How the Modular Construction Industry Is Changing the Construction Workforce

Sarah Truitt[1], Julia Sullivan[1], Sletsy Dlamini[1], Julia Day[2], Shelby Ruiz[2], Donna Laquidara-Carr[3], and Dana Gilmore[3]

[1] National Renewable Energy Laboratory
[2] Washington State University
[3] Dodge Construction Network

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Technical Report

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List of Acronyms

HVAC	heating, ventilation, and air conditioning
MBI	Modular Building Institute
MEP	mechanical/electrical/plumbing
NCCRC	Northern California Carpenters Regional Council
NREL	National Renewable Energy Laboratory

Executive Summary

The modular construction industry has been gaining market share in North America, growing from just 2.1% of new construction starts in 2015 to 6.64% in 2023 (Modular Building Institute 2024). Questions about the impact this growth may have on existing construction workers were the impetus for this study.

This study examines how the increasing adoption of volumetric and panelized modular building systems changes the nature of work for the construction industry and analyzes the impacts the industry's growth may have on workers. The research questions guiding the authors' inquiries include:

- Where are the opportunities for new skills, job categories, or occupations related to modular construction, and in what scenarios?
- Where are the dislocations (e.g., what job categories may be displaced, in less demand, or relocated from the jobsite) and in what scenarios?
- What training exists, and what training needs to be put in place?
- Where are the opportunities to expand the workforce to include a wider pool of workers?
- How can we best prepare the workforce to adapt to and benefit from modular construction?
- How will working conditions and wages evolve under different scenarios of modular construction?

Key findings are a result of the mixed-methods research approach that included a national survey of 312 companies and 30 in-depth interviews.

Key Findings

- The number of workers on a construction jobsite is not anticipated to change meaningfully with an increase in the adoption of modular construction practices, although minor shifts in certain professions are anticipated.
- General contractors, crane operators, and transportation and logistics companies are the top three professions anticipated to benefit most from an increase in modular construction.
- Specialty trade contractors, general laborers, and design/architecture firms are the top three professions anticipated to be most negatively impacted.
- Framing contractors; plumbing and heating, ventilation, and air-conditioning professionals; and drywall, insulation, and siding contractors are anticipated to decline most on construction jobsites as more modular construction methods are used.
- Many of the specialty trade professions anticipated to decline on construction sites due to the adoption of more modular construction practices are in demand in modular construction factories.
- While manufacturers believe contractors are better prepared than contractors view themselves, manufacturers also believe (more so than contractors) that more training is necessary for contractors to become proficient with their products.
- Most contractors do not see a major shift in the skill sets needed on the jobsite to implement a modular construction project, and they do not believe it takes much training (a few days to a few weeks) to become proficient in modular construction implementation.
- Lack of training and understanding of the modular construction process are cited as some of the biggest barriers to adoption among those who have implemented modular construction projects and among those who have not.
- Construction firms adopting modular construction practices report positive impacts on wages, benefits, working conditions, schedule changes, productivity, and safety.
- Building codes are not seen as a significant barrier to the adoption of panelized and volumetric modular products.
- Modular construction has not yet had a significant impact on expanding employment opportunities to a wider population who may not have been compatible with the physical demands of a conventional construction job.

Many of the findings in this study show whether the construction and manufacturing industries are aligned in their views of the modular construction industry. Findings from this work provide insight into the impact that adopting more modular construction methods is expected to have on workers and the potential change to the composition of the construction workforce in the future. This information can enable better decision-making by leaders in the conventional and modular construction industries.

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Introduction

According to Associated Builders and Contractors (2024), the construction industry will need to add more than 500,000 jobs in addition to normal hiring to meet labor demand estimates. In a recent survey conducted by the Associated General Contractors of America, 88% of contractors reported having open positions and are facing challenges filling positions. This shortage of workers is contributing to project delays and cost overruns (Associated General Contractors of America 2023). Many companies are turning to modular construction methods to help alleviate the impacts of the worker shortage because they perceive these methods require fewer people than conventional on-site construction. Modular construction involves constructing buildings off-site, often in a factory-controlled environment, then transporting them to the final site for assembly, incorporating elements of both the construction and manufacturing industries (Modular Building Institute [MBI] 2024).

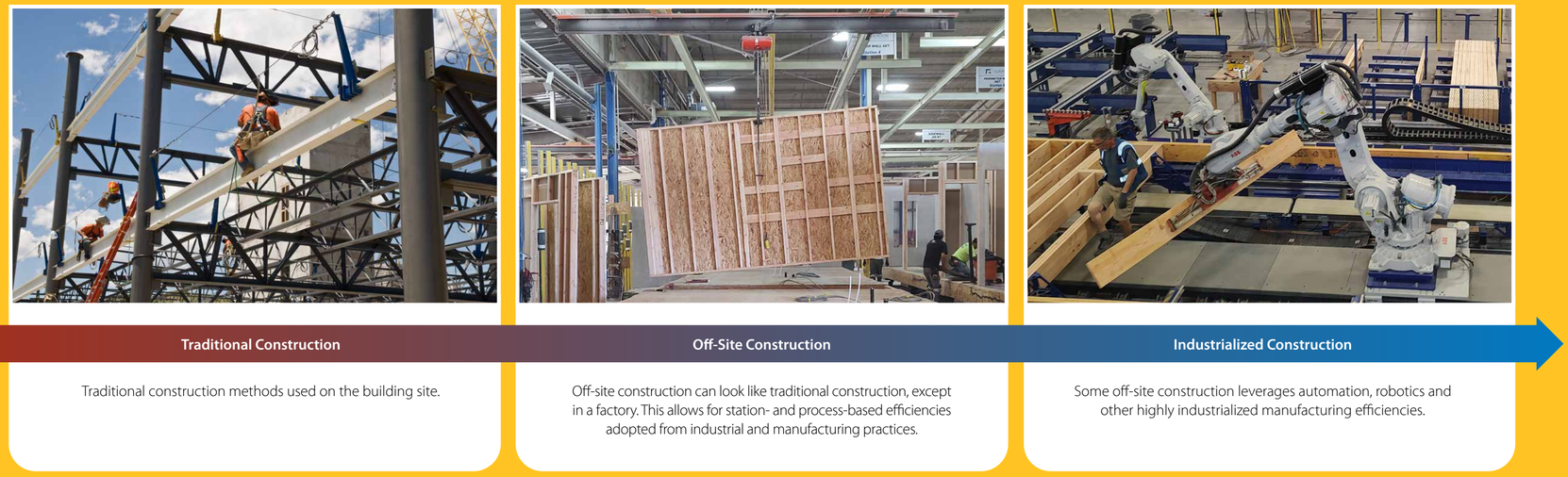

Figure 1. Evolution of construction work from conventional to industrialized construction methods

Photo 1: A conventional construction approach for building a structure from the ground up. *Photo by the National Renewable Energy Laboratory (NREL) 16440.* Photo 2: Construction taking place off-site in a factory where workers manually build wall assemblies at stations on an assembly line. *Photo by Julia Sullivan, NREL 100878.* Photo 3: Robotic arm in a highly automated, industrialized modular factory. *Photo courtesy Autovol, Inc.*

Modular construction products include a range of prefabricated items such as stairs, wall panels, floor panels, roof trusses, room-size components (i.e., bathroom or kitchen pods), and even entire apartment units. This study looks at two product categories: volumetric modular and panelized modular units. For the purposes of this study, the authors define these product categories as follows:

Volumetric modular components, systems, or buildings use three-dimensional modules in the form of pods, bathroom modules, temporary modular mechanical pods, or volumetric modular units to create building systems or buildings.

Panelized modular systems include wall panels, mechanical, electrical, and/or plumbing (MEP)-integrated walls, structurally insulated panels, cross-laminated timber, wall assemblies, curtain walls, flat-packed construction assemblies, and precast/prestressed concrete walls.

A recent report from the Modular Building Institute estimates there are 255 modular factories in North America spanning a wide range of automation levels, from relying primarily on conventional construction methods in an assembly line/factory setting (referred to as off-site construction) to highly automated and robotic systems (referred to as industrialized construction) and everything in between (MBI 2024). For this study, authors refer to the range of methods from largely manual off-site construction to highly automated factory-line construction as **modular construction.**[1]

[1] Note, this definition relates only to manufacturing and does not consider technologies used at the build site to assist with construction.

The modular construction industry has been gaining market share in North America, growing from just 2.1% of new construction starts in 2015 to 6.64% in 2023 (MBI 2024). Concerns and questions regarding the impact of modular construction methods on existing construction workers are arising as the industry's market share continues to grow.

This study examines how the increasing adoption of volumetric and panelized modular building systems changes the nature of work for the construction industry and analyzes the impacts the industry's evolution may have on workers.

The following research questions guided this study:

- Where are the opportunities for new skills, job categories, or occupations related to modular construction, and in what scenarios?
- Where are the dislocations (i.e., what job categories will be displaced) and in what scenarios?
- What training exists, and what training needs to be put in place?
- Where are the opportunities to expand the workforce to include a wider pool of workers?
- How can we best prepare the workforce to adapt to and benefit from modular construction?
- How will working conditions and wages evolve under different scenarios of modular construction?

Results from this work provide transparency into how the adoption of more modular construction methods is expected to impact workers and potentially change the composition of the construction workforce in the future. This information can inform decision-making by leaders in the conventional and modular construction industries and by public policymakers.

Photo courtesy Autovol, Inc.

