Monitor Institute
by Deloitte.

AUTODESK FOUNDATION

Supporting worker success in the age of automation

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Preface

Across the United States, millions of people are working but still struggling to get ahead. At the same time, employers are trying to fill millions of job openings, but many are struggling to find workers with the right skills. This is the result of a fundamental mismatch between the supply of labor and demand for skills. This "skills gap" is a challenge for everyone—and it's likely to worsen as cognitive technologies and automation become more widespread.

This report is a joint endeavor by the Autodesk Foundation and Monitor Institute by Deloitte. In it, we describe what we have learned from our inquiry into the challenges that underlie the skills gap. We decided to focus specifically on the US construction and manufacturing industries and workers who have specialized job skills but not a traditional four-year degree. It is the product of secondary research and interviews with thought leaders and experts in construction, manufacturing, future of work, and workforce development, as well as primary input gathered from actual workers, in late 2018. (Please see acknowledgments and endnotes for a full list of the experts and secondary sources we consulted for this work.)

The Autodesk Foundation engaged in this research to inform a new portfolio investment strategy to help workers adapt and thrive in the age of automation. As a foundation that sits at the intersection of Autodesk, Inc. and the social sector, we have a unique vantage point into the breadth and speed of technological change in the construction and manufacturing industries. We inherently believe that technology can, and must, be a force for good, and we are happy to be labeled as techno-optimists. Yet technology is not deterministic—it is only as good as the human beings using it. It's up to all of us to decide how to wield the technologies available. We need to understand the effects of technology adoption, how to mitigate the risks, and how to ensure that long-term incentives for success are aligned for all parties.

At Monitor Institute by Deloitte, we work with social impact-focused organizations and their leaders to help them make hard choices and take actions to advance progress on pressing societal challenges. We know that current technology and demographic trends are dramatically changing the future of work. These trends will have implications for all types of workers and companies, and there's a risk that some workers may have difficulty adjusting to this new world. We engaged in this work with the Autodesk Foundation motivated by a deep-seated interest in helping workers through this transition. We want to help job seekers learn about and prepare for in-demand careers and high-paying jobs and enable employers to tap into new and diverse sources of talent. Ultimately, we would like to see more equitable opportunity and economic mobility for all Americans.

Our collaboration began with a seemingly straightforward question: What skills will construction and manufacturing workers need to succeed in the age of automation? However, experts and workers alike compelled us to expand our focus and think more holistically about the skills gap, which involves intervention along multiple dimensions, including investment in workers, improved corporate practices, and systems-level policy change. The following report outlines a comprehensive framework for examining the skills gap challenge and eight specific opportunity areas for investment.

It will be up to different actors—be they local, state, or federal governments; corporations; nonprofits; or foundations—to figure out which pieces of the puzzle they will tackle based on their aspirations and capabilities. While some opportunities are better suited to certain stakeholders, our research highlighted the importance of employers throughout. As such, we have tried to describe the opportunities with the employer audience in mind.

Finally, while this report focuses on the construction and manufacturing industries, we believe that many of our insights are widely applicable across industries. Accordingly, we hope this report stimulates discussion and action among employers and in workforce development circles nationwide. We welcome continued dialogue around the skills gap challenge and how we can work together to address it.

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With thanks to the many others who provided valuable input (please see page 42 for a full list of acknowledgments).

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Executive summary

As technology evolves and automation increases across industries like manufacturing and construction, machines will expand their domain over complex problems. This will enable great advances—but it will also have a significant impact on the labor market. To achieve the most positive outcome for companies, workers, and society as a whole, we must prepare the workforce to leverage these new technological tools.

Our approach

Between September and December 2018, a Monitor Institute by Deloitte team reviewed more than 50 field reports; interviewed dozens of subject matter experts in construction, manufacturing, workforce development, and future of work; crowdsourced input from 53 workers; surveyed more than 1,100 Autodesk University participants about the future of work; and engaged in rich discussions during a scenario workshop. This report represents the culmination of what we learned about the "skills gap" and what can be done to address it.

In speaking with subject matter experts in construction, manufacturing, workforce development, and the future of work, and with workers themselves, most agree that we are likely to experience a future in which the hiring gap in construction and manufacturing continues to grow and in which the accelerating pace of technological innovation will necessitate a continually evolving mix of soft and technical skills as well as continuous learning models. While questions remain about the pace at which these shifts will occur, their nature, and how industry will respond, it is clear that companies and workers will experience significant disruption.

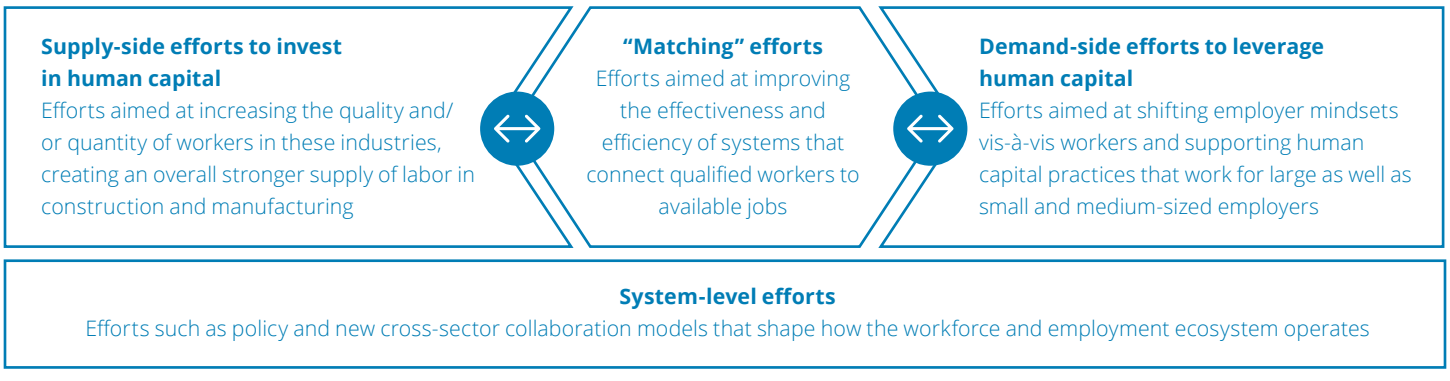
Our work focused on the question: *How can actors committed to the American workforce support US-based construction and manufacturing workers with specialized job skills but not a traditional four-year degree?* While many discussions related to this topic center on effectively preparing these workers for the age of automation with specific skills and competencies, our research confirms that focusing on skills alone is not enough. It is important to think about the skills gap more holistically, considering the challenges, gaps, and opportunities that exist across the full workforce and employment ecosystem, as depicted in figure 1 below.

Our research reveals that without sufficient investment in human capital, not enough qualified workers will enter the construction and manufacturing industries to keep pace with growth. This broadly reflects the supply side of the labor market. On the other hand, we learned that unless companies leverage their human capital to maximize return on new technologies (as opposed to prioritizing cost reduction), the skills gap cannot be eliminated, and non-college-educated workers would be left particularly vulnerable. Concomitantly, this reflects the demand side of the labor market. Moreover, with no common language around skills and no reliable means for verifying qualifications, it is hard to match workers to jobs. And at the systemic level, public policy to address the multifaceted "social determinants of work" is not keeping pace with the changing nature of work and the workforce.

We admit that this is an imperfect framework, as the components are not entirely mutually exclusive. Nevertheless, we believe that this framework describes the major areas of the skills gap challenge and opportunities for intervention. It also provides a way to start a conversation about the widely varied but interconnected dimensions of the problem. It is important to note that we do not directly address some adjacent topics regarding automation. For example, we do not explicitly tackle the opportunity to leverage technology to create new jobs or reform our K-16 educational system. Instead, we remain focused on addressing the barriers facing workers with specialized job skills but not a traditional four-year degree.

Based on our exploration of trends and uncertainties surrounding the future of automation in construction and manufacturing, the challenges facing workers with specialized job skills but not a traditional four-year degree, and the intersection of these two topics, we have identified a set of **eight opportunity areas**, loosely mapped to different parts of the ecosystem as depicted in figure 2 on the next page. These opportunity areas synthesize the themes that were consistently mentioned in reports and by thought leaders and experts.

Figure 1. Workforce and employment ecosystem



Overview of our eight opportunity areas

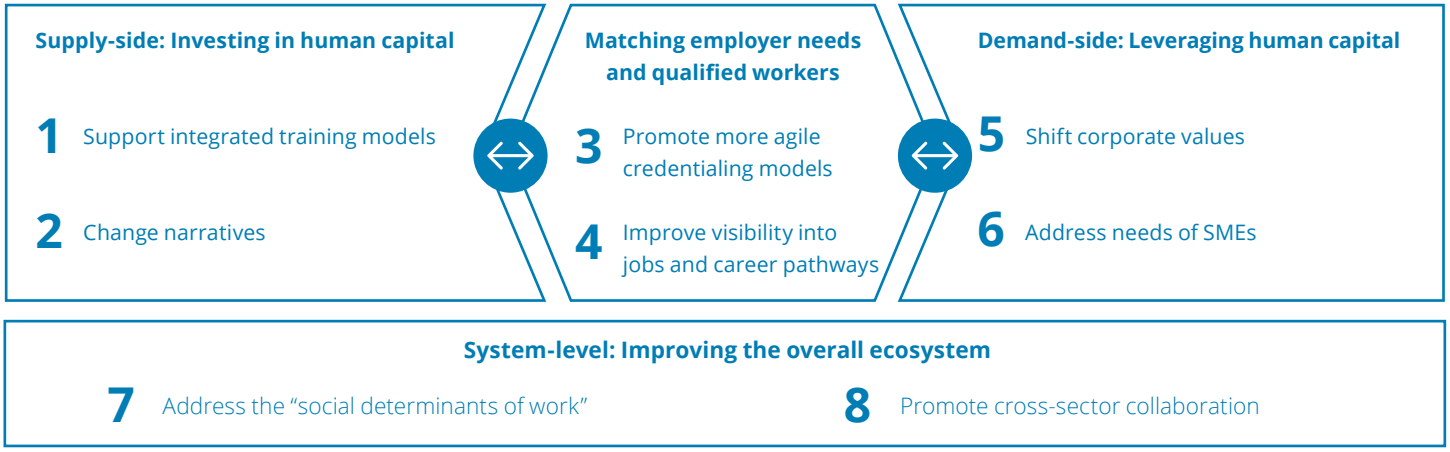
Supply-side opportunity areas for investing in human capital

Areas of opportunity for investing in human capital are efforts aimed at helping workers develop the skills required to succeed and increasing the number of workers interested in construction and manufacturing to create an overall stronger supply of labor in these industries. This category includes efforts focused on equipping workers in a timely way with the critical skills and competencies needed for in-demand, rapidly changing jobs; those centered on attracting new talent that are currently underrepresented in the construction and manufacturing industries; and attempts to retain existing workers to grow the overall size of the talent pool. While these efforts may be driven by a range of actors, including nonprofits, public sector workforce agencies, labor unions, community and technical colleges, and/or employers themselves, most if not all of them critically depend on employer engagement. In this report, we explore two specific opportunity areas:

1. **Support integrated training models:** Overall, training models for construction and manufacturing are not in sync with the twenty-first-century needs of these industries, contributing to growing worker shortages. There is an opportunity to develop more and better training models that are industry- and problem-based, and that cultivate a reinforcing and evolving mix of skills, knowledge, and capabilities (e.g., specific technical tools and techniques, critical thinking, social and creative intelligence). These training models fall into three general categories: 1) demand-driven curricula that expose students in traditional education settings to employer-aligned skills; 2) experiential learning models, such as apprenticeships and integrated training facilities, that combine academic instruction with hands-on experience; and 3) new modes of learning (e.g., virtual training) that leverage technology to help workers develop the new mix of skills required in the age of automation.

2. **Change narratives:** The construction and manufacturing industries continue to be perceived by many as low tech, dangerous, and dirty, according to experts with whom we spoke. To help attract more new talent that is currently underrepresented in these industries (e.g., women, people of color), to encourage current workers to adopt new technology and engage in "continuous skills upgrades," and to nudge companies to adopt new technology and forward-facing human capital practices, the entrenched perceptions of work in these industries must shift in ways that are linked to actual and meaningful change in the nature of work and the working environment.

Figure 2. Opportunity areas



Opportunity areas for matching employer needs and qualified workers

These efforts are aimed at improving the effectiveness and efficiency of the marketplace that connects qualified workers to available jobs. A significant shift is happening in the typical relationship between employers and workers away from a largely stable, long-term relationship and toward a more dynamic system in which workers are often required to change roles, jobs, and careers more frequently and fluidly, also earning income from a combination of full-time and part-time work. This new paradigm makes it necessary to help both employees and employers find new ways to improve the fit between workers and work that fits their skills. Efforts in this broad category include those that give workers better visibility and insight into in-demand jobs, competencies, and pathways; help them identify, obtain, and effectively communicate their qualifications and skills; and allow them to better navigate a more dynamic workforce and employment ecosystem. We explore two specific opportunity areas for matching employer needs and qualified workers:

3. **Promote more agile credentialing models:** As the skills required in construction and manufacturing continuously evolve and frequent job changes require more regular and precise pairing between workers and roles, workers need more nuanced and agile means to effectively develop, capture, and communicate new competencies and experiences, in ways that employers understand and value. Standards-based, nationally portable, industry-recognized credentials are a promising mechanism for enabling workers to do that.

4. **Improve visibility into jobs and career pathways:** Accelerating technology changes and increases in alternative work arrangements (e.g., gig work and contracting) are likely to make workers bear more responsibility for, and more risk associated with, continuous skills upgrades and job transitions. To be able to excel in this dynamic environment and capture the greatest economic value, workers need better guidance on how to navigate the job market and greater ability to align their current and future skills and capabilities to job opportunities. This requires employers and intermediaries to adopt a common language for discussing hiring requirements that goes beyond the standard proxies, and to use integrated platforms that help workers access and compare job opportunities and career pathways.

Demand-side opportunity areas for leveraging human capital

These are efforts aimed at shifting employers' mindsets vis-à-vis their workforce and supporting improved human capital practices that work not just for large employers but also small and medium-sized enterprises (SMEs). Historically, many companies have adopted new technologies to reduce costs, often by reducing headcount. To better leverage human capital, they should instead consider how workers with specialized job skills but no traditional four-year degree can use these new technologies to create more value, both in the back office and on the front lines. We explore two specific opportunity areas for leveraging human capital:

5. **Shift corporate values:** In the United States, the adoption of new automation technologies has largely been driven by the desire to reduce overall costs and make labor costs more variable, which can adversely affect workers. There is an opportunity to build the business case for "high-road" employment models that incorporate investment in worker development and proactive worker involvement in technology adoption and integration decisions. This shift would treat workers as a center of value.

6. **Address needs of SMEs:** Construction and manufacturing are both highly fragmented industries in the United States, with SMEs employing the majority of workers. Because most people in construction and manufacturing work for SMEs, and because SMEs tend to be late adopters of new technology and to have less capital available for workforce development, any effort to support workers should involve addressing the unique human capital challenges facing SMEs and bolstering their capacity to support their employees as they adopt new technologies.

Opportunity areas at the system level
These are efforts that shape how the workforce and employment ecosystem functions overall. In this category are efforts designed to tackle holistic barriers facing workers without college educations and to promote public-private partnership models that share ownership, costs, and benefits. The potential public policy implications of this extensive topic are addressed in detail in a 2019 report co-published by the Autodesk Foundation and the Aspen Institute: *Technology, automation, and the labor market: The case for policy intervention.* As such, in this report, we explore two critical opportunity areas that acknowledge the importance of public policy but focus on additional ways to influence the operating environment that non-college-educated workers will need to navigate:

7. **Address the "social determinants of work":** Workers' ability to adapt to changing technologies and successfully navigate workforce transitions are intricately related to broader issues, such as health care and portable benefits, criminal justice reform and its implications on employability, and accessible high-quality early childhood education. This area includes policy interventions but is not exclusive to that field. There are myriad opportunities to support these issues in ways that improve the operating environment for workers and enable their success in the age of automation.

