.
[42] Burke, "The Future is Now."
[43] Howard et al., "Industrial Exoskeletons," 204.
[44] Maurice et al., "Ethical and Social Considerations," 1.

Social Impacts in 2018, Maurice et al. discuss their findings on the opinions of non-factory workers and factory workers, who would likely be end-users of exoskeleton end-users, in relation to the adoption of exoskeletons in the workplace. While they This paper focused on factory workers, their findings are nonetheless relevant for the construction industry.

Interviews with the worker group revealed concerns about comfort relating to the weight and temperature of the exoskeleton.[45] Howard et al. raised similar concerns, citing an example of a back-assist exoskeleton chest pad causing pressure and discomfort in the thoracic region.[46] Another key concern was the potential for mandated permanent and all-day wear of the technology. Participants stated that they would comply with requests to wear the exoskeletons temporarily or "for a few days," but not permanently. They argued that "its use should remain intermittent; it should not be/have to be worn all day long."[47]

Non-worker participants also expressed privacy concerns, such as the potential for exoskeletons to be hacked and for workers' data to be collected during wear.[48] Indeed, current exoskeleton models can contain as many as 40 sensors designed to reduce injuries by monitoring movement, pressure, and the arm and leg nerve signals of wearers.[49] ABI Research robotics and automation analyst Rian Whitton anticipates that future models may even employ artificial intelligence, which will allow employers to track a

[45] Maurice et al., "Ethical and Social Considerations," 4.
[46] Howard et al., "Industrial Exoskeletons," 202.
[47] Maurice et al., 3.
[48] Maurice et al., 5.
[49] Marinov, "Types and Classifications."

worker's location and collect more detailed data about their performance.[50] Such tracking features, though ostensibly employed for injury prevention measures, pose serious ethical concerns given the implications for worker privacy.

Solving the Exoskeleton Puzzle

While exoskeletons remain an emergent technology, their potential to help the construction industry overcome its stagnant productivity and growth should not be overlooked. Given the industry's high rate of injury and disability from WMSDs, which affect workers' quality of life and financial stability,[51] exoskeletons could play a key role in addressing construction's current shortcomings. Some have argued that protecting workers' health makes employing exoskeletons an imperative. Furthermore, exoskeletons' current shortcomings are solvable, and can be addressed through tangible action recommended by academics and undertaken by developers.

To capitalize on the technology's potential in construction, research should be conducted to evaluate and verify the purported scale at which benefits of exoskeletons can reduce job-site injuries and ensure workers' safety. Such research should also identify technical issues that might compromise these benefits, which in turn should influence developers' production process. This exchange is already taking place with developers who are cognizant of these issues and are working to address them in future models. Employers' concerns about the exoskeleton's suitability in a construction environment are also being addressed

[50] Shein, "Exoskeletons Today."
[51] Howard et al., "Industrial Exoskeletons," 202.

by developers such as suitX, which notes that their industrial exoskeletons have been developed with consideration for the use of tools and construction tasks.[52] Standard measures for evaluating the "usefulness and usability" of exoskeletons are also in development by ASTM International's Committee on Exoskeletons and Exosuits (F48).[53]

Regarding the cost-prohibitive nature of exoskeletons, market analysts like Rian Whitton are confident that prices will fall as exoskeletons develop further and become "commoditized."[54] Whitton anticipates that prices will decrease as costs "shift from hardware to software" and monthly subscription payment models are introduced.[55] Furthermore, if researchers are able to establish the validity of claims that exoskeletons can increase productivity, construction companies may be more willing to accept the upfront costs and invest for long-term economic gains.

Studies are also needed to determine attitudes among construction workers about the adoption of exoskeletons. Given ethical concerns including mandated duration of wear, data privacy issues, and potential monitoring of employee location and performance, further research needs to be conducted to establish the extent to which these concerns are valid, as well as how they might be best addressed.

Some researchers have concluded that a legal framework is needed to "guarantee the transparency and fairness of use" of

[52] Kazerooni, "Exoskeletons Lend Muscle."
[53] Howard et al., 204.
[54] Shein, "Exoskeletons Today."
[55] See note 53.

exoskeletons and associated data collection.[56] Such frameworks are currently being developed by organizations including the International Organization for Standardization (ISO) and ASTM International, which have each released standards addressing possible risks and terminology and labelling requirements respectively.[57] Developing further standards to address other aforementioned ethical issues can and should also be prioritized to ensure integrity of exoskeleton use in industrial contexts. A separate set of rigorous standards for implementation and use should also be established within the construction industry itself to address the unique conditions and nature of construction work.

Reception of Industry to Exoskeletons

Based on previous studies, The construction industry as a whole appears receptive to using exoskeletons in the workplace. From an employee's point of view, Maurice et al. .'s study highlighted some workers' concerns about exoskeletons in the workplace but also revealed overall positive support for the technology. Workers reported that, apart from increased safety, they liked the ability to maintain agency and job control afforded by exoskeletons. Maintaining such control over their gestures would allow them to both exercise psychological agency and also logistically continue their tasks if the exoskeleton stopped working.[58]

Exoskeletons are also not seen as threatening to workers' job-site employment, another reason for and this fact increases workers' warm reception to the idea of widespread adoption. Previous

[56] Delgado et al., "Robotics and Automated Systems," 6.
[57] Howard et al., "Industrial Exoskeletons," 205.
[58] Maurice et al., 3.