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Methodology

This mixed-methods study used qualitative and quantitative data collection in a phased approach, including a literature review, a stakeholder input session, 30 in-depth interviews with industry leaders, and a national survey of 312 individuals from companies involved in the conventional and modular construction industries (Figure 2). Research questions were based on an initial literature review of 30 reports and stakeholder input through individual and group discussions. In-depth interviews completed between June and October 2023 helped us refine our research questions and develop the survey questions, which were issued in November and December 2023. A more detailed description of the methodology is included in Appendix A.

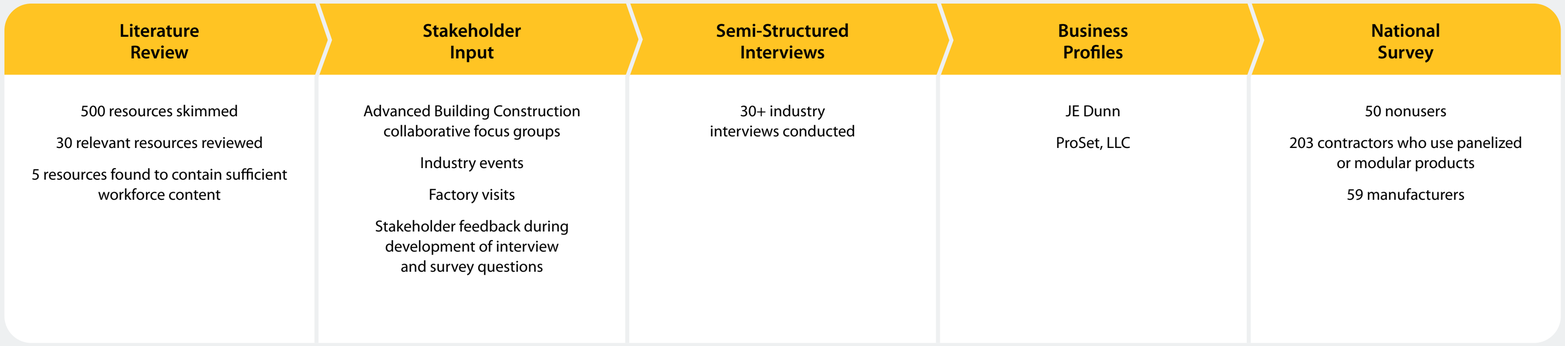


Figure 2. Methodology

A literature review helped identify the initial research questions and scope for this study. An initial scan of 500 reports and articles was narrowed to 30 based on relevancy to the workforce topic. Of all 30 resources reviewed, none presented a comprehensive picture of how modular construction is changing the nature of work and the associated impacts on the construction workforce. Furthermore, all resources focused on the off-site and factory-based workforce, without considering how the full construction workforce ecosystem may evolve as a result of the increasing adoption of prefabricated building components, systems, and modules. Stakeholder input gathered through a focus-group-style webinar helped refine the research questions and scope of the study.

With information gathered through the literature review and stakeholder input, researchers put together interview and survey procedures and questions. In accordance with federal guidelines on human subjects research, the procedures and questions were reviewed and approved by a participating Institutional Review Board through Washington State University's Human Research Protection Program Office of Research Assurances.

2.1 Interviews

Interview questions were semi-structured and targeted toward participant type. For example, modular manufacturers and construction companies received different questions that directly related to their expertise, experiences, and share of work in a project. Interviews lasted, on average, 60 minutes, and they were recorded with participant consent (via Zoom) and securely stored. After data collection concluded in early October 2023, raw interview audio recordings were securely downloaded, stored on an encrypted access-restricted server, and transcribed. Once the interviews were transcribed and identifying information was removed, the transcripts were coded and analyzed to identify themes, perceptions, and meaningful findings using the Saldaña and Kawakita affinity diagramming methods of qualitative coding (Kawakita 1982; Saldaña 2021). Findings from the interview phase helped the team understand some of the challenges in the modular construction industry and helped inform the survey questions for a national survey that was issued in November 2023.

2.2 Survey

The survey was designed for two participant groups: modular manufacturers and conventional construction companies. Research data were collected using two separate national survey panels via the survey platform Forsta. Dodge Construction Network conducted the survey from Nov. 14, 2023, to Dec. 18, 2023.

2.3 Limitations

While these results provide important insights into the modular construction workforce, various aspects of the survey created limitations in terms of its generalizability to the broader population and industry. The results reported throughout this report represent the views and experiences of those who chose to participate in the interviews or survey but not the views and experiences of the wider industry.

The survey portion of this research has four known potential sources of error, due to the limited scope of the survey:

Coverage Error: The extent to which the surveyed population represents the total population is difficult to determine. Not everyone in the target audience had the opportunity to answer due to the panel structure, and the sample frame (panel) may not be representative of the population.

Measurement Error: Survey results can be affected by misinterpreted questions, incomplete answers, unclear questions, ambiguous questions and wording, and vague or improper response options.

Sampling Error: Randomness of sampling means that confidence in the robustness of the sample is impossible.

Nonresponse Errors: Incomplete or absent responses to questions create uncertainty about how different those answers might be compared to those who did respond.

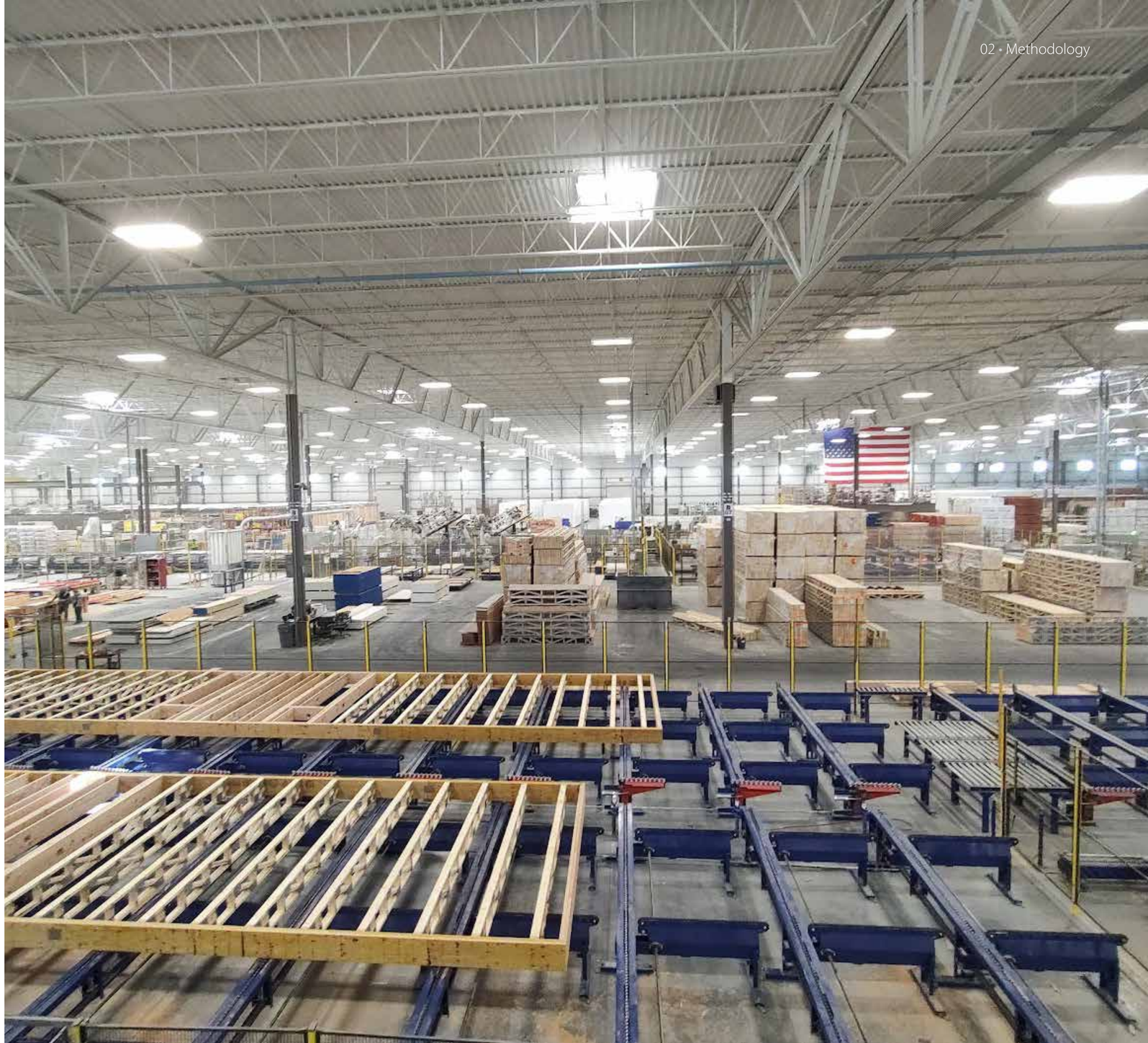


Photo courtesy Autovol, Inc.

03

Survey Participants

Overall, 312 survey participants provided responses, including 50 who do not use either panelized or volumetric modular products or methods (Figure 3). Participant perspectives are broken out by company type, shown in Figure 4. Respondents were asked to indicate which category best describes their company.

312
INDUSTRY MEMBERS SURVEYED

- **50** NONUSERS
  - **32** GENERAL CONTRACTORS
  - **18** SPECIALTY CONTRACTORS
- **203** CONTRACTORS WHO USE PANELIZED OR MODULAR PRODUCTS
  - **151** GENERAL CONTRACTORS
    - **17** DESIGN-BUILD CONTRACTORS
    - **134** GENERAL CONTRACTORS
  - **46** SPECIALTY TRADE CONTRACTORS
  - **6** ON-SITE SETTING CONTRACTORS*
- **59** MANUFACTURERS

Figure 3. Survey respondent categorizations

* On-site setting contractors are primarily involved in staging, lifting, and installing the modular components on-site.