8. **Promote cross-sector collaboration:** Coordination across diverse stakeholders at the national, regional, state, and/or local level is a critical success factor for training and connecting workers to jobs. As the construction and manufacturing industries grapple with the speed of technological change and seek to support the success of non-college-educated workers, public, private, and social sector organizations have new opportunities to communicate, share data, and collaborate more frequently and clearly.

In the following sections, we provide additional detail about the nature of the challenge with detailed descriptions of these eight opportunity areas for helping workers thrive in the age of automation. Success across these diverse areas requires the involvement of a wide variety of stakeholders, including government, companies, educational institutions, worker organizations, and other workforce development actors.

We hope that organizations looking to support workers in construction and manufacturing can use this document as a starting place for understanding the multidimensional challenge and potential areas for intervention. Our goal is that this knowledge, combined with deep understanding of their own aspirations and capabilities, enables organizations to select areas to intervene that best leverage their resources. Additionally, while this report is focused on the construction and manufacturing industries, we believe that its insights can be applied broadly, and we hope that it will stimulate discussion and action within a number of different industries. We invite you to share your feedback with us on the concepts and ideas laid out in this report and how we can work together to help close the skills gap.

The nature of the challenge

According to US Bureau of Labor Statistics estimates, construction and manufacturing together made up 16 percent of total private employment in the United States in 2016.[1] Both industries represent significant aspects of the US economy, and a number of broad trends suggest that they are poised for even greater significance. Over the next 20 years, the US population is projected to grow by 13 percent, reaching 370 million people, and to become increasingly urbanized (87 percent by 2038).[2] This suggests that more than 320 million people will be living in US cities, which is likely to drive substantial demand for both new construction and more manufactured goods.

From a global perspective, a rapidly growing middle class is expected to continue to drive increased global consumption. Brookings estimates that by 2030, there will be 1.7 billion more middle-class consumers worldwide, with middle-class markets in China and India comparable to that in the United States.[3] These global trends toward increased consumption suggest significant growth opportunity for US manufacturing.

In addition, the country's aging infrastructure and the demands of climate adaptation are already increasing pressure to rebuild and retrofit our built environment, increasing demand for construction and manufacturing to meet these needs. In 2017, the American Society of Civil Engineers (ASCE) reported an anticipated "infrastructure gap" of $2 trillion that will need to be addressed by 2025,[4] and the 2018 National Climate Assessment highlighted a number of profound risks that climate change poses to the built environment and economy of the United States.[5]

For American workers without a traditional four-year college degree, the construction and manufacturing sectors have historically been key sources of relatively well-paying jobs. For example, analysis in 2013 found that manufacturing employed a disproportionately high number of workers with a high school degree or less[6] and that non-college-educated workers' wages in manufacturing exceed those of similar workers in other industries by 11 percent.[7] Construction similarly employs a disproportionate number of non-college-educated workers.[8]

The age of automation threatens these workers' stability. A 2017 report by McKinsey concluded that occupations that currently require only a secondary education or less will likely see a net decline in jobs due to automation, while occupations requiring college degrees and higher can expect to see growth in the number of jobs.[10] This suggests a critical need to understand how construction and manufacturing workers can be supported as automation increases.

Why combine construction and manufacturing?
In this report we largely take a combined approach to discussing the challenges facing construction and manufacturing. While there are significant differences between the industries, they have important similarities in their skills gaps. Both industries rely on a combination of psychomotor and cognitive skills, and both industries have traditionally provided high-paying employment opportunities for America's non-college-educated workers. Additionally, experts that we spoke with highlighted the close relationship created by the extensive use of manufactured products in construction and suggested a trend toward convergence between the two industries. While the extent of this convergence is still uncertain, there are indicators, like prefabricated construction, that point toward greater transferability of technologies and skills between the two industries.

Which workers are we talking about?
In this report, we focus on exploring the challenges and opportunities facing workers with specialized job skills but not a traditional four-year college degree. A worker with specialized job skills is any worker who has distinct skills, training, knowledge, and (usually acquired) ability in their work. In some cases, we refer to sources that use the terms "low skill" or "middle skill" to describe this population. Low-skilled labor is generally characterized by a lower educational attainment, such as a high school diploma, GED, or lack thereof, and typically pays lower wages. According to the National Skills Coalition, middle-skill jobs, which require education beyond high school but not a four-year degree, make up the largest part of the labor market in the United States.[9]

The influence of these sectors on the US economy, their historical importance for workers with specialized skills but not a traditional four-year degree, and the significant changes that lie ahead make these industries particularly interesting for those seeking to support workers as automation increases.

The Autodesk Foundation sits at the intersection of Autodesk, Inc. and the broader private and social sectors, giving it a unique vantage point into the extent and speed at which technological change is occurring in the construction and manufacturing industries and the opportunity for dramatic change in the near future. Despite the uncertainty that exists, we believe both industries will see important changes in the ways they operate, which will significantly change how work is done. We also believe that workers with specialized skills but not a traditional four-year degree are likely to be especially vulnerable as the economy becomes increasingly digital. As Accenture points out in its recent report on the future of work, some workers face a "double disadvantage" as work changes, driven by limited financial safety nets, lower job security, lower proficiency in high-demand skills, and unequal access to training.[11]

To better understand how to support construction and manufacturing workers through the changes and opportunities of increased automation, we must better understand where and why current challenges exist for workers, employers, and the various stakeholders that support them, and how these challenges could evolve over time. This understanding of the "problem space"—developed with Monitor Institute by Deloitte through research, expert interviews, and input from workers themselves—allows us to identify opportunities to address specific needs, help fill the gaps that create these needs, and pursue structural changes that can prevent problems and create new opportunities.

Below, we explore the challenge collectively facing workers, employers, and the broader system in ensuring that workers can succeed in construction and manufacturing as an (uncertain) future of increased automation is realized.

The "skills gap" as the presenting problem

At the time of writing, a quick online search for US-based, English-language publications related to the skills gap in construction or manufacturing yields millions of hits. These publications discuss a shortage of qualified talent to meet the needs of construction and manufacturing firms, which is a problem that is likely to continue.

US firms report a significant skills gap, which threatens to stifle a resurgence in both industries.
Recovery from the 2008 recession in both construction and manufacturing has increased demand for labor. Through the first quarter of 2018, employers were looking to fill an average of nearly 225,000 construction jobs each month.[12] As recently as August 2018, there were 508,000 open jobs in the US manufacturing sector, part of the best annual job sector gain in more than 20 years.[13] While demand for labor seems to be increasing, employers report concerns about talent as one of the top issues affecting their business. In a recent survey, 91 percent of contractors, construction managers, builders, and trade contractors reported difficulty finding skilled workers.[14] In manufacturing, the average time to fill a skilled production position went from 70 days in 2015 to 93 days in 2018.[15]

The skills gap is likely to worsen in the next 5–10 years, although experts disagree on pace/extent.
Continued growth in both construction and manufacturing is expected to increase the total number of new jobs created over the next 10 years. Construction's strong recovery from the 2008 recession (3.4 percent growth from 2013 to 2018) is expected to continue but slacken over the next 5 years (0.8 percent growth, 2018–2023).[16] IBISWorld projects that manufacturing's growth will accelerate over the next 5 years, growing from a slight contraction (-0.5 percent) from 2013 to 2018 to 1.5 percent growth from 2018 to 2023.[17] And a recent study by Deloitte and The Manufacturing Institute estimates that 1.96 million new jobs will be created in manufacturing between 2018 and 2028.[18]

Meanwhile, an aging US workforce (especially in construction and manufacturing) will worsen the situation by increasing the number of jobs left unfilled by retirement. Between 2008 and 2015, the average age of a US worker increased less than 1 year, while the average age of a construction worker increased by 2 years.[19] Similarly, between 2000 and 2012 the gap between the median age of the manufacturing workforce and the total non-farm workforce more than doubled from 1.1 years to 2.4 years. Deloitte and The Manufacturing Institute[20] estimate that retirement will open 2.69 million manufacturing jobs between 2018 and 2028.

It is less clear how much new technologies will penetrate both industries and require new types of workers, creating more demand for new labor. Recent surveys have shown that manufacturers now believe that "the shifting skill set due to the introduction of new advanced technology and automation" is the No. 1 factor driving the employment gap,[21] but experts we spoke with cautioned that the history of low productivity in construction and decreasing productivity in manufacturing implied that new technology adoption may be more incremental and limited than is commonly assumed.

The future of the skills gap is further complicated by the broader conditions in the US labor market. While the US unemployment rate has been on a steady decline since 2010 (3.9 percent in December 2018),[22] the labor force participation rate also decreased steadily between 2008 and 2014 and has remained at approximately 63 percent since that time,[23] a figure that is stubbornly low despite signs of economic improvement. This "sideline" labor could help to alleviate the skills gap if coaxed back into the workforce with higher wages or opportunity, but persistent low participation could continue to worsen the issue.

Real wages for the average American worker have also stayed stubbornly flat since the 1970s. For example, the "usual weekly earnings" for full-time and salary workers, measured consistently in 2018 dollars, barely moved from $840 (adjusted) in 1979 to $879 in the second quarter of 2018.[24] Within this general stagnation, most of the gains have gone to top earners, at the expense of the lowest-earning workers. According to analysis by the Pew Research Center, the top 10 percent of earners have seen their real wages rise 15.7 percent between 2000 and 2018, while the bottom 10 percent have only seen a 3 percent increase in real wages in the same time frame.[25] This divergence has led to a 5x difference in weekly earnings between the top and bottom 10 percent. Higher wages are a potent tool for attracting and retaining workers with the right skills, and trends in wage growth in the broader economy will have a significant effect on how workers invest in new skills and whether employers in construction and manufacturing are able to compete for the types of talent they need.

Despite some disagreement among the experts that we interviewed, the opportunities that we highlight in this analysis assume that the "skills gap" we are experiencing today will continue to worsen. Despite the threat of recession and continued offshoring, we assume that construction and manufacturing will continue to grow. And, despite the structural barriers in the construction and manufacturing sectors, we assume that technology adoption will increase, albeit shaped by the characteristics of each industry.

The "skills gap" as a multidimensional challenge

The skills gap problem is multidimensional. For example, some experts believe that without intervention, the supply of high-quality training will be inadequate. Workers often have difficulty understanding job opportunities in construction and manufacturing or pathways for getting there. Employers tend to have outdated human capital practices that artificially narrow the workers they consider. System-level behavior patterns impede actors from collaborating to help workers. Those are just a few of the challenges.

While there is significant uncertainty, experts we spoke with believe that these challenges could become even more pronounced in the age of automation, with the potential to disproportionately influence non-college-educated workers. For example, as the construction and manufacturing industries become more dynamic, worker transitions (e.g., activities, positions, employment models, industries) are likely to become the norm, but many workers lack the economic stability and know-how to navigate these transitions effectively. Similarly, workers would be negatively affected if employers continue to focus on new technology predominantly for cost reduction instead of a way to augment workers while also improving the bottom line.

We use the four components of the workforce and employment ecosystem to loosely organize the key challenges facing workers with specialized job skills but not a traditional four-year degree in the age of automation:

- **Supply-side challenges** relate to attracting and training workers and creating a stronger supply of labor
- **"Matching" challenges** relate to connecting workers to jobs and facilitating job and career transitions
- **Demand-side challenges** relate to influencing employers' employment practices vis-à-vis workers
- **System-level challenges** relate to policy and cross-sector collaborations that impact how the workforce system operates as a whole

Supply-side: Challenges to investing in human capital

The skills gap in construction and manufacturing suggests at least three things about most workers: they do not have the necessary skills, they are not aware or do not know how to access the opportunities that are available to them in these industries, and/or they are not interested in employment in these industries. We tackle the challenge of an adequately skilled workforce here, exploring the shifting nature of the types of skills and competencies demanded of workers. We also tackle the overall awareness and perception challenges facing these industries in attracting workers.

As technology adoption increases, workers will need a new mix of skills, knowledge, and capabilities, and these will need to be updated more frequently. Some experts we spoke with suggested that the skills required to succeed in construction and manufacturing haven't changed significantly over the past 50 years. However, Deloitte's Future of Open Talent Optimization (FOTO) research,[a] a survey at Autodesk University,[b] and conversations with experts indicate that tasks and jobs in these industries are likely to change more rapidly with increased technology adoption.

Several recent research efforts, industry and government reports, and convenings of experts have tried to define the combination of skills required of workers in construction and manufacturing given new automating technologies. For example, Deloitte and The Manufacturing Institute perform a periodic survey of skills needed in manufacturing; the Lightweight Innovations for Tomorrow (LIFT) has published several recent reports detailing the skills needed in light manufacturing; and the National Academies of Sciences, Engineering, and Medicine have studied the needs of America's technical workforce.

We have synthesized what these nascent studies reveal about the critical skills, knowledge, and capabilities that are required and the relationship among them in figure 3 on the next page. It reflects our emerging understanding of what workers with specialized job skills but not a traditional four-year degree will need to succeed in rapidly automating industries. This framework is intended to highlight the relationship between these in terms of their specificity (technical versus generalizable) and pace of change (fast versus slow), as well as their interdependencies (e.g., technical skills require digital literacy, and rapidly changing technical skills require increased worker agency in navigating learning). So, while highly specialized technical skills will always be critical for certain roles, the fundamental capabilities required for any role may be just as important to understand, incorporate into the learning environment, and reflect in the hiring process.

[a] Deloitte's Future of Open Talent (FOTO) methodology uses analysis of O*NET occupational descriptions to estimate the extent to which traditional roles can be affected when new ways of working (i.e., automation, the open talent continuum, and workplace location) are introduced.

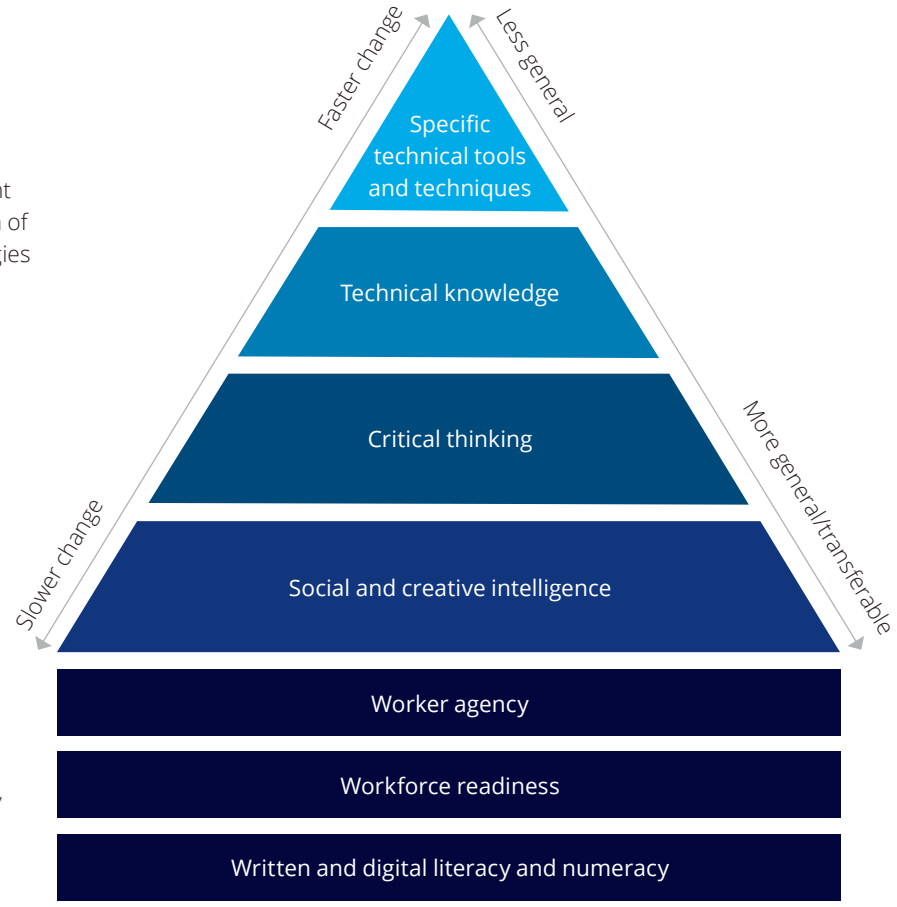
[b] In November 2018, Autodesk Foundation worked with Monitor Institute by Deloitte to administer a survey to Autodesk University participants (1,104 respondents) that aimed to better understand how work is changing in construction and manufacturing in the age of automation, as well as ways to support workers through these changes.

Figure 3. Skills, knowledge, and capabilities pyramid

The "nested" relationship among these skills, knowledge, and capabilities is animated by lifelong learning–a continuous process of developing new skills, knowledge, and capabilities as individuals progress through their careers.

These elements are important as there is greater integration of physical and digital technologies and collaboration between humans and machines

These elements are important as industries undergo significant change and modes of work diversify (e.g., gig, virtual, etc.)



Each category includes, for example:

- **Specific technical tools and techniques:** The combination of psychomotor and cognitive skills aligned to specific materials, techniques, or tools (e.g., advanced welding)
- **Technical knowledge:** Understanding of relevant science, technology, engineering, and mathematics concepts and applications that are necessary for the role (e.g., understanding machine data outputs and troubleshooting)
- **Critical thinking:** Using context, experience, communication, and reflection to rationally analyze and evaluate information to form a judgment (e.g., problem structuring, hypothesis testing)
- **Social and creative intelligence:** Human capabilities related to collaborating with other people and adapting to ambiguous circumstances (e.g., teamwork, curiosity, adaptability)
- **Worker agency:** Drive and ability to take on and navigate difficult challenges and connect with others to learn more quickly how to have more of an impact on an issue
- **Workforce readiness:** A set of skills required to find and maintain employment
- **Written and digital literacy and numeracy:** A set of skills including basic reading, writing, math, and computer skills

Experts emphasized that a worker's mix of skills, knowledge, and capabilities across the pyramid becomes increasingly important as automating technologies require them to engage in greater problem solving, instruct machines and interact with them, and collaborate more across human teams. In the words of one manufacturing expert, "In the fast-changing and dynamic world of manufacturing, analytical skills, creativity, and learning quickly are primary. STEM topics are second-level skills, and you can build technical skills on those."

> "In the fast-changing and dynamic world of manufacturing, analytical skills, creativity, and learning quickly are primary. STEM topics are second-level skills, and you can build technical skills on those."
>
> **—Expert interview, Manufacturing**

Experts also emphasized that the specific skills at the top of the pyramid are changing at a rapid pace that is likely to increase. As one future-of-work expert put it, "Today the half-life for new technical skills is approximately five years, and it's likely to get shorter." However, industry and training programs are only starting to discuss the implications for workers. For example, the accelerating pace of technological change means that workers will need to engage in more—and more frequent—learning to stay up to date on the skills at the top of the pyramid, but the idea of "continuous learning" or "continuous skills upgrades" is not yet part of the mainstream conversation in the United States, particularly in the construction and manufacturing industries.

> "Today the half-life for new technical skills is approximately five years, and it's likely to get shorter."
>
> **—Expert interview, Future of Work**

Our survey of 1,104 participants at this year's Autodesk University also highlighted the importance of learning. Although 78 percent of respondents agreed that "employees are well prepared to cultivate new skills and capabilities related to their work if they are required," many cited the need for firms to emphasize learning as a core part of work and for management to make continued training and learning more accessible and effective.

The speed of change is impeding a shared understanding of what these skills look like and hindering timely refinements of workforce development programs to match demand. Nascent efforts among manufacturing leaders to identify specific technical skills for niche advanced manufacturing areas have started to pay off. For example, LIFT recently published the results of a collaborative effort with educators to identify specific psychomotor and cognitive skills needed for new light manufacturing technology.[26] Similarly, the Associated General Contractors of America (with support from Autodesk) released an updated workforce development plan.[27]

However, our literature review and interviews revealed that career and technical education (CTE), community colleges, industry associations, and other workforce development educators that train construction and manufacturing workers are struggling to keep up with the rapidly changing pace of technology and to understand the implications of new technologies for workers and education/training programs.

The 2017 National Academies of Sciences report, *Building America's skilled technical workforce,* and other recent reports have emphasized several challenges in delivering training around the full mix of skills. Our interviews with experts corroborated their findings, which include the challenges of:

- Updating curricula with enough frequency to keep up with advances in science and technology and changing occupational requirements
- Focusing on experiential learning approaches that include work-based learning, including access to commercial environments and collaboration with workers across roles
- Increasing the number of technically qualified teachers able to integrate technology in the classroom and engage in agile curriculum development
- Providing adequate and up-to-date hardware and software, training equipment, and facilities

Additionally, deep-seated perception issues narrow the pipeline for talent into both industries. An important issue that influences the supply of workers in construction and manufacturing is pervasive negative perception of both industries. For example, two-thirds of respondents to a recent poll said they would never consider a career in the construction industry.[28] Many blue-collar workers think construction jobs are dirty and dangerous, while white-collar workers may feel jobs in the industry lack innovation and challenge.[29] And a recent survey of manufacturing executives ranked "negative perception of students/their parents toward the manufacturing industry" as the second greatest cause of the skills shortage.

Clearly, there is a broad perception among workers that jobs in construction and manufacturing are of low quality or otherwise unattractive. Addressing this wariness among prospective talent requires addressing issues that exist with work in each industry and also correcting misperceptions.

There is evidence to suggest that despite real challenges, non-college-educated workers can find attractive employment in construction and manufacturing. For example, average hourly compensation (wages and benefits) in construction and manufacturing is 25 percent and 28 percent higher, respectively, compared to all industries that have gained jobs since the 2008 recession.[30] According to ADP, turnover in construction and manufacturing is equivalent to turnover in finance and extractives, but lower than professional services, transportation, and hospitality.[31] While these measures of stability and wages only capture part of the equation for how workers perceive industry, they suggest that more work is required to increase and communicate the attractiveness of work in construction and manufacturing.

Meanwhile, the homogeneity of the construction and manufacturing workforce points to a failure to reach broad segments of the population. Both workforces are aging faster than the general population. For example, between 2008 and 2015, the average age of the construction workforce increased by two years, while the general workforce aged less than one year.[32] The same trend is true in manufacturing, where the gap between the median age of the manufacturing workforce and the median age of the general population more than doubled between 2000 and 2012.[33]

Moreover, as shown in table 1 below, despite overall growth, women continue to be underrepresented in both industries and particularly in construction, which has seen only one percentage point of growth in female employees over the past two decades.[34] And white workers continue to be overrepresented, particularly in construction, versus all other industries.

Table 1. Demographic data for US construction and manufacturing[35]

	Construction	Manufacturing	All other industries
Women	9%	29%	46.8%
White	89%	80%	78%
Hispanic or Latino†	30%	17%	17%
Black or African American	6%	10%	12%
Asian	2%	7%	6%

† US Census data does not report "White, Non-Hispanic" as a category, so there is some overlap among categories.

"Matching": Challenges in how supply meets demand

An important aspect of the skills gap challenge is the structure of the marketplace for getting the right workers into the right jobs. More specifically, a lack of transparency and common language, as well as the shifting nature of employment in these industries, may be hindering more efficient matching of supply and demand.

We lack sufficient information about new jobs and opportunities created by automation in construction and manufacturing. A recent Accenture report points to at least two types of information gaps in the marketplace for jobs: information about how technology will affect workers and information about employment opportunities that are available to workers.[36]

Employers struggle to explain how—and how much—new technology will affect the workforce. In general, this creates anxiety for workers. According to a recent Accenture report, 37 percent of "vulnerable workers" worry that their skills will become obsolete. Our own research with 53 frontline workers in construction and manufacturing specifically revealed that the less experience workers had with technology in their jobs, the more they were concerned about how technology would affect them, and vice versa. This disconnect points to misunderstandings among workers regarding how technology will affect their jobs and how they can prepare.

Meanwhile, a lack of transparency around market demand contributes to limited visibility of opportunities, especially in a dynamic context in which requirements and opportunities for employment are changing. According to the Committee on the Supply Chain for Middle-Skills Jobs,

> "It is particularly challenging for students and job seekers to identify viable career options and the associated education and training requirements. At the same time, data suggest that K-12 schools, postsecondary schools, and worker assistance agencies have reduced support for counselors and advisors because of budget pressures and changing priorities (Good and Strong, 2015). Inadequate occupational guidance potentially increases the cost of education and training, creates imbalances in labor markets, and reduces ROI in skilled technical workforce development… [moreover] without career counseling and reliable occupational information, experts believe that students pay insufficient attention to labor market trends in choosing fields of study."[37]

Meanwhile, the government resources on which these counselors and advisors rely often use historical, outdated data to identify growth industries, while private sources of data tend to target companies, not workers, in their information about the skills needed for specific roles. Changes focused on providing accessible and actionable information to workers will require new investment or business models that capture, synthesize, and share labor market intelligence targeted at workers themselves.

This confusion is compounded by a lack of common language around competencies and unreliable means of verifying qualifications. Our interviews with experts and hiring managers emphasized that workers have a difficult time articulating their work in terms of skills or competencies. A future-of-work expert we spoke with explained, "It is very difficult for employees and employers to talk in terms of skills. The predominant focus on tasks gets in the way of understanding how workers' experiences and abilities are transferable to new types of tasks and roles."

However, organizations like the National Network and others have done significant work to demonstrate how competencies translate to job performance in certain roles in manufacturing (and other industries).[c] An expert who we spoke with lamented, "We have evidence that shows the connection between competencies and job performance—critical information to improve labor markets—but competencies are not being used throughout industry as part of hiring." These competency-based occupational descriptions are increasingly seen as more relevant, however, as new technologies begin to reshape work in both manufacturing and construction. Experts emphasized that, for workers, this difficulty in articulating their skills is further complicated by difficulty accessing information on which jobs align to certain skills and competencies and which skills or competencies are most valuable for them to develop.

"We have evidence that shows the connection between competencies and job performance—critical information to improve labor markets—but competencies are not being used throughout industry as part of hiring."

—Expert interview, Manufacturing

[c] For example, National Network's collaboration with Burning Glass has resulted in occupation profiles for competency-based job descriptions.

On the employer side, focus group conversations with hiring managers at Autodesk University 2018 revealed that they often distrust employees' self-assessments and tools, like certifications, and prefer to verify qualifications themselves. Similarly, the hiring managers with whom we spoke emphasized the significant importance of "soft skills" in employees but relied on intuition and assessment through interviewing to try and assess these skills. Overall, hiring managers expressed low confidence in their ability to hire the right people for their needs.

The proliferation of alternative work arrangements—and belief that workers will be more frequently transitioning jobs and roles—further complicates the matching of workers and employers. One measure of labor market dynamism, gross job gains and losses, has been in steady decline since the late 1990s. However, another measure, alternative work arrangements, has increased significantly. While newly created jobs decreased 1.6 percentage points over the last few decades,[38] the percentage of workers engaged in alternative work arrangements—defined as temporary help agency workers, on-call workers, contract workers, and independent contractors or freelancers—rose from 10.1 percent to 15.8 percent between 2005 and 2015.[39]

Additionally, a significant percentage of top occupations in construction and manufacturing are susceptible to alternative work arrangements. A Deloitte FOTO analysis[d] of the top 10 occupations in construction and in manufacturing—representing a total of 14.6 million US workers[40]—indicates that with aggressive effort to automate, an average 69 percent of occupational activities could be automated (e.g., by robotic process automation, chatbots) and an average 79 percent of activities could potentially be performed by a different talent model (e.g., crowdsourcing, gig work, assembly line).

The desire among employers to use more contingent and flexible workforces is likely to result in more regular and fluid movement between jobs and learning experiences. There are indications that, in general, employers across industries prefer to hire contingent workers[41] and are reluctant to invest in training,[42] suggesting that workers may bear the burden of new skill development at their own time and expense.

The more frequent need for new skills will also strain the traditional relationships between employers and workers regarding skills development. Speculating about the future of training, several experts with whom we spoke suggested that the need for more frequent learning will require more and more learning to happen on the job to minimize disruption to production and the costs associated with frequent workforce turnover. While there is uncertainty about the extent to which these various dynamics will play out, most experts that we spoke with agreed that we are moving toward a period of more frequent worker transitions and less stable workforces within organizations.

The rapid pace of change in skills needed and the increase in alternative work arrangements can put additional risk on individual workers. The recent Shift: The Commission on Work, Workers, and Technology report summarized the issue, saying, "Individuals take more personal risk under almost any scenario [for the future of work]. So, our society needs to provide new pathways to stability in work, while at the same time empowering people to reap the rewards of risks taken."[43] This potential change in relationships between employers and workers underscores the need for workers to be able to create new types of stability in their work and capture the value from their own risk-taking around new skills development and job transitions.

[d] Deloitte's FOTO methodology uses analysis of O*NET occupational descriptions to estimate the extent to which traditional roles can be affected when new ways of working (i.e., automation, the open talent continuum, and workplace location) are introduced.

Demand-side: Challenges in leveraging human capital

An additional challenge (and opportunity) facing workers is related to the extent and manner in which firms adopt new technology in construction and manufacturing, and implications on workers.

There is disagreement about the extent to which new, automating technologies will take hold in US construction and manufacturing. Slowing labor productivity in manufacturing and historically low labor productivity in construction both point to stagnant technology adoption. Manufacturing productivity growth was 0.7 percent from 2007 to 2017, while total non-farm business productivity grew by 1.2 percent during the same period.[44] Meanwhile, in the US construction industry, annual labor productivity growth averaged close to zero in the 50 years leading up to 2012, and annual labor productivity growth has been negative for the past two decades.[45]

The extent to which these industries will be able to adopt new technologies may be limited by their structure, which is dominated by SMEs. As illustrated in figure 4 below, 92 percent of US construction establishments and 75 percent of US manufacturing firms have fewer than 20 workers.[46] Additionally, 44 percent of employment in manufacturing and 82 percent in construction occurs at SMEs, defined as companies with fewer than 500 employees.[47] The thin margins, high cyclicality, and limited scale of smaller companies limit investment in new technology.

Both of these trends suggest that technology adoption in construction may continue to be limited, but a look at accelerating venture capital investment in construction technology suggests the tide may be shifting. Between 2008 and 2012, construction technology received $9 billion in cumulative investment, but that doubled between 2013 and 2018 to $18 billion.[48]

A focus on using technology for cost reduction leaves workers vulnerable. In the past, when these industries have adopted new technology, the focus has been primarily on cost reduction. From 2010 to 2016, the manufacturing sector saw 10–20 percent increases in output, but only a 2–5 percent increase in jobs.[49] Despite these increases in worker productivity, wages in manufacturing in the United States have been essentially flat (in real terms) over the same period.[50]

Experts we spoke with emphasized that this cost-reduction perspective is still pervasive, even when new technology presents the opportunity for value creation. They emphasized that firms today tend to view the objective of work as efficiency and the ultimate goal as more effectively executing routine tasks. This perspective also emphasizes workers' specific skills on particular tasks rather than their broader capabilities.

Figure 4. Construction and manufacturing, by firm size (%)

As discussed in the "Skills gap" as the presenting problem section on page 10 of this report, the history of wage stagnation and focus on reducing the number of workers needed exacerbates the skills gap directly by failing to attract and retain workers to fill existing job openings, as well as indirectly by discouraging people from entering the pipeline for careers in construction and manufacturing. Attracting workers with new skills and improving the skills of the existing workforce will require changes to this singularly cost-reduction-focused approach to automation and efforts to shift the broader popular perceptions of these industries.