Survey participants worked in both small and large companies. Figure 5 breaks out company size based on the number of W2 employees by participant group.

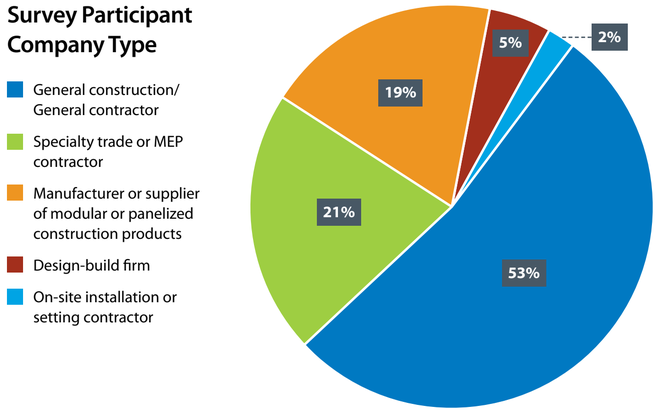


Figure 4. Breakdown of survey participant company types

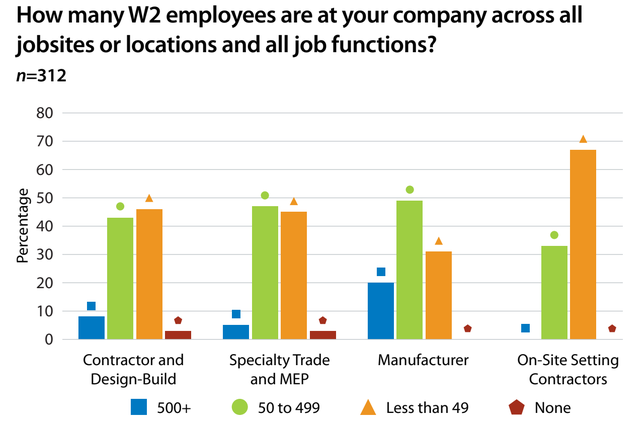


Figure 5. Percentage of respondent types by number of W2 employees

The majority of survey respondents reported more familiarity with panelized modular than volumetric modular products. Of all 262 respondents working with panelized and volumetric modular products and methods, only 20% reported familiarity with volumetric modular, whereas nearly 80% were familiar with panelized modular methods. Figure 6 shows the breakdown of participant level of experience based on the number of projects completed with each product type in the last three years.

Survey participant companies serve multiple market segments and cover all regions of the United States, with a heavier concentration in the South and Midwest (Figure 7).

Many of the 262 participants who use modular construction methods indicated that their company directly served multiple parts of the value chain. For example, 28 (or 9%) of survey respondents offer transportation services in-house, including 16 manufacturers and 12 contractors. While only six respondents identified their company as set contractors, 60 respondents indicated their companies provide setting services, which represents 22% of respondents with modular construction experience overall. These statistics indicate that many companies are providing setting services—which involve staging, lifting, and installing the modular components on-site—rather than using specialty setting contractors. Likewise, a number of companies offer transportation services, which include hauling modular units between off-site manufacturing or fabrication sites to jobsites and to/from staging, rather than using independent transportation contractors. These data suggest setting and transportation are being vertically integrated and may be more widespread services than the "set contractor" respondent pool suggests.

The number and proportion of survey participants who indicated their companies provide services related to various aspects of the value chain are shown in Table 1.

Additional questions and responses relating to the company characteristics of survey participants can be found in Appendix A.

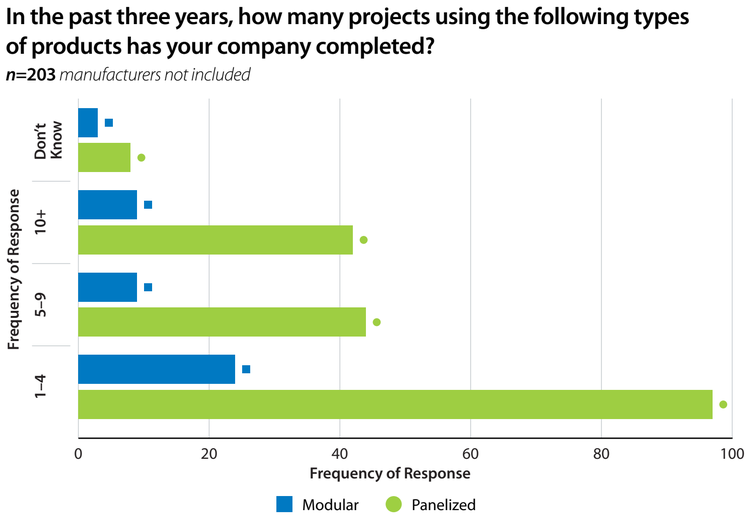


Figure 6. Number of projects completed with panelized and volumetric modular products by survey participant companies in the last three years

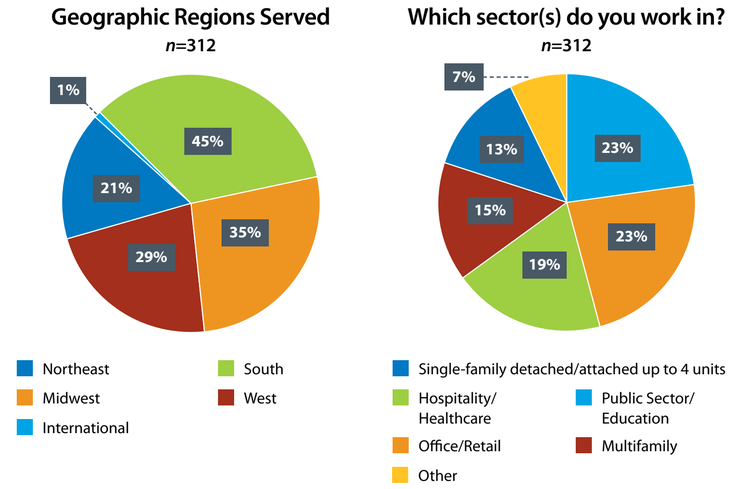


Figure 7. Market segments and geographic regions served by participant companies

Table 1. Breakdown of Survey Participant In-House Services

Value Chain Services	Number of Participants Providing the Service	Proportion of Overall Participants Providing the Service
Transportation	28	9%
Commissioning/Permitting	34	11%
Setting	60	19%
Design	62	20%
Manufacturing	73	23%
Construction	268	86%

04

Results From Workers Using Modular Construction Products and Methods

4.1 Perceived Impacts on Specific Occupations and Professions

Contractors and manufacturers were generally aligned in their responses when asked whether the adoption of volumetric or panelized modular construction products and practices would require more or fewer workers in specific occupations. Overall, survey participants did not anticipate the number of people needed on a jobsite to change meaningfully with an increase in the adoption of modular construction practices, although they anticipated minor shifts in certain professions to accommodate more volumetric and panelized products.

Survey respondents indicated that general contractors would benefit most by an increase in modular construction, followed by crane operators, transportation and logistics companies, and skilled trades contractors (Figure 8). Respondents cited faster project timelines, cost efficiencies, easing workforce shortages, and increasing transportation service needs as main reasons these professions would benefit.

Survey respondents were asked which professions would be most negatively impacted if the use of volumetric and panelized methods increased significantly. Professions most negatively impacted included specialty trade contractors, general laborers, and design/architecture firms (Figure 9).

Specialty trade contractors and design/architecture firms appeared in the top five professions anticipated to be most positively and negatively impacted, although they ranked higher (first and third, respectively) on the negative impacts scale than they did on the positive impacts scale (fourth and fifth, respectively).

Which professions/occupations are positioned to gain the most benefit if the use of volumetric modular and panelized modular construction methods were to increase market penetration significantly?

***n*=262**

Select top three

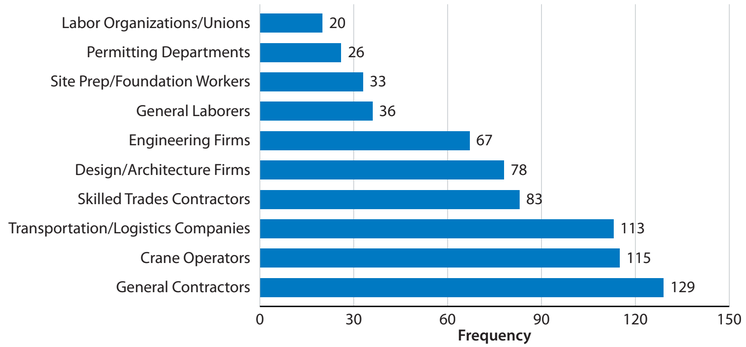


Figure 8. Occupations that may be the most positively impacted by modular construction

Which of the following will be the most negatively impacted if the use of volumetric modular and panelized modular construction methods were to increase market penetration significantly?

***n*=262**

Select top three

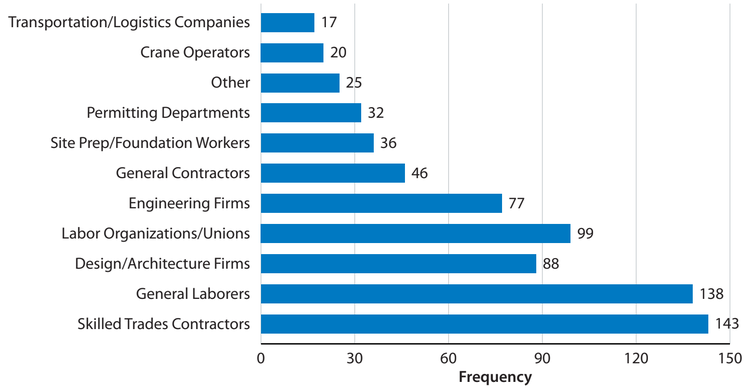


Figure 9. Occupations that may be the most negatively impacted by modular construction

Demand for specialty trade contractors is explored in Figure 10. Many of the specialty trades that are in demand in modular construction factories correlate with the trades that are anticipated to decline on-site due to increased use of these products.