Additionally, predominant HR practices within industry can create barriers to addressing the challenge. Experts we spoke with commented that firms tend to treat talent supply issues "like the weather," and see it as something that happens to them rather than something over which they have control. One expert we spoke with said, "They hope for the best, but they are not actively trying to shape it. Part of the reason is that it is not a problem that they're used to solving." The issue is further complicated, according to experts, by the tendency of firms to place all of the burden of talent issues on human resource (HR) departments rather than treating it as a priority for the core business. An expert in workforce strategy said, "The entire recruiting strategy and business model is based on the fact that people will be there their whole life and assumption that HR is the part of the business responsible for ensuring the organization has the right skills. The world isn't like that anymore."

"The entire recruiting strategy and business model is based on the fact that people will be there their whole life and assumption that HR is the part of the business responsible for ensuring the organization has the right skills. The world isn't like that anymore."

—Expert interview, Construction and Manufacturing

Looking toward the future, experts emphasized that automating technology could change firms in ways that have profound implications for their relationships with workers but disagreed on the timing and magnitude of these changes. Most experts that we spoke with agreed that the skills workers need in the future are not only more complex but need to also be upgraded more frequently. Some experts described the shift as "continuous skills upgrades." This requirement, they agreed, will mean that more and more training and development will need to happen on the job and in ways that minimize disruption to production. Despite agreement on the need, it was unclear how firms would change the ways that they operate and engage with workers to respond to the need.

While some experts emphasized the slow and modest ways that they believe automating technology will affect construction and manufacturing, others emphasized the transformative effects that these technologies could have and the impact on relationships with workers. For example, at Autodesk University in 2018, Deloitte Future of Work thought leader John Hagel emphasized, "Optimization is no longer enough to ensure that organizations will be resilient in times of change. Work will increasingly require a move away from driving efficiency at scale toward giving workers the permission to unlock their imagination… all in service of finding new ways to drive value within the organization." In other words, successful businesses of the future will not be defined by their maximal efficiency, but rather by their ability to engage in continuous learning (as an organization) to adapt to the increasingly complex and fast-moving market. This will require new business models that are able to capture value from learning and adaptation at all levels of the organization—from the front line to the C-suite—which will require new technology-enabled collaboration between the "top" and "bottom" of the organization that leverages frontline expertise and decentralizes decision making.

"Optimization is no longer enough to ensure that organizations will be resilient in times of change. Work will increasingly require a move away from driving efficiency at scale toward giving workers the permission to unlock their imagination… all in service of finding new ways to drive value within the organization."

—John Hagel interview, Future of Work

System-level: Challenges impacting how the overall ecosystem operates

Finally, several broader issues stand in the way of closing the skills gap in construction and manufacturing in ways that support all workers. First, issues beyond work influence workers' ability to thrive in an increasingly dynamic employment environment. Second, the responsibility for addressing the skills gap challenge is not well organized.

While we highlight both issues below, we do so with a lighter touch. This is because there already exist numerous industry-level reports that frame workforce development as a shared responsibility and emphasize importance of cross-sector collaboration. Meanwhile, broader policy issues are addressed in detail in a 2019 report co-published by Autodesk Foundation and Aspen Institute, *Technology, automation, and the labor market: The case for policy intervention*.

Significant changes in the nature of work demand rethinking current public policies to enable people to work and also looking beyond policy interventions to address their needs. Since the New Deal, cross-cutting supports that are meant to help workers navigate unexpected challenges in employment and manage the effects of work on other aspects of their lives, such as their health, have been the purview of the public sector. These supports have consisted of various programs such as unemployment insurance and are known collectively as the "social safety net." A 2019 report co-published by Autodesk Foundation and Aspen Institute reviews the potential implications of automating technology for these public policies and suggests an agenda for using policy to help workers succeed.

As alternative work arrangements proliferate, and workers need to more frequently upgrade their skills, experts with whom we spoke emphasized the importance of these traditional policy interventions as well as the need for new models that share responsibility between workers, employers, and the public sector. For example, new business models that offer private unemployment insurance or enable temporary workers to earn benefits could complement existing policy, giving workers and employers more ways to adapt to the effects of technology on how they operate.

Experts emphasized the importance of stepping back to understand how changes to how work is done also create the necessity and opportunity to change how we support workers beyond the workplace and between jobs, particularly our country's most vulnerable groups of workers.

> "Stability for workers in the past meant income; stability in the future will be about continuous skills upgrades. The challenge will be how to help workers achieve stability in this new future of constant transition."
>
> **—Expert interview, Workforce Development**

Meaningful collaboration to support worker success requires significant effort to bring all players, especially employers, to the table. Most of the challenges described in this report require some level of coordination and/or collaboration within industries and across sectors. For example, effectively training the workforce requires coordination between educational institutions, workforce development organizations, employers, and public funding sources to make sure that curriculum keeps up with the market and that there are opportunities for experiential learning. Similarly, better-functioning "matching" infrastructure requires standards and data-sharing protocols, which by definition require coordination. Finally, shifting the dominant narrative about these industries—and certainly tackling broader policies related to the "whole worker"—will involve coordination among the construction and manufacturing industries, the broader workforce development ecosystem, and government.

Many have written about the barriers to coordination and collaboration, particularly when it comes to workforce development. While recent manufacturing reports have reminded us that in the United States there is a precedent for public-private collaboration around workforce development, all the experts that we spoke with stressed the importance of more cross-sector collaboration if we are to address the skills gap and support skilled workers.

In the meantime, some of our interviewees cautioned that while the public and private sectors share an interest in solving the skills gap today, there are warning signs that increased collaboration may be short-lived. That is, while firms are concerned with the immediate lack of talent to support their growing business, they may not be willing to take on broader and ongoing responsibility for developing workers' skills and building jobs:

- A 2018 survey by the World Economic Forum (looking across industries) found that nearly 25 percent of companies are undecided or unlikely to pursue the retraining of existing employees, and 67 percent of companies expect workers to adapt and pick up skills in the course of changing jobs.[51]
- Recent news coverage of the World Economic Forum in Davos highlighted the tension between business leaders' publicly expressed concerns about the impact of automation on workers and the extent to which their private conversations and actions focus on accelerating automation that displaces human workers to gain a competitive edge.[52]

Uncertainty regarding the possibility of deepened cross-sector collaboration emphasizes the need for different layers of actors—within the public sector, nonprofit sector, and private sector—working independently and collaboratively to address the various aspects of the skills gap challenge.

Areas of opportunity

The eight opportunity areas we have identified, summarized in figure 5 below, stem from our understanding of the skills gap challenge and are anchored in the ideas that surfaced throughout our literature review, interviews, and engagement with workers.

The number and diversity of our opportunity areas indicate that there is no silver bullet for "solving" the skills gap problem. This challenge is complex and, in the words of one future-of-work expert, "will require diverse interventions at multiple levels." As such, our opportunity areas cover activities that are very different in type (e.g., piloting or scaling models, shifting narratives, investing in platforms). In addition, while we believe strongly that rigorous evidence is critical for effective intervention, we have not confined ourselves to those opportunities that already have high levels of evidence because we believe that a holistic approach also requires increased innovation and experimentation to take us beyond the status quo.

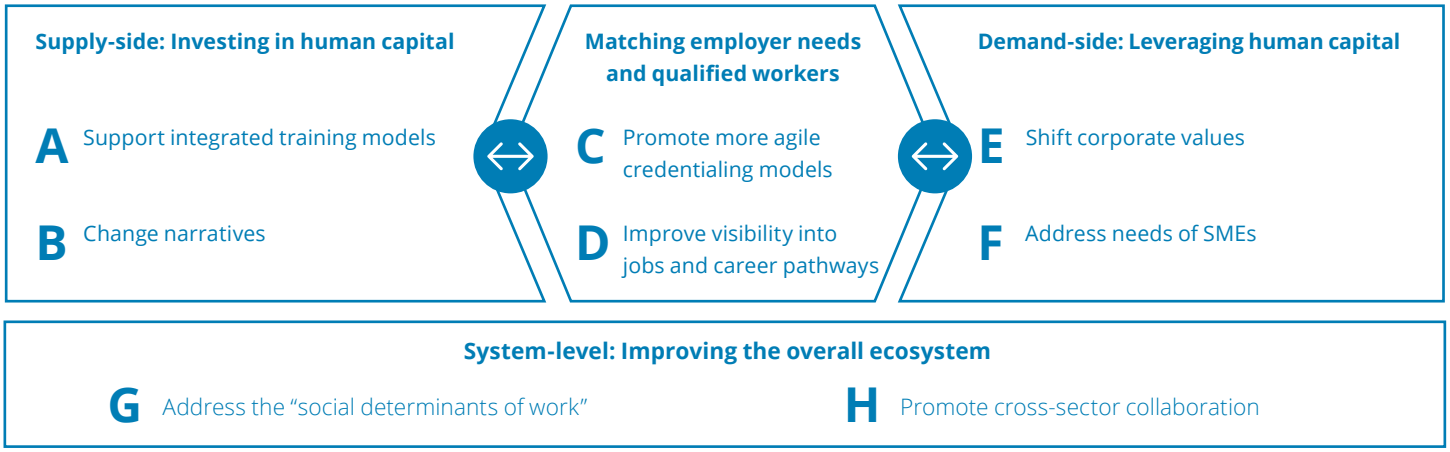
Together, these eight opportunity areas describe the major areas for potential intervention; however, there are certainly nuances of each area and important considerations that we have not been able to deeply address in this report. Success across these diverse areas requires the involvement of a wide variety of stakeholders, including companies, worker organizations, various workforce development actors, and others. While some opportunities are better suited for particular stakeholders, our research highlights the importance of employers throughout. As such, we describe each opportunity with a corporate audience in mind, addressing questions and using language geared toward their mindset.

Illustrating how each opportunity area can be brought to life

Throughout each opportunity area we have highlighted specific companies, organizations, or initiatives that help to illustrate the concepts we discuss.

These examples are not the only or best solutions to the challenges we present. Rather, they are tangible examples of how these opportunities come to life.

Figure 5. Opportunity areas



Supply-side: Investing in human capital opportunity areas

Opportunity A: Support integrated training models

Overview

Overall, training models for construction and manufacturing are not in sync with the twenty-first-century needs of these industries, contributing to growing worker shortages. There is an opportunity to develop more and better training models that are industry- and problem-based and cultivate a reinforcing and evolving mix of skills, knowledge, and capabilities (e.g., specific technical tools and techniques, critical thinking, social and creative intelligence). These training models fall into three general categories: 1) demand-driven curricula that expose students in traditional education settings to employer-aligned skills; 2) experiential learning models, such as apprenticeships and integrated training facilities, that combine academic instruction with hands-on experience; and 3) new modes of learning (e.g., virtual training) that leverage technology to help workers develop the new mix of skills required in the age of automation.

Why this is important and what is needed

Current and prospective workers in construction and manufacturing may not have the necessary skills to succeed at their jobs today and in the future. A 2017 National Academies of Sciences report titled *Building America's skilled technical workforce* states that the United States is not adequately developing and sustaining a technical workforce with the skills needed to compete in the twenty-first century.[53] In construction and manufacturing, a recent survey showed that manufacturers believe that a shifting skill set due to new advanced technology and automation is the No. 1 factor driving the employment gap,[54] and 91 percent of surveyed construction leaders reported difficulty in finding skilled workers.[55]

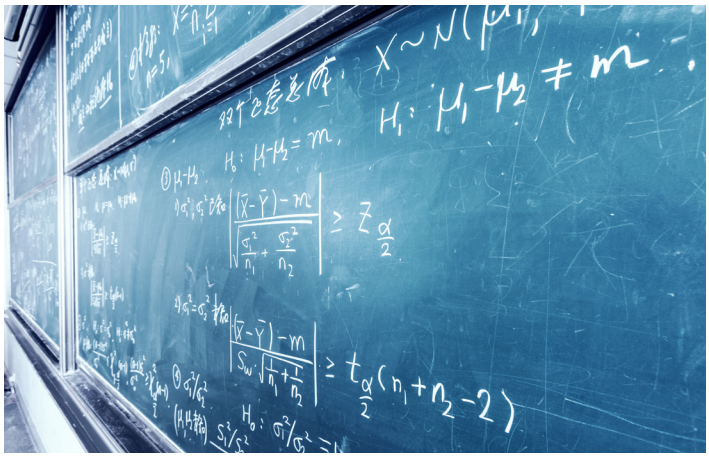
Because the pace of technology adoption is likely to accelerate, the situation is likely to worsen. Multiple reports emphasize the speed with which specific technical skills requirements are likely to change, as well as the rising importance for workers to have a mix of soft, analytical, digital, and software/hardware skills to thrive in increasingly automated work environments.

Models that integrate academic, technical, and hands-on work can help skilled workers cultivate the mix of skills and capabilities they need. The 2017 National Academy of Sciences report synthesizes research around K-16 and alternative education training models, providing evidence that the integration of academic education, technical training, and hands-on work experience improves outcomes and return on investment for skilled technical workers at different career stages.[56]

It describes at least four promising, non-mutually exclusive secondary (academic, CTE) and postsecondary (two-year degrees, four-year degrees, certificates, and apprenticeships) education and training models:

1. **Integrated secondary education models:** Innovative, integrative education models that provide on-the-job opportunities for high school students. Specifically, "early college" schools integrate high school and college education and training through collaborative partnership between a school district and a two- or four-year postsecondary school, with startup costs beginning at $125,000 for a program within an existing high school. Studies have shown this to be a successful model for increasing graduation rates, better preparing students for college-level work, and reducing student debt load.

2. **Partnerships between employers and community and technical colleges:** Demand-driven education and training programs that are developed in partnership with employers, either directly or facilitated by regional workforce intermediaries, cross-sector partnerships, or a "strategic center of excellence" at community and technical colleges.[e] These programs, particularly those that integrate classroom training with workforce experience, can potentially raise earnings for at-risk students.[57]



[e] These centers of excellence serve as points of contact and resource hubs for industry trends, best practices, innovative curricula, and professional development.

InTech: Example of how a community college is partnering with employers to support work-based learning

InTech (Chaffey College Industrial Technical Learning Center) offers residents of San Bernardino and Riverside counties in California work-based learning programs to increase job readiness in advanced manufacturing, partnering with local companies. Programs include Industrial Maintenance Electrician, Industrial Mechanic, HVAC (Heating, Ventilation, & Air-Conditioning) Automation & Process Control, and Conventional Machining.

3. **Registered apprenticeships:** Work-to-learn model that pays participants while providing on-the-job and classroom learning with the support of a mentor, meets national standards, and results in industry-recognized credentials of proficiency.[f] Newer forms of apprenticeships include coursework at a local community college that leads to an associate's degree and includes at least 2,000 hours of paid work and 150 hours of related instruction. The average apprenticeship lasts four years, and apprentices earn an average of $161,000 over the course of their apprenticeship.

   Registered apprenticeships are well-studied and have been shown to demonstrate positive outcomes for workers. For example, a study of a registered program found that apprentices who complete the program earn about 1.4 times as much as non-participants with the same pre-apprenticeship history.[58] In 2017, there were 175,195 registered apprenticeships in construction and 17,559 in manufacturing in the United States,[g] representing 36 percent of total apprenticeships.[59]

   The recent expansion of public funding available for apprenticeship programs, across presidential administrations,[60,61] could signal a resurgence of support for apprenticeship models. Spurred by this investment, local public investments have also grown: 14 states increased the number of apprenticeships by more than 20 percent in 2015.[62]

4. **Joint labor-management programs:** The AFL-CIO has encouraged its members to directly sponsor workplace education and training programs. While more research is needed on joint labor-management strategies, the report suggests that several innovative programs could provide inspiration for skilled technical workforce development nationwide.

   Our research identified a fifth form of training that is centered on the facilities in which the training takes place.

5. **Integrated learning facilities:** Programs that are anchored in technologically advanced facilities that bring together research institutions; local SMEs who join to have access to the technology; vocational high school students from under-resourced communities who gain exposure to the industry; and community college students. Participants can enroll in a cutting-edge, demand-driven, and hands-on training program; obtain stackable certifications; and subsequently enroll in a university and/or pursue careers at the local SMEs with whom they worked.

[f] Other high-touch work-to-learn models include cooperative training, internships, on-the-job training, "returnships," and clinical training/practicums.

[g] By way of comparison, this number falls short of the 1.3 million participants in Germany's dual vocation program (BIBB 2017 Dual VET Figures), a country with 27 percent of the total US workforce (World Bank data).

M2I2: Example of how integrated learning facilities bring together students with educators and SMEs in real-world settings

The Massachusetts Manufacturing Innovation Initiative (M2I2) creates Discovery Centers—dedicated spaces for companies to design, prototype, and pilot new products, integrated with coursework and hands-on education. Students and professors work in the same space as collaborating companies, leading to opportunities for synergy between multiple elements of this innovative, cross-functional community. An example is the LEAP program (Lab for Education and Application Prototypes), a partnership between the state government, ManufacturingUSA's American Institute for Manufacturing Integrated Photonics Academy (AIM Photonics Academy), and academic institutions. LEAP programs partner vocational high school, community college, and university students with experts and local SMEs doing "real" work, helping students build technical, general analytical, and engineering skills while forming relationships with potential employers. The M2I2 investments are part of a $100 million commitment by the Commonwealth of Massachusetts to advance manufacturing across the state.

"But there are challenges related to spreading and guaranteeing the quality of these educational and training programs." As discussed earlier in this report, a recent report by the National Academies of Sciences identified several things that must be done to link K-16 education, training, and work: updating curricula; focusing on experiential and work-based learning approaches; growing the number of technically qualified teachers; and providing adequate access to up-to-date hardware and software, training equipment, and facilities. These challenges echo those documented in recent reports on the skills gap in advanced manufacturing.[63]

"It's not enough to bring software into the classroom. Instructors need tools to thoughtfully integrate those tools into the workflow, in ways that promote important learner skills and competencies."

—Expert interview, Construction and Workforce Development

Recent federal and industry-based construction and manufacturing reports identify specific action steps to address these challenges:[64]

- Introduce agile curriculum development that is responsive to changing industry needs, which requires mapping new technology to basic skill and competency requirements
- Promote work-and-learn expansions (in particular, registered apprenticeships) and facilitate early cross-collaboration between engineers and technicians to ensure they understand each other's roles
- Enhance educator development opportunities (e.g., through externships that expose teachers to the workplace), skills-based employee volunteer programs, and tools and resources for improving learner-centered pedagogy[65]
- Employ more virtual learning models
- Leverage advanced technical facilities to support workforce-related needs

LIFT: Example of mapping new technology to skills and competencies

Lightweight Innovations for Tomorrow (LIFT) has developed a foundational competency model for the "multi-skilled technician" needed in today's manufacturing workplace. This competency model has been translated to an educational and curriculum pathway targeted at the high school level.

Finally, the ability to scale apprenticeships has traditionally been limited by ineffective standards, formal requirements (e.g., registration with the DOL or state agencies), lengthy apprenticeship programs that demand a high degree of commitment, lack of in-company training resources, lack of intermediaries to integrate companies into one program, and historic perception issues around the connection of apprenticeships and organized labor.[66]

Opportunity B: Change narratives

Overview

The construction and manufacturing industries continue to be perceived by many as low tech, dangerous, and dirty. To help attract more talent that is currently underrepresented in these industries (e.g., women, people of color), to encourage current workers to adopt new technology and engage in "continuous skills upgrades," and to nudge companies to adopt new technology and forward-facing human capital practices, the entrenched perceptions of work in these industries must shift in ways that are linked to actual and meaningful change in the nature of work and the working environment.

Why this is important and what is needed

The negative narrative in the United States associated with construction and manufacturing—and the skilled trades more generally—is a major contributor to the skills gap. In the United States, public narratives around construction and manufacturing and around skilled work are less than positive. These industries are not often portrayed as a desired career path. Many workers perceive construction[67] and manufacturing[68] jobs to be transitional and increasingly obsolete in the age of automation.

> "Rather than taking away skilled work, technology has the potential to bring back craft to the industry that has lost craft. But that's not the story we hear."
>
> **—Expert interview, Future of Work and Construction**

These narratives contribute to a lack of interest in construction and manufacturing that shrinks the talent pipeline for these industries, with particularly low representation of women across both industries (29 percent in manufacturing and 10 percent in construction versus 47 percent overall) and overrepresentation of whites in construction (88 percent versus 78 percent overall).[69] In a country that is expected to become "minority white" by 2045,[70] limited penetration among growing demographics may further exacerbate the skills gap.

> "Getting young women interested in these worlds is incredibly important. Talk about an underutilized source of talent; there's no reason why more women can't have exciting careers in these industries. Anything we can do there would be critical (e.g., robotics competitions, engineering-type programs for young women, etc.)."
>
> **—Expert interview, Manufacturing**

Changing enduring perceptions among a diverse group of stakeholders inside and outside of construction and manufacturing requires multiple communications strategies to engage multiple constituencies who hold different perspectives. Achieving this objective is further complicated by the uncertainty surrounding the future of both industries.

Deliberate focus on narrative can mean pursuing direct or indirect interventions. Changing narratives can seem daunting since the impact is often impossible to directly trace back to the specific intervention. However, when pursing narrative change, it is important to consider two modes for engaging: direct and indirect.

"A public awareness campaign can significantly influence the misconceptions [around the construction industry] … As a good example, a national marketing campaign in England has dramatically improved society's perception toward apprenticeships and trade in recent years."

—CII Annual Conference (2018 Edition)

Direct narrative change refers to explicit efforts to shape the broad public discussion on an issue or targeted communication to specific groups (e.g., working with a major news organization to publish a series of stories highlighting new modes of work in construction and manufacturing) or creating targeted marketing messages for certain demographics. Indirect narrative refers to using narratives as a tool to augment other activities. For example, philanthropic funders can use a narrative to add coherence to, and magnify the impact of, several different activities. A clear and compelling narrative around the importance of competency-based hiring that is shared by a variety of different organizations, for example, could help to informally coordinate their activities and lead to greater impact.

Direct and indirect narrative change efforts could have the potential to attract a more diverse workforce and combat the anticipated surge of retirees in these industries, improving the overall supply of labor in construction and manufacturing.

Stories are powerful tools for giving people the information and motivation to think and behave differently. According to a growing body of research, storytelling is a powerful tool for changing people's beliefs and behaviors around complex issues. Annie Neimand, the research director for the Center for Public Interest Communications, argues that people are far more likely to remember information if it reaches them in the form of a story. Stories can also reduce arguments over divisive issues.[71] By allowing people to visualize themselves in new experiences, stories can influence their beliefs and actions.

***The future of work in manufacturing* personas: Example of using storytelling to directly and positively shift industry narratives**

In a recent report titled *the future of work in manufacturing*, Deloitte Consulting LLP highlighted the set of personas it is building to tell the story of what jobs in manufacturing could look like in the digital era. It intends to reshape traditional narratives of the manufacturing industry, particularly in light of digital advancements in technology.

Sharing the stories of frontline workers is an important tool for highlighting what is possible today and connecting a variety of different experiences to a shared set of values and common themes for the future of work. Stories enable people, both inside and outside of the industry, to better understand the current and future state of these industries and determine whether they should be involved.

Our research and conversations also surfaced ways other than storytelling and marketing to think about shifting perceptions. Efforts to improve how work in construction and manufacturing is discussed and where it is discussed can help current workers and potential talent gain a fuller picture of what is possible and empower them to make change themselves.

"In lower-skilled production, one company does a great job engaging with high school principals to help show them the viability and earning potential of running these facilities. It's really incredible work."

—Expert interview, Construction

Workforce development and industry-specific reports stress the importance of early exposure through career fairs, industry tours, externships, pre-apprenticeships, and mentorship programs. They also emphasize the importance of career counseling and reliable occupational information in influencing students' fields of study.[72] Workforce development experts that we spoke with emphasized that reaching young people depends significantly on influencing the adults—parents, teachers, and counselors—who help to shape their decisions.

Efforts to influence the narrative about construction and manufacturing have fallen short of the need. While our research revealed several recruiting initiatives that are focused on shifting the narrative about construction and manufacturing, perception issues about the industry remain:

- The magazine *For Construction Pros* highlights at least three national recruitment efforts underway, including the ACE Mentor Program and Build Your Future, which provide positive messaging about and expose students to the industry.[73]
- In manufacturing, one expert has indicated that "the industry has poured millions of dollars into solving the 'image' problem, but it's about the substance of what those industries are doing and sharing those stories of how the industry is changing to shift the narrative."
- Meanwhile, there are many articles that attempt to dispel the notion that robots are replacing human jobs in the age of automation, but few far-reaching efforts to describe how technology will change and even enhance work in construction and manufacturing.

New narratives must be backed by substance, whether they are focused on correcting current misconceptions or shaping future perceptions. Numerous experts we spoke with highlighted the importance of narrative change regarding construction and manufacturing; however, they caution that these narratives must be backed by reality to have meaningful impact. Preventing a disconnect between new narratives and what is possible requires being clear and confident in the evidence when correcting perceived misconceptions of the industries today. It also requires transparency and substantive action to back up new narratives pushing for changes to the current state of affairs. Though the standards for evidence are different in these two cases, narratives that are divorced from reality in either case can quickly become ineffective and counterproductive for workers.

"ManufacturingUSA Institutes are uniquely positioned to change the narrative in manufacturing, and they are well positioned to bring construction along, especially in shipbuilding and infrastructure."

—Expert interview, Manufacturing

LIFT and Kentucky FAME Teacher Externship Program: Example of educating educators on how to portray work environments

In a collaboration between LIFT and the Kentucky FAME Teacher Externship Program, teachers receive on-site immersive experiences in a manufacturing environment for one week, where they can observe and interact with manufacturers and engage with businesses outside of the classroom context. During the course of the program, teachers work together to create ideas, connecting their curricula with industry and taking their experiences back to the classroom to help students better understand careers in manufacturing.

MakerMinded: Example of changing narratives among the next generation of workers through digital technology

MakerMinded is a digital platform that connects students and schools to market-leading STEM and manufacturing learning experiences. Its objectives are to bring a manufacturing mindset to today's learning infrastructure and to bridge the gap between activities and programs that engage and educate youth and the students who can take advantage of them.

"Matching" opportunity areas

Opportunity C: Promote more agile credentialing models

Overview

As the skills required in construction and manufacturing continuously evolve and frequent job changes require more regular and precise pairing between workers and roles, workers need more nuanced and agile means to develop, capture, and communicate new competencies and experiences in ways that employers understand and value. Standards-based, nationally portable, industry-recognized credentials are a promising mechanism for enabling workers to do that.

Why this is important and what is needed

Workers will increasingly need to actively manage their careers, pursuing continuous skill upgrades and communicating their full breadth of skills and competencies to employers. New and disruptive technologies will require manufacturing and construction workers to upgrade their skills more frequently and move between roles and jobs more often. Given the fragmented nature of the US workforce development ecosystem, however, it is uncertain if workers will have the ability or capacity to develop the new skills required to stay up to date with technology and changing labor market demands (e.g., on the job, in between jobs, or on their own time). Furthermore, it is unclear who will bear the cost of training workers, or if these different modes of learning and experience can even be reconciled.

There are signs that workers will be increasingly responsible for navigating the changes. Recent surveys suggest that, in general, employers prefer to hire contingent workers[74] and are reluctant to invest in training,[75] as labor markets shift and the skills they need among their workforce evolve. Workers, therefore, may bear the burden of developing new skills at their own time and expense. Employers, on the other hand, can choose to manage shifts in the skill sets needed by replacing workers with those who are already trained.

"Credentialing can play an important role in helping to solve the power imbalance between firms and workers during hiring. Firms hold all the cards, which is making it hard for qualified workers to make it into industry without jumping through arbitrary or (sometimes) purposely frustrating hoops. Credentials help bring transparency that levels the playing field."

—Expert interview, Future of Work

NCCER: Example of new tools to help workers plan, track, and verify their skills and credentials across a diverse set of learning and work experiences

National Center for Construction Education and Research (NCCER) develops standardized construction and maintenance curriculum and assessments with portable credentials. These credentials are tracked through NCCER's Registry System that allows organizations and companies to track the qualifications of their craft professionals and/or check the qualifications of possible new hires.

This context raises the importance of equipping workers with better mechanisms for verifying new skills and for comparing these skills and experiences across roles and jobs. Not only is this shift important for helping workers manage the risks of rapidly changing industries, it also presents an important opportunity to provide workers with more negotiating power in the labor market. Currently the prevalence of opaque hiring criteria can put workers at a disadvantage relative to employers. The transparency created by competency-based hiring and enabled by credentials can make it easier for workers to identify and acquire jobs for which they are qualified.

Employers will need to be clear about skills and competencies they are looking for and flexible in terms of where/how workers come to meet these requirements. Workers who must actively chart and navigate a dynamic career need better tools to plan their skills development, pursue formal and informal learning opportunities, and track and verify their skills. Enabling worker success in navigating the labor marketplace will require employers to work in new ways:

- **Clarifying skill and competency requirements.** Firms should develop and communicate clearer expectations regarding which skills and competencies are required for particular roles and what types of development opportunities are available to workers.
- **Recognizing alternate pathways.** Additionally, hiring frontline workers with more complex sets of skills will require employers to reduce their reliance on traditional two- and four-year degrees as employment criteria and find more nuanced ways to assess workers' qualifications.
- **Hiring for potential.** Experts emphasized that hiring for ongoing learning requires a shift from hiring for a specific skill to hiring for a capacity to learn over time.

"The industry is unfortunately still hiring against a qualification versus a competency for the future. Credentialing helps bridge that, but all the applications haven't caught up yet."

—Expert interview, Future of Work

The shift toward these types of competency-based hiring practices is already being pursued through initiatives like the National Network of Business and Industry Associations, which has worked with employers to help them integrate approaches that "link success to mastery of established skill sets, rather than to completing courses that require a rigid set of hours"[76] into their hiring and worker development practices. As technology adoption accelerates, increased transparency and focus around competencies and on-the-job development will become more and more important for attracting the right workers to frontline roles.

Recognized credentials that help workers track and verify their skills could accelerate matching in the marketplace for labor, but there are challenges. Recognized credentials are those developed, monitored, and certified by industry associations. Micro-credentials are digital representations of educational achievements in very specific skills, which can be created and awarded by different types of organizations (e.g., an employer or an online learning platform). Stackable credentials are a series of credentials that can be accumulated to build qualifications, advance one's career, and improve earnings.[h]

"The concept of credentialing is exactly right: Workers need better ways to demonstrate that they have the competencies that are tied to job performance, but the credentials 'system' in the US is convoluted and broken. There are hundreds of credentials, they are largely out of sync with each other, and credentials have low credibility among employers."

—Expert interview, Future of Work

Several barriers stand in the way of credentialing. First, the credentialing ecosystem is convoluted, with hundreds of issuers awarding a broad array of degrees, certificates, certifications, licenses, and micro-credentials. Second, standards are inconsistent. Fewer than 10 percent of certificates are subject to third-party reviews or accreditation.[77] Finally, there is insufficient data or rigorous studies about the value of certification—and mixed evidence of its value[i] in studies that do exist.[78]

[h] While many experts and some employers promote stackable credentials, they seem to have a bigger effect only when individuals earn them before a postsecondary degree, and they often serve as terminal credentials rather than stepping stones to degrees because they do not transfer to degree programs (Cohen et al., 2017).

[i] Evidence suggests that certificates that require long periods of study that are aligned with industry certifications seem to provide more benefit than those that do not (Cohen et al., 2017).

"For credentials to work, they have to be standards-based, nationally portable—in case workers relocate or have to move to a different sub-sector or industry—and industry recognized."

—Expert interview, Workforce Development and Manufacturing

Moreover, certificates may not be transferrable across locations or related industry segments. In our research, this surfaced as a sizable barrier facing workers, particularly in industries like construction and manufacturing that are dominated by SMEs, which are more vulnerable than larger companies to economic shifts and industry developments. Therefore, experts stress the importance of standards-based, industry-recognized, nationally portable credentials.