When asked why they chose their top answer, participants indicated that fewer people would be needed in general and that less skilled labor and conventional design services would have less importance. Interviews revealed that these responses were due to a shift in using modular-specific design methods, although the level with which conventional architects and engineers can design for modular applications may depend on the product's off-site level of completion.

4.1.1 Conventional (On-Site) Construction Sector

Following the overall trend of all survey respondents, general contractors saw themselves as one of the largest beneficiaries of adopting more modular construction methods. When asked about the impacts to specific skilled trades, manufacturers and contractors each responded that fewer framing; drywall and insulation; plumbing; and heating, ventilation, and air-conditioning (HVAC) professionals will be needed on the jobsite as more volumetric modular products are adopted.

After skilled tradespeople, respondents felt that general laborers would be most negatively impacted by the adoption of panelized and volumetric modular construction, with the top reasons being a reduced need for labor and more of the work taking place off-site. With volumetric modular construction, most agreed that demand for general laborers will shrink, but with panelized modular construction, demand may stay the same. Many respondents felt that fewer people will be needed on-site in general, due to the work being completed or fabricated off-site, and that on-site activities may be reduced to assembly, tie-ins, and finishing.

How you would expect the number of workers required at the build-site to change with the adoption of panelized and/or volumetric modular construction?
***n*=262**

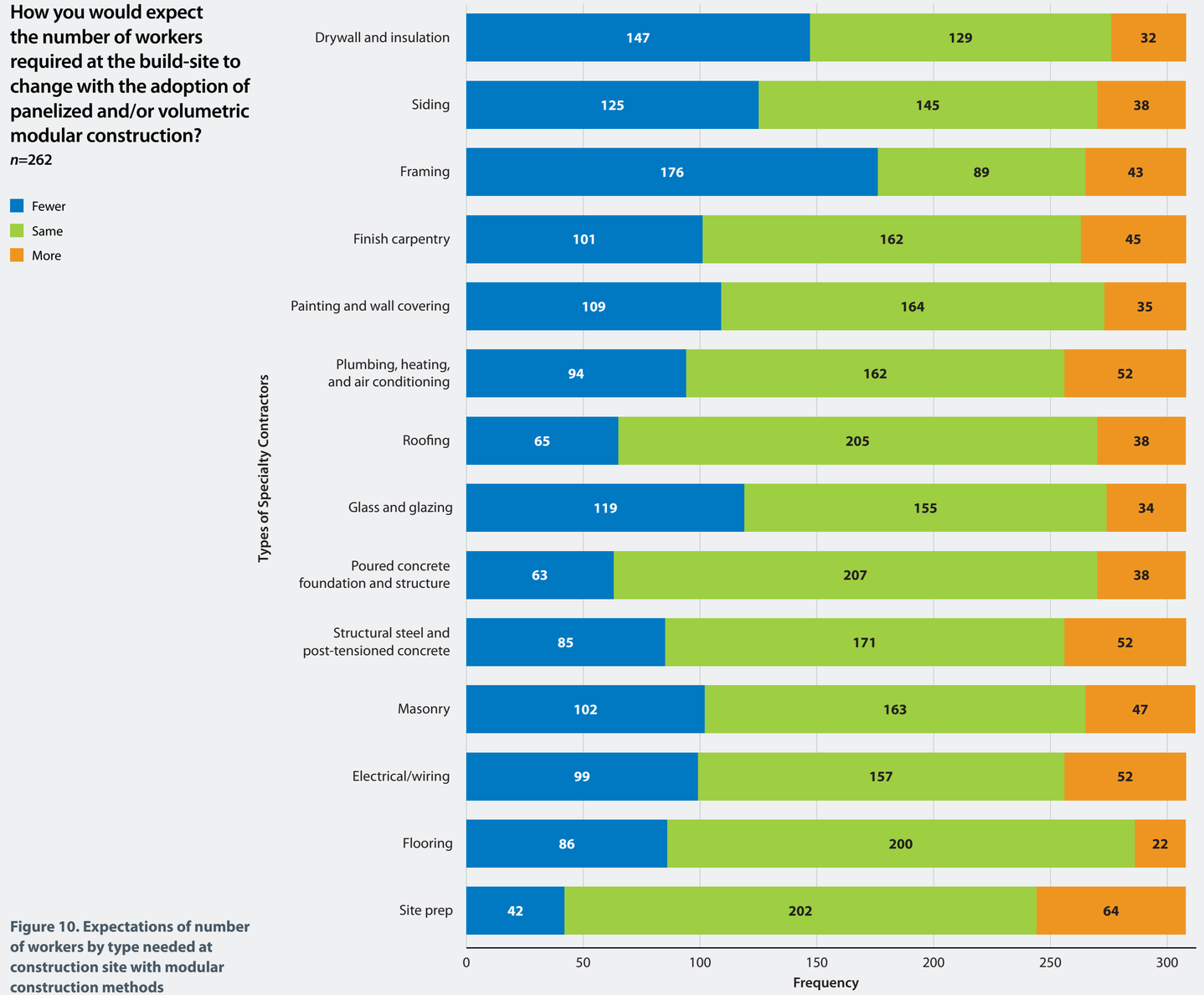


Figure 10. Expectations of number of workers by type needed at construction site with modular construction methods

How would you expect the number of workers required at the build-site to change with the adoption of panelized and/or volumetric modular construction?

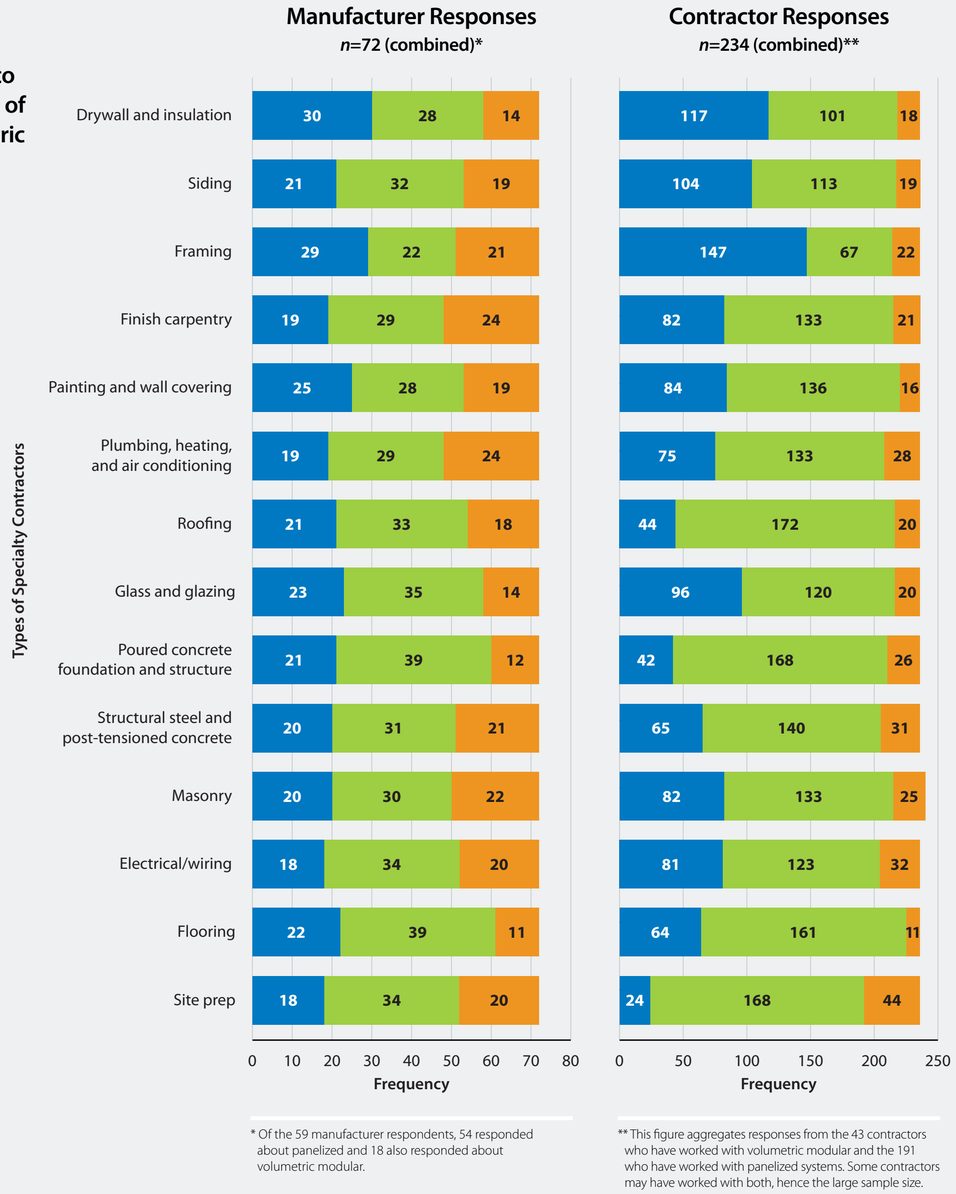


Figure 11. Expectations of number of workers by type needed at construction sites with modular construction methods: manufacturer (left) and contractor (right) perspectives

* Of the 59 manufacturer respondents, 54 responded about panelized and 18 also responded about volumetric modular.

** This figure aggregates responses from the 43 contractors who have worked with volumetric modular and the 191 who have worked with panelized systems. Some contractors may have worked with both, hence the large sample size.

The trades negatively impacted by panelized modular products (in terms of fewer workers needed) were primarily the framing and drywall professions (Figure 11).

Manufacturing and construction industry respondents are generally aligned regarding the impacts of modular construction on the number of skilled tradespeople required on-site to implement modular construction compared with conventional methods. However, manufacturers are more optimistic about the number of skilled trades jobs being preserved on-site than contractors are.

Results from the survey show that both manufacturers and contractors see framing contractors as the skilled trade to most likely decline on the jobsite due to the use of modular construction methods, followed by drywall and insulation contractors.

However, the specialty trades employed in modular construction factories (Figure 12) largely mirror the trades that respondents felt would be less needed on-site, signaling a potential shift in working location rather than job loss.

Survey results show that the trades employed in modular construction factories will still be in demand, even if there is less work for them on-site as the use of modular construction methods grows.

What construction trades do you employ or contract to for the manufacturing of your product?
***n*=59**

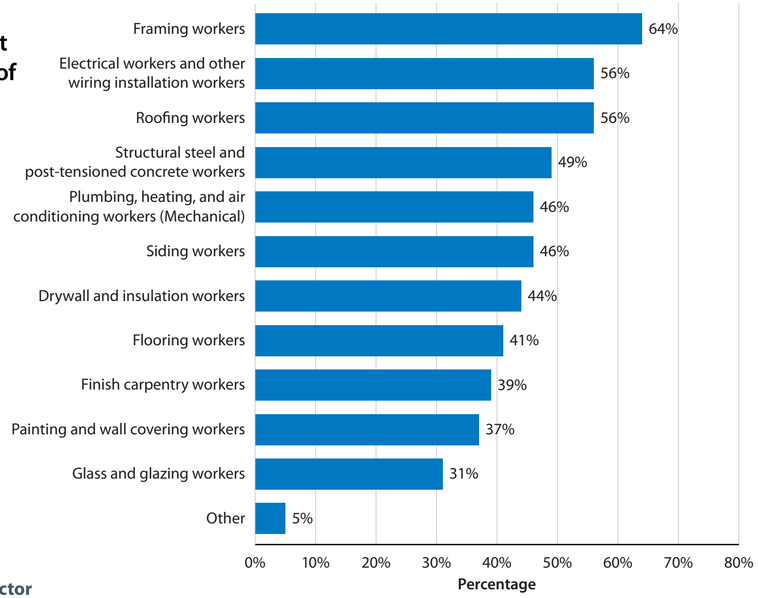


Figure 12. Construction trades employed in the modular construction manufacturing sector

BUSINESS PROFILE

Figure 13. Modular building during construction

Photo from JE Dunn Construction Group

JE Dunn Construction Group

JE Dunn is the eighth largest general contractor in the nation and has embraced using modular construction methods (Figure 13 shows an example of a modular building during construction). JE Dunn Vice President and National Director of Prefabrication and Manufacturing Stacy Scopano says that they use modular construction methods on at least 10% to 20% of their projects, meaning that these construction methods are being deployed on many projects across the United States.

Scopano clarifies that he is deliberately defining modular construction in the broadest sense possible, including anything that moves away from conventional stick-built construction on-site. This includes prefabrication, modular, panelized components, and, in many cases, even conventional single-trade or multi-trade fabrication.

Drivers for Current Engagement With Modular Construction

Scopano cites drivers for JE Dunn's commitment to modular construction from both ends of the project team. One of the biggest drivers is a specific type of customer that they often serve: owner-operators with large capital programs that involve buildings with many repeatable components, such as healthcare, data centers, and lately, manufacturing, which the company has seen increase in demand in the wake of the coronavirus pandemic. He says that these owners are looking to find economies of scale and that their most urgent needs are "certainty, de-risking and speed to market."

Labor scarcity plays an important role in the company's decision-making. Scopano notes that there has been an "explosion of demand [for contractors] if you are fortunate enough to be servicing the right markets in 2024. Unfortunately, we don't see the requisite explosion of labor coming into the market or [expect improvement] in our industry's capability to continue to refresh, regenerate, and grow our capacities." Therefore, JE Dunn needs to find other possible solutions to continue to grow and serve their marketplaces, and they see modular construction as one way to address this challenge.

Factors Driving Adoption of Modular Construction

He also finds that the current wave of interest in modular construction is coming from multinational manufacturers re-onshoring their presence in the United States. He says that these organizations have been exposed to industrialized approaches in their work in other countries and are now bringing that home in a way that has "reshaped the demand equation." He expects the trades to respond to greater demand on the owner side for these approaches, and he describes this moment as having the potential to be the turning point for modular construction as an innovation to treating it as the best practice within some markets.

Skills and Knowledge Needed for Modular Construction

Scopano explains that the only difference between JE Dunn's on-site workforce for projects that include modular construction and stick-built projects is the quantity of workers. He says, "I am not seeing any measurable change in skill sets [of on-site workers]. More of the work is completed off-site, but there is still work on-site left for installation, implementation, and finishing the work. So [the difference] is really [in the] quantity [of workers on-site]."

He also needs project managers who can take a more holistic approach to a full project portfolio. He explains that they need project managers with the ability to "understand production … from [the perspective of] a portfolio of projects versus singular project management," and he finds that conventional project managers have suffered from not approaching the management of modular construction projects in this way.

Staff managing JE Dunn's production center are frequently recruited from their existing workforce of tradespeople and laborers, apprentice journeymen, and certified union workers because they seek construction experience for those in that role. However, Scopano also says that they seek "out-of-the-box" thinkers, and that those are the kind of people that tend to be drawn to this industry.

According to Scopano, design managers and project managers who are successful on projects using modular construction methods demonstrate an increased attention to detail. He explains that this attentiveness is essential to successfully consider how the

building components will be designed for manufacturing and production while also keeping constructability in mind: "These are things we've tried to solve through different kinds of coordination techniques over the last couple of decades. Now, we have the opportunity for pulling production and construction up earlier into design using digital tools, [industrialized construction] processes and production capabilities. [This allows us to think more holistically] as well as be more detailed. It might sound arcane, but this is a next-level skill set that we need out of an increasingly strained design and engineering pool."

He also finds that design and project managers can expand their familiarity with manufacturing techniques more. "I think a broader part of the [construction] market would think about building systems differently if they were more familiar with our production capabilities, like production equipment, shipping constraints, and other constraints. A little more tactical knowledge of production could inform project strategy setting, design, even financing of projects. That would be helpful and obviously benefit the adoption curve for modular and industrialized construction."

Recruitment, Training, and Workforce Development

In recruitment for these kinds of positions, experience with modular construction makes candidates much more attractive. He explains the impact of experience for a project manager as an example: "You have a team of different skill sets at the project level, and one [project] that's going extremely fast. So how do you recalibrate that team? There are different project management demands. Having operators come in with that experience is definitely a differentiator."

Future for Modular Construction at JE Dunn

Scopano expects JE Dunn's use of modular approaches to grow in the next five years. "There is no sign of scarce labor becoming less scarce; we are in a perpetual state of doing more with less," he says. "You've seen it in manufacturing, which went with automation. We have some opportunities for automation, but, overwhelmingly, in our industry, those will pass through an industrialized modular mobilization effort first."

4.1.2 Transportation and Setting Sectors

While transportation of materials has long been a part of construction, survey respondents indicate an increase in demand for these services. With more modular construction taking place, being able to move, store, and lift components and put them into place is becoming an increasingly important piece of the construction process. Survey respondents suggest there are immense opportunities in transportation logistics, site preparation, crane operations, and setting professions. In fact, 78% of the manufacturers surveyed in this study said they use set contractors regularly.[2]

Most survey respondents identified the need for more transportation workers, with only the specialty trades suggesting that demand would likely remain the same. Transportation workers were identified as the third most likely to benefit (after contractors and set contractors) from the adoption of modular construction.

While set contractors themselves do not anticipate a growing need for more set contractors or crane operators, approximately 60% of general contractors expect demand for these services to grow with the adoption of panelized and volumetric modular products. Nearly half of manufacturers expect the need for set crews to grow as volumetric modular construction increases; they expect the need for set crews to stay the same to accommodate panelized modular construction methods. Survey respondents felt that crane operators and set contractors would be the second "most likely to benefit" occupation from the adoption of more panelized or modular construction.

A truck hauling the iUnit arrives at NREL. The iUnit—a Leadership in Energy and Environmental Design Silver, 380-squarefoot modular apartment unit—will be tested at scale at NREL. *Photo by Dennis Schroeder, NREL 41368*

[2] Using set contractors "regularly" is defined by manufacturer respondents who indicated they use set crews as sometimes, frequently, or always.