Credly: Example of using digital credentialing to verify skills and achievements

Credly provides tools to help employers provide and manage digital credentials for their workforce to verify skills and achievements. Employees are able to share their digital credentials over a variety of media to help improve their brand and personal eminence.

There is significant activity in and funding for "fixing" our fragmented credentialing system, with a focus on tools, infrastructure, and system alignment. A shift seems underway in the credentialing ecosystem, with "hundreds of initiatives launched to make credentials more transparent, connected, equitable, navigable, and competency-based."[79] These range from tech startups like Degreed and others, to industry associations such as The Manufacturing Institute's Skills Certification System. Funding for credentialing initiatives has come primarily from private and nonprofit sources, with investments in the following three categories:

1. **Tools,** including the matching platforms referenced above, learning frameworks and pathway maps, and digital learning platforms

2. **Infrastructure,** including human resource systems, data technology standards and systems, and credentialing databases

3. **System alignment,** including better connections between employers and credentialing organizations and shared priorities and approach among organizations

"Lumina has poured millions into the registry of credentials, and now they are funding the clearinghouse. I fear they will become white elephants. I feel that the user community won't take them into account."

—Expert interview, Workforce Development and Manufacturing

Opportunity D: Improve visibility into jobs and career pathways

Overview

Accelerating technology changes and increases in alternative work arrangements (e.g., gig work and contracting) are likely to make workers bear more responsibility for, and more risk associated with, continuous skills upgrades and job transitions. To be able to excel in this dynamic environment and capture the greatest economic value, workers need better guidance on how to navigate the job market and greater ability to align their current and future skills and capabilities to job opportunities. This requires employers and intermediaries to adopt a common language for discussing hiring requirements that goes beyond the standard proxies, and to use integrated platforms that help workers access and compare job opportunities and career pathways.

Why this is important and what is needed

The current labor marketplace is limited by lack of integrated information about job opportunities, skill requirements, and career pathways, which can hurt workers' and employers' bottom lines. Numerous workforce development and industry-specific reports mention that skilled workers today have limited visibility into what job opportunities are available, how their current skills and competencies align to these jobs, what new skills they might need to keep up with a dynamic job market, and how best to develop these skills and competencies.[80]

Limited visibility impedes the ability of workers to enter, navigate, and advance in the construction and manufacturing industries. It may contribute to the mismatch between the supply of and demand for jobs in those industries as well. Furthermore, it limits employers' ability to find the "right" person for the job, which can be costly in terms of job vacancies and mismatches; for example, a 2008 study indicated that the cost of replacing a worker can be as high as 60 percent of an employee's annual salary.[81] According to experts, this problem is likely to worsen with accelerating technology adoption, which is creating new tech-enabled jobs and shifting skill requirements in ways that are generally not well understood.

In a world where workers must actively navigate a dynamic career in construction and manufacturing, they need a common language to describe the necessary skills and better tools to plan their development, align with the market's need, and easily access the jobs that provide the greatest value for the skills they have.

Competency-based hiring shows promise as a common and robust "language" for improved job matching. Competency-based role descriptions and assessment of a worker's qualifications have the potential to be a robust and widespread "language" for improving hiring, according to experts that we spoke with. A rich, standardized, and verifiable set of competencies provides more nuance than a two- or four-year degree and could be a common way for workers to articulate their skill sets. Encouraging firms to describe their roles and hiring needs in the same terms would allow for more precise job matching by making it easier for workers to find the jobs for which they are best qualified.

> "We have validated frameworks that show that competencies can be tied to job performance and can be used to drive hiring and worker development, but this information is not widely generated by employers, updated as roles change, nor used in practice to drive hiring and worker development."
>
> **—Expert interview, Workforce Development**

Experts emphasize that substantial work has already been done to describe current roles in manufacturing (and other fields) using competencies and to validate that these competencies lead to better on-the-job performance. Expanding this approach and creating the data for more roles and job openings could transform the ability of firms and job-matching platforms to place workers.

Several platform solutions are attempting to solve the problem of limited data availability. The lack of integrated and accessible data on labor market needs, job openings, and skill-building opportunities has been well documented in the workforce and skills gap literature. In a recent report describing how technology is changing "matching" in the workforce, JPMorgan mentions at least four types of labor market matching platforms that are attempting to tackle this data challenge:[82]

- **Algorithmic matching technologies** rely on data science and machine learning to identify potential candidates and make precise matching recommendations (e.g., SkillSmart, WorkFountain, and others).
- **Online skills assessments** can be used by employers and job seekers to assess an individual's suitability for a job or career based on job skills, cognitive ability, or behavioral assessments (e.g., Aspiring Minds and others).

- **Skill-building and career development portals** enable individuals to build their skill sets and learn more about potential career paths or vocational opportunities; they often include interest assessments to identify potential career fits and provide information regarding the credentials that are required to obtain these jobs (e.g., LearnUp, Skillful, and others).
- **Online social networks** allow individuals to create profiles and build online personal and professional networks, enabling both active and passive job-matching activity (e.g., WorkHands and others).

While these platforms make the labor marketplace more efficient and accessible, they come with limitations. These types of platform innovations make labor matching more efficient, enable greater access to information, help reduce costs for employers and job seekers, and offer new ways to validate job seekers' skills (e.g., by proving skills through sophisticated tests or enabling coworkers to offer testimonies).

"I wish there was a program that said, 'Given your skills, here are potential job opportunities for you in high-growing industries, and here are ways you could build additional marketable skills through these platforms to make you more competitive for this position.'"

—Expert interview, Workforce Development

Manufacturing Connect: Example of a career pathways program

Manufacturing Connect is a nationally recognized career pathways program that creates and expands the linkages between communities, schools, and opportunity in manufacturing for the benefit of participants and local industry. It arms high school graduates with nationally recognized industrial credentials, work experience in manufacturing, and the technical and soft skills required of them. Its desired outcome is to develop a prototype pathways program for public education that is being embraced by Chicago Public Schools.

But these types of platforms also face challenges associated with data, high burdens of technology adoption for employers and employees, and access issues due to differing digital literacy levels among non-college-educated workers.

To help overcome some of these challenges, the 2017 JPMorgan report recommends the following:

- **Address data availability, validity, and timeliness:**
  - Execute third-party standardization of occupational and skills definitions, which would improve and streamline data collection.
  - Design local tools with local data to ensure that they provide relevant information to local markets.
  - Collect longitudinal data to document job seeker outcomes after using technology, to provide further information about the job market and prove the value of technologies.
- **Address the high burden of tech adoption for employers and job seekers:**
  - Support intermediaries that make it easier for employers and job seekers to navigate the labor market and can reduce the costs associated with adoption (e.g., by identifying sector-specific needs and providing training for job seekers).
  - Continue to invest in tools as well as occupational and skills definitions that ensure useful data undergirds matching technology.
  - Cultivate partnerships among industry and technology experts that improve matching tools and increase the number of firms that adopt the technology.

A crucial element in directing the right talent into and throughout these industries is human support in navigating the labor marketplace (e.g., through mentorship, career coaching, and pathways). In a 2017 white paper titled *Realizing human potential in the fourth industrial revolution,* the World Economic Forum calls for "early exposure to the workplace and ongoing career guidance," specifically highlighting the importance of providing mentorship and career coaching.[83]

Another example of support that has been tested in various states is career pathways programs, which provide education and training in increments that accumulate toward employment opportunities in specific, high-growth occupations, helping employees to achieve credentials with labor market value.[84]

These pathways, which focus on adult learners, are "roadmaps" of the education and training required to attain credentials associated with success in specific industries.[85] There is some evidence that career pathways programs have significant impacts on employment and earnings. To that end, ongoing, rigorous trials of these approaches are underway.[86]

Demand-side: Leveraging human capital opportunity areas

Opportunity E: Shift corporate values

Overview

In the United States, the adoption of new automation technologies has largely been driven by the desire to reduce overall costs and make labor costs more variable, which can adversely affect workers. There is an opportunity to build the business case for "high road" employment models that incorporate investment in worker development and proactive worker involvement in technology adoption and integration decisions. This shift would treat workers as a center of value.

Why this is important and what is needed

With accelerating technology adoption, learning will increasingly need to happen on the job. Indications that, in general, employers prefer to hire contingent workers[87] and are reluctant to invest in training[88] suggest that workers may assume the financial burden of developing new skills. While there is uncertainty about the extent to which these various dynamics will manifest, most experts expect more frequent worker transitions and less stable workforces within organizations.

Speculating about the future of training, several experts suggest that the need for more frequent learning will necessitate on-the-job training to minimize disruption to productivity and help reduce costs associated with frequent workforce turnover.

"High road" business practices that invest in worker development can drive profitability for companies. A growing body of academic research argues that "high road" business practices drive profitability based on increased investment in human capital instead of labor cost-cutting. For example, the research of Susan Helper at Case Western and Zeynep Ton at MIT has helped substantiate the business case for investing in training and retaining workers. Firms that take this approach in manufacturing can achieve gains in productivity through higher capacity utilization and continuous process improvement based on worker knowledge.[89] Nonetheless, this research is still nascent. More research is needed to understand the potential value of investing in worker development for construction and manufacturing firms.

"Construction is at the bottom of the barrel in terms of employer expenditures on training, but the distribution is bimodal."

—Expert interview, Construction

Good Companies, Good Jobs Initiative: Example of how to bridge academia and business to understand the ROI of investing in workers

The MIT Sloan program, Good Companies, Good Jobs Initiative, focuses on building the evidence base for business practices (including in construction and manufacturing) that help improve the quality of work and enhance long-term business value. Focusing on producing research examining the best practices and policies that yield strong financial performance and meaningful jobs, it bridges academics and leaders in the business world in an effort to discuss innovative and lucrative ideas and/or management models.

There is a lot of activity focused on nudging corporations to value workforce development, and several experts point to promising new inroads. Efforts such as the Aspen Institute's UpSkill America initiative and Good Companies, Good Jobs Initiative have taken the lead on translating academic and industry research on the value of investing in workers into practical tools and resources that firms can use. By describing effective approaches such as tuition reimbursement or rotation programs, and highlighting companies and cross-sector initiatives that are employing these approaches, Aspen and others have inspired and empowered firms to invest in their workers in ways that help improve business outcomes.

Another set of approaches has focused on the power of marketplace relationships and risk reduction to promote better employer practices. Numerous experts whom we spoke with emphasized the importance of large OEMs and investors in pushing for workforce development and investment in workers throughout their supply chains and projects. By focusing on risk reduction, these players can build business cases to bolster investments in workers throughout the market, especially by the smaller firms that make up the supplier base. Tools like Working Metrics facilitate how firms assess and track employment practices. Examples like the AFL-CIO's MidWest@Work program demonstrate how investment dollars can be directed to support workers.

Factory_OS and Northern California Carpenters Regional Council Partnership: Example of a partnership among organizations with shared values and goals
The partnership between Factory_OS and Northern California Carpenters Regional Council to employ union workers is an example of how new technology adoption in the construction industry is being paired with commitments to workers, creating shared incentives to find new ways to make human labor more productive using technology.

The opportunity for these types of relationships to positively influence employment practices is further accelerated by broader trends related to creating long-term value rather than short-term returns and encouraging firms to steer their businesses with a clear sense of purpose. One prominent indication of this trend has been the chairman and CEO of BlackRock's recent letters to CEOs. In 2018,[90] Larry Fink exhorted CEOs to focus more on long-term value creation that included their company's environmental, social, and governance practices; employee development; and long-term financial well-being. In his 2019 letter,[91] Fink encouraged CEOs to consider how a clear purpose can drive long-term profits. He also highlighted the importance of companies taking on proactive leadership around employment issues like retirement.

Teachbot: Example of how scalable training technologies can help incumbent workers develop technical skills
Teachbot is an experimental collaboration now underway between ManufacturingUSA and MIT to develop a relatively low-cost robot that independently teaches incumbent workers how to program robotics in manufacturing settings, based on an apprenticeship model.

We believe that trends like these point to ways of leveraging corporate governance, investment dollars, and marketplace relationships to motivate better employment practices and align them to organizations' business objectives.

Moreover, engaging frontline workers in technology adoption and integration decisions helps to create new value for companies. At Autodesk University this year, John Hagel spoke about the need for employers to redefine work and create new value by considering three shifts:

- Shifting opinions on the objective of work: *from efficiency to expanding value delivered to customers and other participants*
- Fundamentally redefining work: *from executing routine tasks to addressing unseen problems and opportunities*
- Cultivating and using our human qualities: *from skills to capabilities*[92]

"One important aspect of this work is to shift the conversation from one that is technologically deterministic to one that sees technology as a tool for shaping the future we want. That's harder than predicting the set of skills, but so important."

—Expert interview, Future of Work

Frontline workers are core to this redefinition of work and value creation. By engaging them more in technology adoption and integration decisions, they can improve decision making and address problems and opportunities as they arrive—all while honing their capabilities across the skills, knowledge, and capabilities pyramid (see the *Supply-side: Challenges to investing in human capital* section on page 12).

Greater engagement may also begin to change the negative narrative around jobs in the construction and manufacturing industries.

Opportunity F: Address needs of SMEs

Overview

Construction and manufacturing are both highly fragmented industries in the United States, with SMEs employing the majority of workers. Because most people in construction and manufacturing work for SMEs, and because SMEs tend to be late adopters of new technology and have less capital available for workforce development, any effort to support workers requires addressing the unique human capital challenges facing SMEs and bolstering their capacity to support their employees as they adopt new technologies.

Why this is important and what is needed

SMEs dominate the US construction and manufacturing industries, but it's typically harder for them to adopt automation technology and implement proactive human practices. SMEs, which employ 84 percent of non-college-educated workers in construction and nearly half of employees in manufacturing,[93] operate at small scales and under tight profit margins. Therefore, investment in technologies, particularly disruptive technologies, is very risky. New technologies fight an uphill battle to be adopted, and the same features of tight profit margins and strong cyclicality may leave frontline workers exposed to business risk.

Massachusetts AIM Photonics Academy: Example of how to involve local SMEs in technology and workforce development

The Massachusetts AIM Photonics Academy is part of a new lab that will involve local SMEs as part of the collaborative effort between advanced manufacturing research labs, student training programs, and work preparedness, giving those firms exposure to advanced technology, potential employees, and new training methodologies.

"One of the three driving forces in US construction is that SMEs run the market. The rhetoric is focused on the big players, but the vast majority is all SMEs."

—Expert interview, Construction

Scalable workforce solutions are needed, but tough economics make risk-tolerant capital to invest in them scarce. Any solution that helps a significant number of workers and employers must be scalable to a large number of firms and flexible enough to meet their varied needs. As such, there is a need for risk-tolerant capital to support startups in developing training and worker development solutions geared toward SMEs and their workers, where customer fragmentation and tight economics might scare off traditional capital and entrepreneurial activity.

Additionally, there is opportunity for philanthropic capital to support market research and prototyping to understand the needs of these enterprises, determine what works, and make these insights broadly available. These efforts could facilitate the growth of an innovation ecosystem that targets SMEs as customers for workforce products and services.

The currently available solutions that seek to address the skills gap challenges of SMEs are limited in scale and evidence. Efforts to meet the needs of SMEs have focused on two distinct approaches. First, as digital technologies change the nature of construction and manufacturing work, academic and commercial efforts are underway to develop training and professional development tools that are scalable to firms of various sizes. For example, the development of modular online training resources and platforms and relatively inexpensive training robots increases the affordability of new modes of training for smaller firms.

The second approach focuses on aggregating the needs of small firms and integrating them into broader initiatives to lower the cost of adopting new technologies and hiring qualified talent. For example, the ManufacturingUSA Institutes have various initiatives to incorporate local SMEs in technology transfer efforts and initiatives to recruit and train talent.

More research is needed to understand the drivers of automation technology adoption in SMEs and the implications for new skills demand and development in these contexts. However, it is clear from our conversations with workforce experts, workers, and managers that solutions need to accommodate the significant heterogeneity of technology use among firms and the economic constraints governing their relationships with talent.

System-level opportunity areas

Opportunity G: Address the social determinants of work

Overview

Workers' ability to adapt to changing technologies and successfully navigate workforce transitions are intricately related to broader issues such as health care and portable benefits, criminal justice reform and its implications on employability, and accessible high-quality early childhood education. There are opportunities to support these issues in ways that improve workers' chance of success in the age of automation.

Why this is important and what is needed

Navigating frequent job and career transitions will likely become the new status quo for workers, but many lack the economic stability to do so. Rather than workers transitioning only when they are hired for or fired from a job in which they are employed for a relatively long period of time, it is expected that workers will shift their jobs and/or careers more frequently in the future. However, according to the Shift: The Commission on Work, Workers, and Technology report, these moments of transition can become crises for workers:

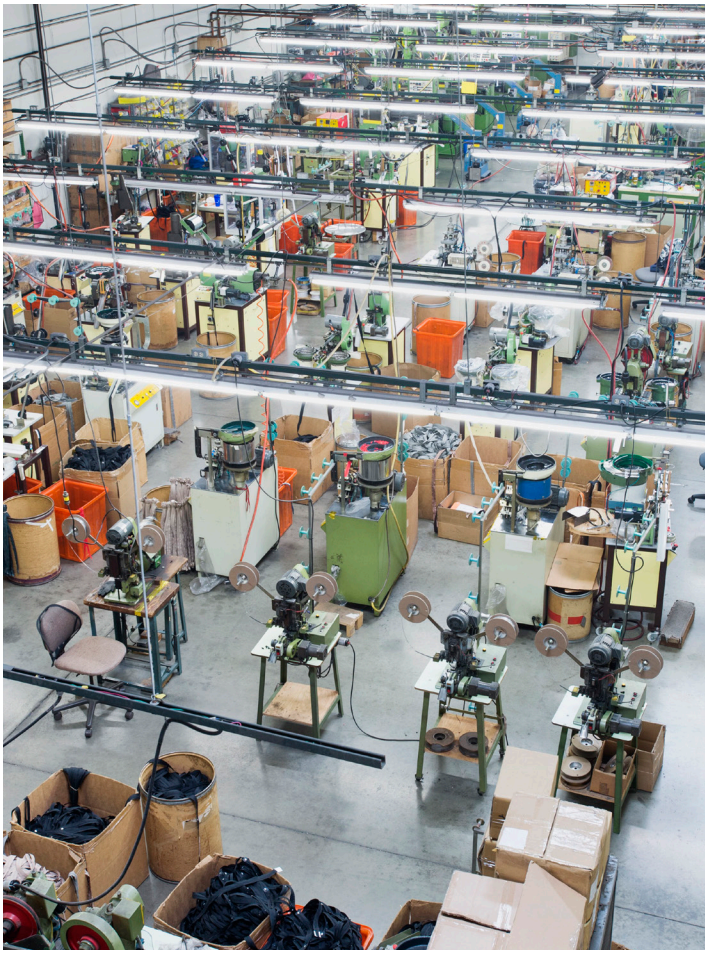
- Most workers value a stable income—and benefits such as health care and retirement—more than making money or having meaningful work.[94]
- In a nationally representative survey, 81 percent of respondents reported they would be unable to handle an unexpected expense of more than $1,000.[95]

There is a need to innovate around the "safety net" supports available to workers, many of which extend beyond typical workforce supports.

The traditional way to think about these workforce transitions from an employer and public perspective has been to provide public "safety nets"—backstops designed to prevent problems when workers are forced to transition. As these transitions become increasingly common, supporting stability for workers will be that much more important. Still, it is unlikely that the current set of public programs will keep up with the pace of change, necessitating new and innovative approaches.

"53% of Americans make varying amounts (or no) money per month, and more than a quarter must cope with income that varies by the week. In the last month, 36% reported receiving income from more than one source."

—Shift: The Commission on Work, Workers, and Technology report



As the National Academies of Sciences, Engineering, and Medicine notes, "Workers who pursue continuing education and training often have a wide range of responsibilities to coordinate along with their studies."[96] These responsibilities cover a range of issues, such as health and family care, and can affect students' ability and willingness to complete education and training. Reconciling these considerations often requires support that goes beyond academic issues. Experts suggested that students need a range of services that are aligned to their needs and that the barriers vary by worker and geographic region. For example, experts in California's Bay Area suggested that the dramatic growth in the cost of housing and living is making it difficult for frontline construction workers to live (and work) in the region, further complicating the industry's ability to find and retain sufficiently skilled workers.

Freelancers Union: Example of a new safety-net model that caters to the needs of gig and independent workers
Freelancers Union is a nonprofit membership organization that offers health insurance and other benefits (through its B-corporation Freelancers Insurance Company) and advocacy for people who work as freelancers, consultants, independent contractors, temps, part-timers, contingent employees, and those who are otherwise self-employed.

Recently, policy proposals from across the political spectrum have explored expansions and adjustments to traditional safety- net programs that aid displaced workers and those transitioning between geographic regions or industries due to disruption. For example, the Obama administration recommended providing financial support for worker retraining and expanding wage insurance.[97] A bipartisan bill introduced in 2014, the American Worker Mobility Act, proposed a lump-sum relocation voucher to assist the long-term unemployed to move to areas of high economic growth.[98] However, these proposals tend to replicate a traditional model of intervention that subsidizes training and lost wages, failing to consider a broader set of supports that address the increasingly transitory nature of work.

Specific subpopulations are particularly vulnerable to these social determinants of work. Attracting new subpopulations, such as veterans, women, and opportunity youth (people aged 16–24 who are neither in school nor working), can be a way to grow the pool of workers in these industries; however, these "surround sound" issues can be particularly constraining to these subpopulations.

"We need to bring opportunity youth into the fold. These proactive approaches have worked in hospitality, and we need to build on those experiences."

—Expert interview, Manufacturing

For example, accessible high-quality early childhood education could help more workers, including women, enter the job market, build skills, and take professional risks. Opportunity youth who are disconnected from both work and school and veterans returning to civilian life could benefit from the full gamut of wraparound supports to help them develop fundamental job-readiness skills, receive health care, and get financial support to take on costly but valuable skills training. These supports are critical for enabling talent from these demographics to access pathways to industry and be able to succeed as they take on new and greater roles.

Operation Next: Example of an organization supporting the transition of veterans into the workforce
Operation Next helps separating military personnel to develop the skills and connections to begin a post-military career in manufacturing. The program enrolls pre-separation military personnel so that they can begin a hybrid online and lab-based learning program immediately after they return from service. The program allows participants to pursue customized learning aligned to specific manufacturing roles and culminates in industry recognized (NIMS) credentials and job-matching support.

These supports often go beyond the scope of any one actor or public authority. However, there are promising examples of how organizations can create cross-sector partnerships to understand the needs of workers and specific subpopulations; develop supports that help workers to prepare for and access opportunities in construction and manufacturing; and help employers understand why those populations are attractive sources of talent and how to adapt their human capital practices to support them.

Opportunity H: Promote cross-sector collaboration

Overview

Coordination across diverse stakeholders at the national, regional, state, and/or local level is a critical success factor for training and connecting workers to jobs. As the construction and manufacturing industries grapple with the speed of technological change and seek to support the success of workers, public, private, and social sector organizations have new opportunities to communicate, share data, and collaborate more frequently and clearly.

Why this is important and what is needed

Workforce development is a complicated collective action challenge and highly fragmented within the United States. The experts we spoke to about cross-sector collaboration unanimously agreed that it is essential to addressing the skills gap in construction and manufacturing. Unfortunately, cross-sector collaboration in the United States is fragmented across many groups, including educators; students; workers; employers; the federal, state, and local governments; labor organizations; and civic associations.

> "The workforce development industry in the United States is broken. The mechanisms we have in place to solve the fragmentation of responsibility are not working, and we need significant effort to make our historical approach of 'letting lots of flowers bloom' coherent."
>
> **—Expert interview, Workforce Development**

Sufficient resources, infrastructure, and accountability are needed to catalyze cross-sector collaboration. For example, labor organizers we spoke with emphasized that overcoming these challenges requires mutual willingness to collaborate. More importantly, there must be mechanisms to hold all parties accountable. In construction, for example, labor organizations must be able to negotiate commitments from building developers to require that their contractors use union labor and apprentices. These mechanisms foster motivation, enforce accountability, and lead to greater work-to-learn opportunities in that industry.

Collaboration is already happening in construction and manufacturing but to very different degrees. Cross-sector collaboration takes many forms in construction and manufacturing. In construction, there are numerous state-level efforts to develop the construction workforce.[j] Initiatives like the Construction Industry Institute are working to coordinate public and private efforts around new technology, workforce development, and other topics. However, the degree to which these initiatives are successful remains unclear.

In manufacturing, cross-sector collaboration is occurring through initiatives like the national ManufacturingUSA network, strategic centers of excellence and employer partnerships at community and technical colleges, and state-level sector employment strategies. Though the types and level of collaboration vary significantly, evaluations suggest that training programs that engage employers have the potential to produce positive outcomes for youth and adults.[99]

[j] See a summary of state-level initiatives at forconstructionpros.com.

AMTEC: Example of a cross-sector workforce initiative focused on upskilling workers

AMTEC is a large, cross-state sector partnership that integrates federal, state, and private investments in skilled technical workforce development. AMTEC was funded by a National Science Foundation grant, but that grant ended in January 2018. Since then it has been funded by the Kentucky Community and Technical College System and has entered into a sustainability phase where it is now generating revenue through its partnerships with industry and community and technical colleges.

The initiative is a collaboration of community and technical colleges and industry partners that aims to prepare technicians and engineers for work in advanced manufacturing and technology. Today it has 22 active community college and technical education partners and 15 industry partners located across eight states. It is actively growing the number of schools and industries that are partnered with AMTEC.

Place-based initiatives are setting the example for tangible and concentrated cross-sector collaboration that puts workforce development in the context of broader public-private priorities. Throughout our research, experts highlighted the importance of place-based collaboration strategies that allow specific actors based in the same local economy to collaborate on specific needs, shared infrastructure, and common economic interests. Some of the most prominent examples of place-based strategies are:

- **ManufacturingUSA Institutes** that concentrate R&D resources in specific advanced manufacturing technologies, which they then use to engage large and small firms and various educational institutions from the local economy. Centered primarily on promoting new technology and commercialization, these centers promote collaboration across firms, link participating firms to new suppliers, coordinate technological roadmapping in new areas, and introduce different industrial sectors to these new technologies.
- **AIM Photonics Academy** (an extension of one of the ManufacturingUSA Institutes) brings together community colleges, universities, employers, and researchers in Massachusetts to use the resources of the institute in providing exposure, training, and certification to the next generation of workers. It uses work-based learning models to connect local employers with potential employees able to work in cutting-edge photonic manufacturing.

While effective, these collaborations are resource-intensive. Continued work is needed across manufacturing and construction to identify the most effective and scalable models for collaboration.

Collaborations can also be bolstered by connecting them to national priorities. Our research and conversations with experts highlighted the relationship between issues like national security, job creation, and economic growth in driving increased public and private collaboration around manufacturing, especially advanced manufacturing. This interest in manufacturing has had a positive effect on addressing workforce development challenges and has created the impetus for increased collaboration around the issue. Construction, on the other hand, has not been prioritized nationally, contributing to a lack of broad or well-resourced efforts to drive collaboration.

Given the distribution of responsibility, layers of activity around workforce development are important for achieving outcomes. Experts highlighted the emergence and importance of overlapping efforts from different actors in providing the "layers" of support needed to address workforce development challenges at the ecosystem level. For example, California has a statewide strategy,[100] and experts we spoke with mentioned a number of regional strategies focused on workforce development. These strategies share common objectives but are not necessarily coordinated. Also, specific partnerships between individual firms and local community colleges often overlap with state-level strategies and industrywide initiatives to engage education institutions.

This redundancy and complexity creates confusion among workers, employers, and other stakeholders. However, in the absence of an overarching national framework for collaboration, this layered approach provides important resiliency. Moreover, it enables experimentation and allows initiatives to be customized to the needs of different regions and industries. In its 2018 Strategic Plan for Advanced Manufacturing, the White House emphasized that, "This lack of coordination makes it crucially important to support secondary-to-postsecondary CTE, project-based curricula, competency-based training, career pathways, and self-directed learning programs."[101] Developing scalable models, tools, and resources that can be adapted by different types of collaborative efforts is critical for improving the overall impact of a fragmented ecosystem.

ShiftLabs: Example of a community-sponsored collaboration to address emerging challenges for workers in the future

ShiftLabs is a community design lab run by New America, with initial support from the Rockefeller Foundation. ShiftLabs works in partnership with communities across the United States to diagnose automation risk in their region, surface potential responses to prepare for the future of work, and design and experiment with new, innovative ways to help workers connect to opportunity.

Finally, better sharing of information at the industry and national level is critical for coordinating efforts across sectors. Better public information and data are essential in coordinating workforce efforts across construction and manufacturing. In its recent report on US manufacturing, the Century Foundation summarizes the importance of increased collaboration among state agencies to "produce and use timely, accurate labor market information, provide up-to-date analysis of industry sectors, and support strategic planning that meets worker and employer needs."[102] Similarly, there is a growing need for collaboration between industry and the private sector to determine what skills will be needed as technology adoption accelerates the pace of change.

Creating timely, transparent, and accessible information for consumption is an indirect means of increasing coordination among the many layers working on workforce development. Additionally, leading public sector and industry organizations should make their expertise regarding workforce needs and models of collaboration available during the research, planning, and implementation phases of sectoral partnerships.[103]