BUSINESS PROFILE

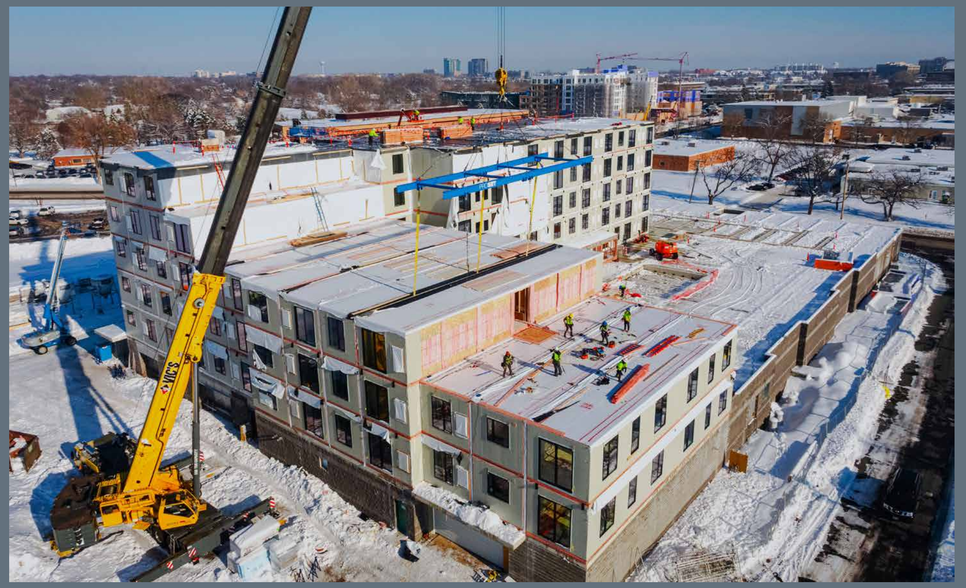


Figure 14. Proset LLC's landing team guides a modular unit into place and prepares to tie the unit in

Photo from ProSet LLC

ProSet, LLC

Also known as setting, the installation of large-scale, permanent modular building units is a specialized operation involving a unique set of skills. In 2014 Scott Bridger had never heard of this specialized contracting field or heard terms like "making boxes fly," but he did have a very large and experienced conventional framing crew. While travelling to North Dakota for a project, he met Matt Mitchell, the owner of a small set contracting firm with 25 years of experience self-installing modular units. He was working on a multifamily housing project and invited Bridger and his crew to join his team on-site. Soon after, Bridger and Mitchell cofounded ProSet, with the goal to build a professional, large-scale, modular installation company that could respond to market needs and scale up with the modular industry.

In 2017, Marriott gave the young specialty modular installation company a chance to test its vision. The hospitality company launched an initiative to drive modular hotel construction in North America, committing to sign 50 modular hotel deals that year alone. The announcement provided momentum for large-scale commercial modular construction. ProSet was ready to respond to the surge in demand and successfully set the first-ever modular hotel units for Marriott at its Fairfield Inn property in Folsom, California. Since then, ProSet has been the set subcontractor for many Marriott, Hilton, Choice, and IHG hotels and has branched into other markets like manufacturing facilities and multifamily housing units. In 2023 alone, the company was the set contractor for 20 factories across the country, including 500 units for a single manufacturer.

The growth of large-scale modular projects, in turn, drove a need for modular construction expertise in the general contracting world.

The Nature of Modular Installation Work

Bridger explains the process in which a modular installer is typically engaged. First, they have a unique relationship with the general contractor compared to most other trades. ProSet must plan the logistics, which include trucking, storage of units, crane logistics, and traffic control, as needed with the general contractor months in advance. When the general contractor has completed the foundation and the site work, including underground utilities, grading, and any required demolition, ProSet then arrives on-site to set the building. Their work is usually completed in a week or two. During that time, they completely take over the site, so they have little to no interaction with other subcontractors on the project.

They have four crews on each project, and Bridger describes their work as follows:

- The strip crew removes all the plastic off the boxes.
- One crew rigs the modular unit with their specialty equipment and operates the crane to place it.
- The landing crew receives the unit from the crane and guides it very precisely to the intended location.
- The final crew manages structural connections and anything else required before the next unit is ready to set.

With the right planning and logistics, the division of work into the four crews allows the work to flow smoothly and quickly. Bridger describes the process as a "beautiful symphony to watch."

Given the unique nature of their work, ProSet trains all their crews internally, and they actively cross-train their workers as well, so that their crew members can take on different roles on their projects. Because the crew size varies based on project scope and complexity, they see a great advantage in coordinating staff across their organization to work on multiple crews as they deploy across a wide geographic area.

The nature of their work seems to also carry inherent risks, but ProSet has proactively addressed those. According to Bridger, "Set work is unique in that if everything goes smoothly and all the conditions are ideal, it isn't that complicated, but it can be very complicated and dangerous in specific situations." Borrowing a phrase often used in aviation to describe the risk involved, he calls set work "safe but unforgiving."

Labor and Recruitment

ProSet recruits workers with construction experience, but it is not a requirement since they provide their own internal training. Bridger says, "We are not in a part of the construction world, like I have always been in the past, where [you would seek individuals who]

have really good skills and experience in the particular trade or field. In our world, we look for people who are willing to be trained, because you just don't have a pool of folks that are trained in what we do."

Bridger finds that the impact of the work they do helps them attract and retain workers. He says, "If you think about the work we do, it is very rewarding. We find that our crews take a lot of pride in what they do because they are constantly getting great accolades from our clients and even, frankly, passersby, because, when you think about the pace that we erect a building, it is pretty fun to watch. Our crews will show up on a Monday morning, and maybe by Friday, there is an entire hotel standing there. A lot of folks really value being able to stand back and look at what they accomplished in a day."

4.2 Modular Construction Impacts on Wages and Working Conditions

Survey respondents largely indicated positive impacts from working with panelized and/or volumetric modular products. These impacts related to wages, benefits, working conditions, schedule changes, worker productivity, and employee benefits. While some set contractors reported that these impacts weren't trickling down to the employee level, contractors, specialty tradespeople, and manufacturers all reported positive impacts on employees, as shown in Figure 15.

Survey respondents were asked which benefits their W2 employees received, and they had the option to select multiple answers. Most respondents indicated they provided all the typical W2 benefits to their employees such as paid time off and sick leave, health and/or dental insurance, retirement programs, and overtime pay. Transportation stipends and professional development opportunities were less common. Specialty trade contractors were more likely to offer professional development opportunities, perhaps due to the rapid changes in code, safety, and equipment specifications. Although there was a small sample size for on-site set contractor respondents, all said they offer paid time off, retirement, and overtime pay to their employees, with almost all (five of the six) offering health and/or dental insurance. Roughly 80% of general and specialty trade contractors offered paid time off, health insurance of some form, and overtime pay. In the four open-ended responses, participants mentioned they also offer their W2 employees stock purchasing options, annual bonuses, or reimbursement for work-related out-of-town travel expenses, as shown in Figure 16.

4.2.1 Impacts on Contractors and Construction Workers at the Jobsite

Survey respondents were asked how their safety record has changed when using volumetric or panelized construction methods compared to conventional construction methods: 66% of respondents said about the same safety records, 22.7% said fewer incidents or less severe incidents, 10.8% said they did not know. While 5% said they experienced more incidents or more severe incidents using modular construction methods, most respondents believed that safety records would stay the same or slightly improve with the adoption of modular construction methods.

One company interviewed, JE Dunn, noted the positive safety outcomes as one of the most important ways that industrialized manufacturing of modular products impacts the workforce. In addition to benefits that JE Dunn Vice President and National Director of Prefabrication and Manufacturing Stacy Scopano considers to be widely understood, such as getting people out of the weather and better ergonomics by being able to work on elements at waist height, he calls attention to the fact that the work done on-site is safer because other work has been moved off-site. JE Dunn has done some early studies that show significant reductions in incident rates, although more research is needed to fully quantify the impact of improving safety on-site by engaging in this approach.

While final assembly and erection of structures can be done at a faster pace using modular construction compared to building a structure from the ground up on-site, contractors must spend more time in the planning process because changes are very difficult and expensive to make once a product is delivered to the build site. Set contractor ProSet says that before they set a building, they spend an average of four to six months working with the general contractor on logistics, which include trucking, storage of the units, crane logistics, and traffic control as needed.

To what degree have the following been impacted by the adoption of volumetric and/or panelized modular construction practices?

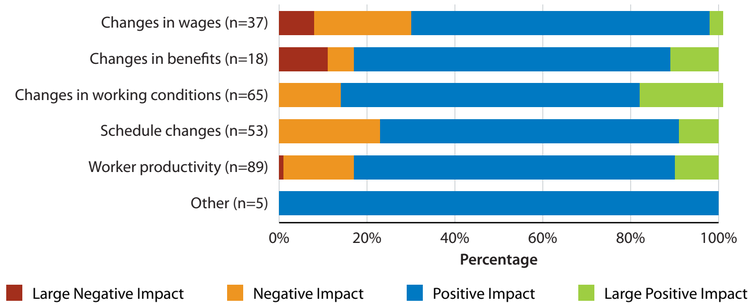


Figure 15. Impacts on workers using volumetric and panelized modular construction methods

What benefits do your W2 employees receive?