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Endnotes

1. Bureau of Labor Statistics, May 2017 National Occupational Employment and Wage Estimates by ownership, Department of Labor, May 2017, https://www.bls.gov/oes/2017/may/000001.htm#00-0000.
2. Statista, Forecast on the Degree of Urbanization in the United States from 2000 to 2050, May 2018, https://www.statista.com/statistics/678561/urbanization-in-the-united-states/.
3. Homi Kharas and Kristofer Hamel, "A global tipping point: Half the world is now middle class or wealthier," Brookings Institute, September 27, 2018, https://www.brookings.edu/blog/future-development/2018/09/27/a-global-tipping-point-half-the-world-is-now-middle-class-or-wealthier/.
4. ASCE, Current Infrastructure Needs by System Based on Current Trends, Extended to 2025, 2017 Infrastructure Report Card, https://www.infrastructurereportcard.org/the-impact/economic-impact/.
5. USGCRP, 2018: Impacts, Risks, and Adaptation in the United States: *Fourth National Climate Assessment,* Volume II, U.S. Global Change Research Program. DOI: 10.7930/NCA4.2018.
6. Robert E. Scott, *Trading away the manufacturing advantage: China trade drives down US wages and benefits and eliminates good jobs for US workers*, Economic Policy Institute Briefing Paper #367, September 30, 2013, https://www.epi.org/files/2013/trading-manufacturing-advantage-china-trade.pdf.
7. Robert E. Scott, *The manufacturing footprint and the importance of US manufacturing jobs*, Economic Policy Institute Briefing Paper #388, January 22, 2015, https://www.epi.org/files/2015/bp388-manufacturing-footprint.pdf.
8. CPWR Data Center, "Educational attainment and internet usage in construction and other industries," *The Construction Chart Book: The U.S. Construction Industry and Its Workers* (6th ed.), February 2018, https://www.cpwr.com/chart-book-6th-edition-education-and-training-educational-attainment-and-internet-usage-construction.
9. National Skills Coalition, "United States' Middle-Skill Jobs" fact sheet, 2015, https://www.nationalskillscoalition.org/resources/publications/2017-middle-skills-fact-sheets/file/United-States-MiddleSkills.pdf.
10. James Manyika et al., *Jobs lost, jobs gained: What the future of work will mean for jobs, skills, and wages*, McKinsey Global Institute, November 2017, https://www.mckinsey.com/featured-insights/future-of-work/jobs-lost-jobs-gained-what-the-future-of-work-will-mean-for-jobs-skills-and-wages#part4.
11. Lisa Neuberger-Fernandez, Christopher Chu, and Allison Horn, *Inclusive future of work: A call to action*, Accenture, 2018, https://www.accenture.com/_acnmedia/PDF-90/Accenture-Inclusive-Future-Of-Work-Full-Report.pdf#zoom=50.
12. Andrew Soergal, "Where are all the builders?" *US News & World Report*, The Civic Report, June 15, 2018, https://www.usnews.com/news/the-report/articles/2018-06-15/the-us-construction-industry-is-booming-but-where-are-the-builders.
13. Craig Giffi et al., *2018 Deloitte and The Manufacturing Institute skills gap and future of work study*, Deloitte Insights and The Manufacturing Institute, 2018, http://www.themanufacturinginstitute.org/~/media/E323C4D8F75A470E8C96D7A07F0A14FB/DI_2018_Deloitte_MFI_skills_gap_FoW_study.pdf.
14. Soergal, "Where are all the builders?"
15. Giffi et al., *2018 Deloitte and the Manufacturing Institute skills gap and future of work study.*
16. IBISWorld, Construction Industry in the U.S., June 2018, https://www.ibisworld.com/industry-trends/market-research-reports/construction/construction.html.
17. IBISWorld, Manufacturing Industry in the U.S., 2018, https://www.ibisworld.com/industry-trends/market-research-reports/manufacturing/.
18. Giffi et al., *2018 Deloitte and the Manufacturing Institute skills gap and future of work study.*
19. CPWR Data Center, "Worker age in construction and other industries," *The Construction Chart Book: The U.S. Construction Industry and Its Workers* (6th ed.), February 2018, https://www.cpwr.com/chart-book-6th-edition-labor-force-characteristics-worker-age-construction-and-other-industries.
20. Giffi et al., *2018 Deloitte and the Manufacturing Institute skills gap and future of work study.*
21. Ibid.
22. Bureau of Labor Statistics, Seasonally Adjusted Unemployment Rate (Jan. 2008 – Dec. 2018), Department of Labor, https://data.bls.gov/timeseries/lns14000000, accessed January 29, 2019.
23. Bureau of Labor Statistics, Seasonally Adjusted Labor Force Participation Rate (Jan. 2008 – Dec. 2018), Department of Labor, https://data.bls.gov/timeseries/lns11300000, accessed January. 29, 2019.
24. Drew Desilver, "For most U.S. workers, real wages have barely budged in decades," The Pew Research Center: Fact Tank, August 7, 2018, https://www.pewresearch.org/fact-tank/2018/08/07/for-most-us-workers-real-wages-have-barely-budged-for-decades/.
25. Ibid.
26. Ibid.
27. Associated General Contractors of America, *The Workforce Development Plan 2.0*, October 2018, https://www.agc.org/sites/default/files/Files/Communications/Workforce_Development_Plan_2.0_FINAL.pdf.
28. Till Zupancic et al., "Future scenarios and implications for the industry," *Shaping the future of construction*, World Economic Forum and The Boston Consulting Group, March 2018, http://www3.weforum.org/docs/Future_Scenarios_Implications_Industry_report_2018.pdf.
29. Ibid.
30. Robert E. Scott, "We still haven't recovered well-paying construction and manufacturing jobs," Economic Policy Institute, August 16, 2017, https://www.epi.org/publication/we-still-havent-recovered-good-paying-construction-and-manufacturing-jobs/.
31. ADP, Workforce Vitality Report, Third Quarter 2018.
32. CPWR Data Center, "Worker age in construction and other industries."
33. Manufacturing Institute, Median Age of the Manufacturing Workforce, October 2013, http://www.themanufacturinginstitute.org/Research/Facts-About-Manufacturing/Workforce-and-Compensation/Median-Age/Median-Age.aspx.
34. Bureau of Labor Statistics, *Women in the labor force: A databook*, Report 1071, United States Department of Labor, November 2017, https://www.bls.gov/opub/reports/womens-databook/2017/home.htm.
35. Ibid.
36. Neuberger-Fernandez et al., *Inclusive future of work: A call to action.*
37. National Academies of Sciences, Engineering, and Medicine, "Key lessons for programs and policies," *Building America's skilled technical workforce* (Washington, DC: The National Academies Press, 2017), https://www.nap.edu/read/23472/chapter/8, pp. 123–66.

38. David W. Perkins, "Declining Dynamism in the U.S. Labor Market," CRS Insight, June 15, 2016, https://fas.org/sgp/crs/misc/IN10506.pdf.

39. Lawrence F. Katz and Alan B. Krueger, "The rise and nature of alternative work arrangements in the United States, 1995–2015," *ILR Review*, 72, no. 2 (2019): pp. 382–416.

40. Bureau of Labor Statistics, May 2017 National Industry-Specific Occupational Employment and Wage Estimates, United States Department of Labor, May 2017, https://www.bls.gov/oes/2017/may/oessrci.htm.

41. National Academies of Sciences, Engineering, and Medicine, "Challenges in developing a skilled technical workforce," *Building America's skilled technical workforce* (Washington, DC: The National Academies Press, 2017), https://www.nap.edu/read/23472/chapter/7, pp. 93–122.

42. Till Alexander Leopold, Vesselina Stefanova Ratcheva, and Saadia Zahidi, *The Future of Jobs Report 2018*, World Economic Forum, September 17, 2018, http://www3.weforum.org/docs/WEF_Future_of_Jobs_2018.pdf, accessed October 17, 2018.

43. Anne-Marie Slaughter, Roy Bahat, and Kristin Sharp, *Report of findings*, Shift: The Commission on Work, Workers, and Technology, May 16, 2017, https://shiftcommission.work/findings-of-shift-the-commission-on-work-workers-and-technology-a071bc169df0.

44. Bureau of Labor Statistics, Labor Productivity and Costs, United States Department of Labor, May 2018, https://www.bls.gov/lpc/.

45. Cardiff Garcia, "The remarkable productivity stagnation of the US construction sector," *Financial Times*, April 15, 2014, https://ftalphaville.ft.com/2014/04/15/1821522/the-remarkable-productivity-stagnation-of-the-us-construction-sector/.

46. Economic Wide Statistics Division, County Business Patterns: 2015, United States Census Bureau, https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=BP_2015_00A1&prodType=table.

47. Ibid.

48. Jose Luis Blanco et al., "Seizing opportunity in today's construction technology ecosystem," McKinsey & Company, September 2018, https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/seizing-opportunity-in-todays-construction-technology-ecosystem.

49. Darrell M. West, "How technology is changing manufacturing," Brookings Institute, June 2, 2016, https://www.brookings.edu/blog/techtank/2016/06/02/how-technology-is-changing-manufacturing/.

50. Jacob Bogage, "What wages really look like in American manufacturing," *Washington Post*, March 7, 2016, https://www.washingtonpost.com/news/business/wp/2016/03/07/what-wages-really-look-like-in-american-manufacturing/?noredirect=on&utm_term=.c58c17a2d12c.

51. Leopold et al., *The Future of Jobs Report 2018*.

52. Kevin Roose, "The hidden automation agenda of the Davos elite," *New York Times*, January 25, 2019, https://www.nytimes.com/2019/01/25/technology/automation-davos-world-economic-forum.html.

53. National Academies of Sciences, Engineering, and Medicine, "Key lessons for programs and policies."

54. Craig Giffi et al., *2018 Deloitte and The Manufacturing Institute skills gap and future of work study.*

55. Soergal, "Where are all the builders?"

56. National Academies of Sciences, Engineering, and Medicine, "Key lessons for programs and policies."

57. Sheila Maguire et al., *Tuning in to local labor markets*, Public/Private Ventures, July 2010, http://www.aspenwsi.org/wordpress/wp-content/uploads/TuningIntoLocalLaborMarkets.pdf; Anne Roder and Mark Elliott, *Sustained gains: Year Up's continued impact on young adults' earnings*, Economic Mobility Corporation, May 2014, https://economicmobilitycorp.org/wp-content/uploads/2018/01/Sustained-Gains-Summary.pdf.

58. Robert I. Lerman, *Can the United States expand apprenticeship? Lessons from experience*, Policy Paper No. 46, IZA Institute of Labor Economics, September 2012, http://ftp.iza.org/pp46.pdf.

59. Deloitte analysis based on Department of Labor's Registered Apprenticeship National Results Fiscal Year 2017, https://doleta.gov/oa/data_statistics2017.cfm.

60. Katie Spiker, "DOL releases funding to expand apprenticeship and work-based learning," National Skills Coalition, Skills Blog, July 18, 2018, https://www.nationalskillscoalition.org/news/blog/dol-releases-funding-to-expand-apprenticeship-and-work-based-learning.

61. Jeffrey Zients, "Expanding apprenticeships to invest in American workers," White House Blog, Obama White House Website Archive, September 10, 2015, https://obamawhitehouse.archives.gov/blog/2015/09/10/expanding-apprenticeships-invest-american-workers.

62. Ibid.

63. National Academies of Sciences, Engineering, and Medicine, "Key lessons for programs and policies."

64. Research Team 335, *Improving the U.S. workforce development system: Annual conference edition*, Final Report 335, Construction Industry Institute, Conference 2018, July 2018, https://www.construction-institute.org/CII/media/Publications/publications/fr-335_ac18.pdf.

65. Till Alexander Leopold, Aditi Trehan, and Saadia Zahidi, *Realizing human potential in the fourth industrial revolution: An agenda for leaders to shape the future of education, gender and work*, World Economic Forum, January 2017, http://www3.weforum.org/docs/WEF_EGW_Whitepaper.pdf.

66. National Academies of Sciences, Engineering, and Medicine, "The complex U.S. system of workforce education and training," *Building America's skilled technical workforce* (Washington, DC: The National Academies Press, 2017), https://www.nap.edu/read/23472/chapter/6, pp. 63–92.

67. Rose Quint, "Young adults & the construction trades," National Association of Home Builders, Home Eye On Housing, April 19, 2017, http://eyeonhousing.org/2017/04/young-adults-the-construction-trades/.

68. Craig Giffi, Michelle Drew Rodriguez, and Sandeepan Mondal, *A look ahead: How modern manufacturers can create positive perceptions with the US public*, Deloitte and The Manufacturing Institute, 2017, http://www.themanufacturinginstitute.org/~/media/9607397D3AFC423AB68133505EE2C348/2017_US_Public_Perception_Manufacturing_Study.pdf.

69. Deloitte analysis based on US Bureau of Labor Statistics from the current population survey.

70. William H. Frey, "The U.S. will become 'minority white' in 2045, Census projects," Brookings Institute, March 14, 2018, https://www.brookings.edu/blog/the-avenue/2018/03/14/the-us-will-become-minority-white-in-2045-census-projects/.

71. Annie Neimand, "How to tell stories about complex issues," *Stanford Social Innovation Review*, May 7, 2018, https://ssir.org/articles/entry/how_to_tell_stories_about_complex_issues.

72. Mark C. Long, Dan Goldhaber, and Nick Huntington-Klein, *Do students' college major choices respond to changes in wages?* Center for Educational Data & Research, Working Paper 2014-6, 2014, http://www.cedr.us/papers/working/CEDR%20WP%202014-6.pdf.

73. Kimberly Hegeman, "Nationwide initiatives work to recruit construction laborers," *For Construction Pros,* July 27, 2015, https://www.forconstructionpros.com/business/business-services/article/12092760/nationwide-initiatives-work-to-recruit-construction-laborers.

74. National Academies of Sciences, Engineering, and Medicine, "Challenges in developing a skilled technical workforce."

75. Leopold et al., *The Future of Jobs Report 2018*.

76. National Network, *Learning while working: Building 21st century competency-based apprenticeships*, July 22, 2014, http://nationalnetwork.org/wp-content/uploads/2015/05/Competency_Based_Models-03-30-151.pdf.

77. National Academies of Sciences, Engineering, and Medicine, "Challenges in developing a skilled technical workforce."

78. Ibid.

79. The Competency Project, *The state of credentialing*, 2018, http://thecompetencyproject.com/state-of-credentialing/.

80. See, for example, JPMorgan's 2017 report, *Swiping right for the right job*, and Accenture's 2018 report, *Bridging the skills gap for the future workforce*.

81. JPMorgan Chase & Co., *Swiping right for the job: How tech is changing "matching" in the workplace*, 2016, https://www.jpmorganchase.com/corporate/Corporate-Responsibility/document/nsaw-tech-training-report-web.pdf.

82. Ibid.

83. Leopold et al., *Realizing human potential in the fourth industrial revolution.*

84. Career Pathways, "About career pathways," Abt Associates, http://www.career-pathways.org/about-career-pathways, accessed October 2018.

85. National Academies of Sciences, Engineering, and Medicine, "Key lessons for programs and policies."

86. Ibid.

87. National Academies of Sciences, Engineering, and Medicine, "Challenges in developing a skilled technical workforce."

88. Leopold et al., *The Future of Jobs Report 2018*.

89. Susan Helper, *Renewing U.S. manufacturing: Promoting a high-road strategy*, Economic Policy Institute Briefing Paper #212, February 13, 2008, http://www.sharedprosperity.org/bp212/bp212.pdf.

90. Larry Fink, "Larry Fink's 2018 letter to CEOs: A sense of purpose," BlackRock, 2018, https://www.blackrock.com/corporate/investor-relations/2018-larry-fink-ceo-letter.

91. Larry Fink, "Larry Fink's 2019 letter to CEOs: Profit & purpose," BlackRock, 2019, https://www.blackrock.com/corporate/investor-relations/larry-fink-ceo-letter.

92. John Hagel, John Seely Brown, and Maggie Wooll, "Can we realize untapped opportunity by redefining work?," Deloitte Insights, October 24, 2018, https://www2.deloitte.com/insights/us/en/focus/technology-and-the-future-of-work/redefining-work-organizational-transformation.html.

93. Deloitte analysis of data from the US Census Bureau 2015, American Community Survey (ACS), Comparing 2015 American Community Survey Data, https://www.census.gov/programs-surveys/acs/guidance/comparing-acs-data/2015.html.

94. Ibid.

95. Ibid.

96. National Academies of Sciences, Engineering, and Medicine, "Challenges in developing a skilled technical workforce."

97. Jeffrey Zients and Jason Furman, "New reforms to strengthen support for unemployed workers," White House Blog, Obama White House Website Archive, January 16, 2016, https://obamawhitehouse.archives.gov/blog/2016/01/16/new-reforms-strengthen-support-unemployed-workers, accessed January 8, 2019.

98. Roll Call, "Improving worker mobility will help fix the economy: Commentary," February 12, 2014, https://www.rollcall.com/news/improving_worker_mobility_will_help_fix_the_economy_commentary-230859-1.html.

99. Sheila Maguire et al., *Tuning in to local labor markets*; Roder et al., *Sustained gains: Year Up's continued impact on young adults' earnings*.

100. California Workforce Development Board, *Skills attainment for upward mobility; aligned services for shared prosperity*, California's Unified Strategic Workforce Development Plan under the Workforce Innovation and Opportunity Act (WIOA) for Program Years 2016–2019, https://cwdb.ca.gov/wp-content/uploads/sites/43/2017/12/Unified-State-Plan-plain-text.pdf.

101. Subcommittee on Advanced Manufacturing Committee on Technology of the National Science & Technology Council, *Strategy for American Leadership in Advanced Manufacturing*, Executive Office of the President of the United States, October 2018, https://www.whitehouse.gov/wp-content/uploads/2018/10/Advanced-Manufacturing-Strategic-Plan-2018.pdf.

102. Joel S. Yudken, Thomas Croft, and Andrew Stettner, "Revitalizing America's manufacturing communities," The Century Foundation, October 16, 2017, https://tcf.org/content/report/revitalizing-americas-manufacturing-communities/?agreed=1.

103. Ibid.

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