***n*=262**

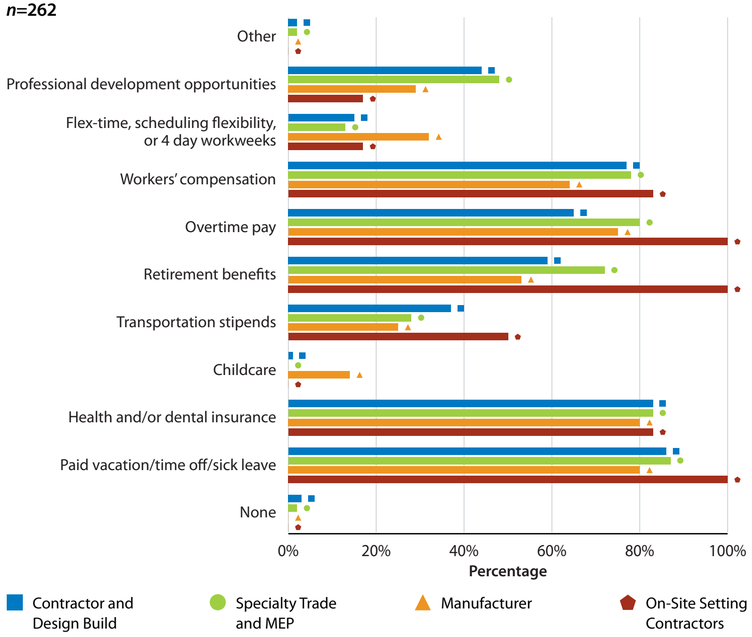


Figure 16. Benefits offered to employees

> "The Occupational Safety and Health Administration, as detailed as they and their book of safety standards are, doesn't have a lot of actual safety codes for what we do because it is pretty new. It is unique to be craning these modular units 5, 6, or 10 stories into the air."
>
> SCOTT BRIDGER, CO-FOUNDER, PROSET, LLC

> "Instead of physically manipulating raw materials with equipment piece by piece out in the field, [increasing the potential for] running power cords, dropped material, and dirt, the chaos potential of the site radically changes when you are clicking large chunks of the project together. The risk profile of the project on-site becomes inherently safer."
>
> STACY SCOPANO, VICE PRESIDENT AND NATIONAL DIRECTOR OF PREFABRICATION AND MANUFACTURING, JE DUNN

In survey write-in responses and interviews, many contractors cited project schedule predictability and faster build timelines as major benefits, allowing for more predictable work schedules. Additional project oversight and management was another benefit of modular construction, lending support for answering questions and addressing workers' concerns.

4.2.2 Impacts on Modular Construction Manufacturing Workers

Modular construction manufacturers have wide-ranging approaches to the mix of construction-based labor and automation they rely on for the fabrication of panelized and volumetric modular products. Three manufacturers we interviewed shared their respective levels of automation, output, and number of workers. A largely automated factory reported 140 workers with an output of five units per day. Two less automated factories reported 180 to 200 workers with an output of two to three modules per day. Figure 17 shows the areas of automation respondents expect in modular construction factories.

Temperature- and humidity-controlled manufacturing facilities that offer shelter from the outdoor environment, comfortable working stations, adequate lighting, and easily accessible restrooms are generally viewed as positive features of working in a modular construction factory.

Overall, respondents noted that there may be more oversight, quality control, and procedural structure with modular construction methods than in conventional on-site construction approaches. Manufacturing companies can modulate staffing, materials, and resources to ensure stable working conditions and meet expectations from employees. For example, one participant explained that they can plan for workforce needs based on their backlog of work, which also leads to more predictable outcomes and delivery times for their clients.

Stability and flexibility were common topics brought up by manufacturers during interviews. Two companies indicated they took a different approach to accomplishing stability and flexibility by accommodating the scheduling that best fit their workers. One offered a four-day work week with four 10-hour days, comparable to the hours of a conventional office job. All staff would receive Friday, Saturday, and Sunday off. The second had five-day work weeks that would start at a more typical construction day start time and end by 2 or 3 p.m. Workers would be organized by teams, based on their stations within the assembly line. When a team hit its quota for the day, the team members' work would end and they would be free to go early, incentivizing them to work faster. According to their management, this strategy was elected by the workers themselves, because many had children to get home to and this would allow them to be available by school pickup times.

Automation may impact current modular construction manufacturing workers. Framing, electrical work, and structural steel and roofing are the top areas modular construction manufacturers identified as areas to automate in the next three years. Notably, these are also the trades manufacturers currently employ the most. Also of note is that manufacturers overwhelmingly stated that none of the functions would be automated (shown in Figure 17), signaling that specialty trades are needed now and in the near future in modular construction factories.

As more manufacturers adopt automation, workers with construction experience often have the opportunity to cross-train in leadership, management, and other skills that allow them to move into other careers. Many manufacturers cited that they regularly hire and advance workers from within.

Which of the following trades that work in your factory (as noted in previous question) do you think will be automated in the future?
n*=59; *Select all that apply*

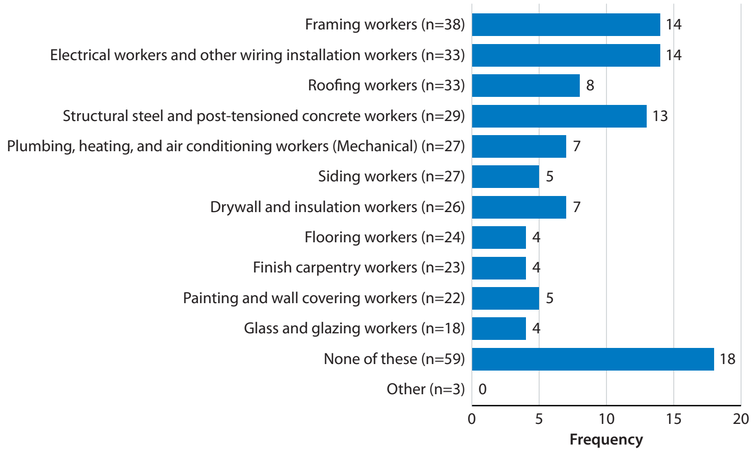


Figure 17. Anticipated automation coming to factories

> "[Manufacturers] are able to put people in better ergonomic positions for repetitive work that they're doing, whereas they may not be able to do that at the jobsite."
>
> GENERAL CONTRACTOR

* Note: this was a select all that apply question, and only shows the response options that participants selected, which is why the sample sizes are different.

4.3 Adapting to Modular Construction Methods

Manufacturers and contractors agree that the top barriers to the adoption of modular construction methods are training and understanding of the process followed by a shift in mindset to accept the change in construction practices (Figure 18). Interviews with manufacturers and write-in survey responses from the construction industry also indicated that a lack of clarity on how to revise pricing, specifically around labor, is a challenge when using panelized or modular construction methods.

Those working with panelized or modular products typically do not find that codes, costs, or equipment changes are a major barrier. Less than 5% of survey respondents felt that cost or wages were a major challenge to adopting these products on the jobsite. A few contractors using panelized or volumetric modular products indicated in the write-in portion of the survey that pricing or estimating the cost of a job was a barrier, which contradicts the opinions of manufacturers we interviewed.

To understand how daily tasks on a build site change when moving to modular construction methods, we needed to understand how "complete" the panelized and volumetric modular products are when they arrive at the build site. Survey results show that there is a large range of products and levels of completeness in the modular construction industry. The level of completeness of a product when arriving on-site dictates how much work needs to be done by contractors to finish the job. Responses regarding the completeness of panelized and volumetric modular products are shown in Figure 19 according to the frequency of each response.

Each contractor group was asked how their daily tasks change when using panelized and volumetric modular products compared with conventional methods of construction. Responses differ by survey participant group, presumably based on that group's specific job tasks related to the products. The most frequent responses included planning and management, scheduling, and coordination as the most impacted daily tasks. No set contractors selected planning and management as a way their tasks change, likely because they are deeply involved with the planning and logistics on a daily basis. Only 13% of specialty trade contractors and 12% of contractor and design build firms felt that using modular construction methods had little to no impact on their daily tasks.

What do you think the biggest challenges conventional construction crews face in adopting volumetric or modular construction practices?

***n*=312,** *Write-in question, coded by category*

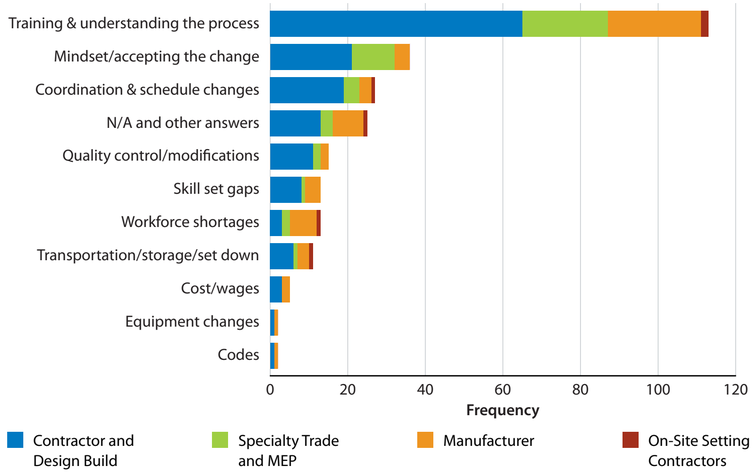


Figure 18. Ranking of the survey respondents' biggest challenges to adopting modular construction

On average, how "finished" are the following product types when they arrive at the build site? (i.e., how much connecting and finishing work has to be done to "complete" the installation of the product?)

***n*=312**

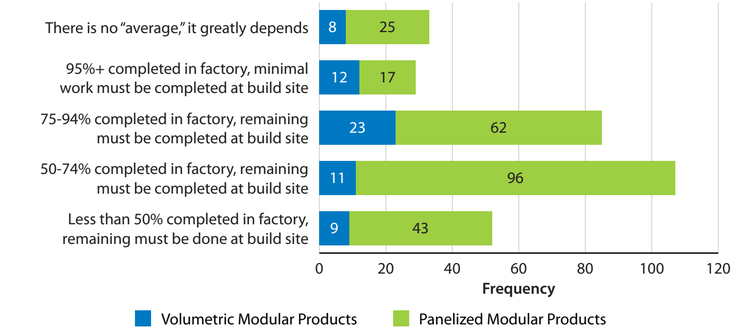


Figure 19. Survey responses regarding completeness of modular construction products

How do your daily tasks change when utilizing panelized or volumetric modular products compared to conventional methods of construction?

***n*=203,** *Manufacturers were not asked this question*

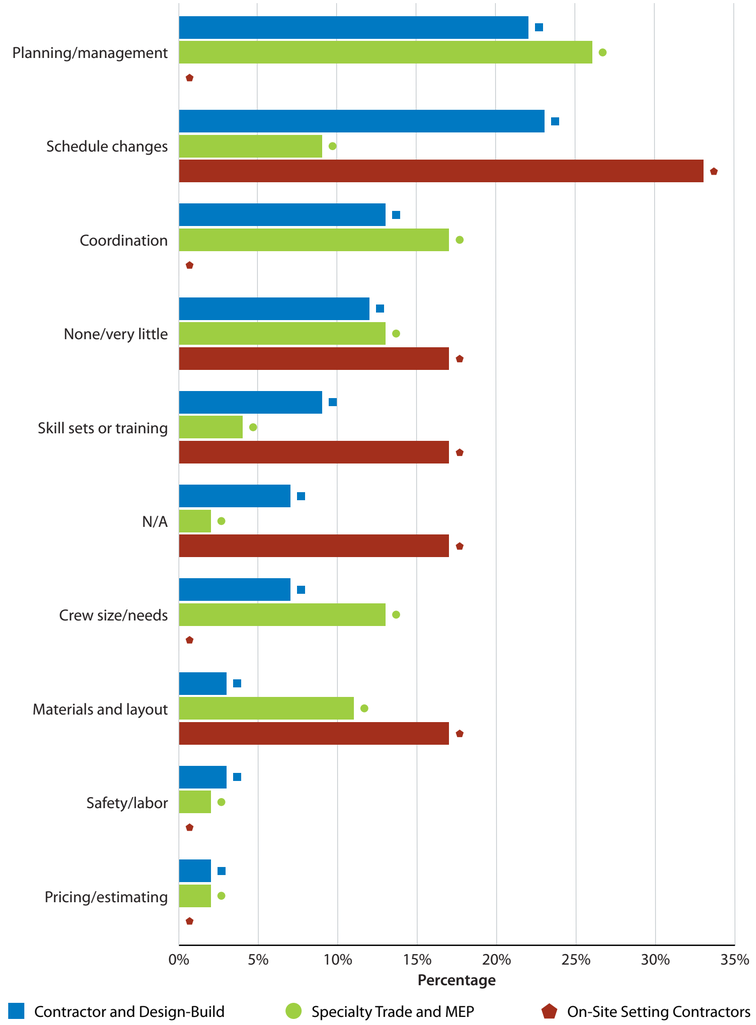


Figure 20. Contractor view of how daily tasks change when using modular construction methods

4.3.1 Skills Needed To Increase Adoption of Modular Construction Methods

As modular construction practices grow and evolve, new skill requirements will emerge within factories, for transportation and logistics companies, and for conventional construction crews. The current snapshot of survey responses to the questions about skill requirements reflects the relative maturity and automation seen within the industry today across the value chain, from product manufacturing through transportation, delivery, and construction. The items that change within the day-to-day work on a conventional construction site are shown in Figure 20.

Interviews and write-in survey responses provided a better understanding of what skills and training are needed. While conventional construction skills remain critical to the day-to-day work on-site, there is increasing importance placed on workers' soft skills, their willingness to learn and adopt new skills, and their ability to develop more technical hard skills.

Soft Skills: Respondents cited the need for a problem-solving mindset, clear communication, organizational understanding, common sense, and open-mindedness as the most in-demand soft skills needed to accelerate the adoption of modular construction methods.

Hard Skills: Hard skills include understanding detailed drawings, facilitating on-site coordination of transportation and set crews, building information modeling comprehension, and being able to operate machinery like computer numerical control equipment and ergonomic-assistive equipment like lifts and cranes.

Willingness To Learn New Things: As indicated in Figure 18, mindset and accepting the changes associated with modular construction remain one of the top barriers to adoption. Interviews revealed that using modular products procedurally changes how construction is done and requires a willingness to learn new things and approach construction projects in a new way.

4.3.1.1 Conventional (On-Site) Construction Sector

The majority of contractors surveyed indicated that no new skills would be necessary for on-site construction workers when adopting modular construction methods (Figure 21). However, some contractors indicated a need for highly skilled workers in machinery operation and digital technology such as building information modeling and computer-assisted design.

> "It's more of a learning process. It's kind of like… being a kid, going from [Lincoln] logs to LEGO or LEGO turned Erector Set. It's just a better understanding of what's happening, knowing how things work for modular, how they connect, knowing the proper layout on the panels."
>
> MANUFACTURER

4.3.1.2 Modular Construction Manufacturing Sector

Demand for various skills within modular construction factories largely depends on the level of factory automation. Nearly half (42.4%) of manufacturers surveyed said that their manufacturing process is close to equal amounts of manual labor and automation (Figure 22).

When asked about the most in-demand skills in the workplace, manufacturers listed specialty trades such as framing, electrical, and roofing and structural steel workers as their top needs. Assembly and construction skills, experience with technology, and MEP trades are the next most in demand skills in modular construction manufacturing facilities.

As discussed in Section 4.1.1, many of the skills respondents felt would be in less demand on-site align with those that are in demand in modular construction manufacturing facilities for panelized and modular solutions. Manufacturers' top two skills they look for in hiring are (1) construction and (2) specialty or trade skills, with nearly three-quarters (71.2%) of manufacturers indicating that construction experience was somewhat or very important for new employees. These responses suggest construction experience is a critical pathway to careers in modular construction. Very few ranked construction experience as "highly important," which may be because many offer in-house training.

What are the new occupations and/or job skills that become available to on-site construction workers when adopting volumetric/panelized construction methods?

***n*=203,** *Asked only to contractors who use panelized or modular*

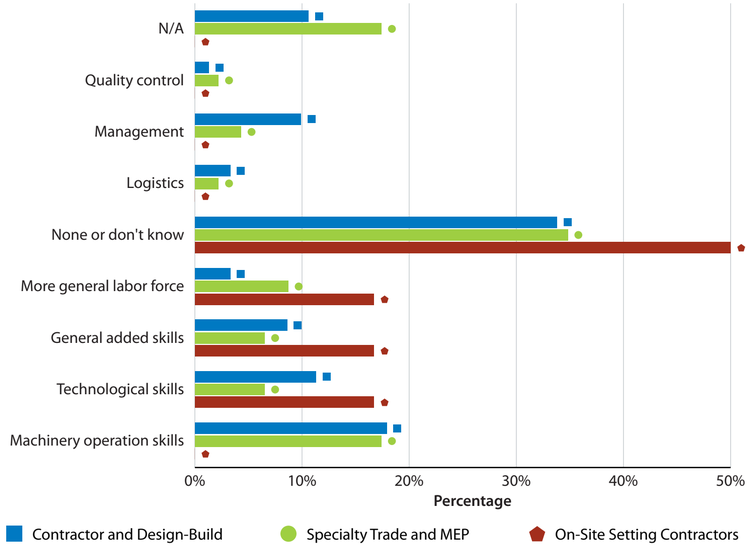


Figure 21. New occupations or skills needed in modular construction

How labor-intensive vs. automated is your manufacturing process from materials input to output of your product?

***n*=59,** *Asked only of manufacturers*

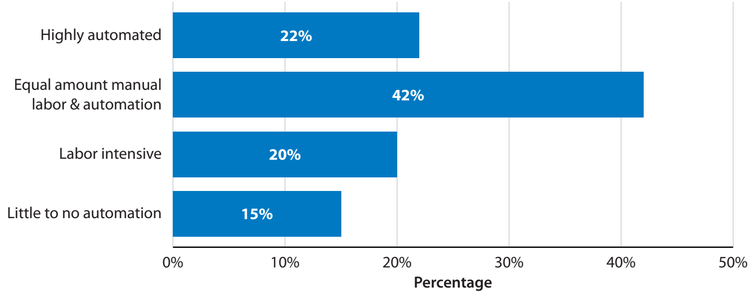


Figure 22. Labor intensity vs. automation in the factory

Figure 23. A set crew guides and positions a modular unit

Photo from ProSet LLC

4.3.1.3 Transportation and Setting Sectors

When asked about the skills that transportation and setting crews need to handle their products, manufacturers ranked permitting and operator skills the highest (37%), followed by safe driving skills (22%). Soft skills (17%) and previous experience (15%) were also listed as important attributes needed for delivery and transportation crews. When asked to identify the top skills needed for set crews working with their products, manufacturers reported skills in basic technology (22%) such as measuring and computer literacy, trade skills (21%) such as carpentry and drywall, and soft skills (21%) such as communication and customer service as top mentions. Machinery operation experience, a clean safety record, and basic building skills were also mentioned.

4.4 Workforce Readiness and Training

This study examined various groups' perceptions of workforce readiness to implement modular construction methods, the skills needed to implement these types of projects, and the amount of training various professionals will need to be successful with modular construction practices. Survey results reveal an interesting contrast in perceptions between manufacturers and contractors regarding workforce readiness and the training needed to implement modular construction projects.

4.4.1 Workforce Training for Conventional Construction Crews

Nearly one-third of all survey participants indicated that a lack of training presents the biggest challenge to adopting panelized or volumetric modular construction methods. Survey responses about the amount of time needed for experienced workers to be sufficiently trained on modular construction methods varied considerably, ranging from no time at all to a year or more. Participants were asked to indicate how much training an experienced construction crew, architect, and engineer would need to implement panelized and volumetric modular projects. Figure 24 compiles all survey responses and compares them across responses for construction crews, architects, and engineers for panelized and volumetric modular projects.

How much training would an experienced on-site construction crew, architect, structural engineer, or (other) engineer need to design the following project type(s)?

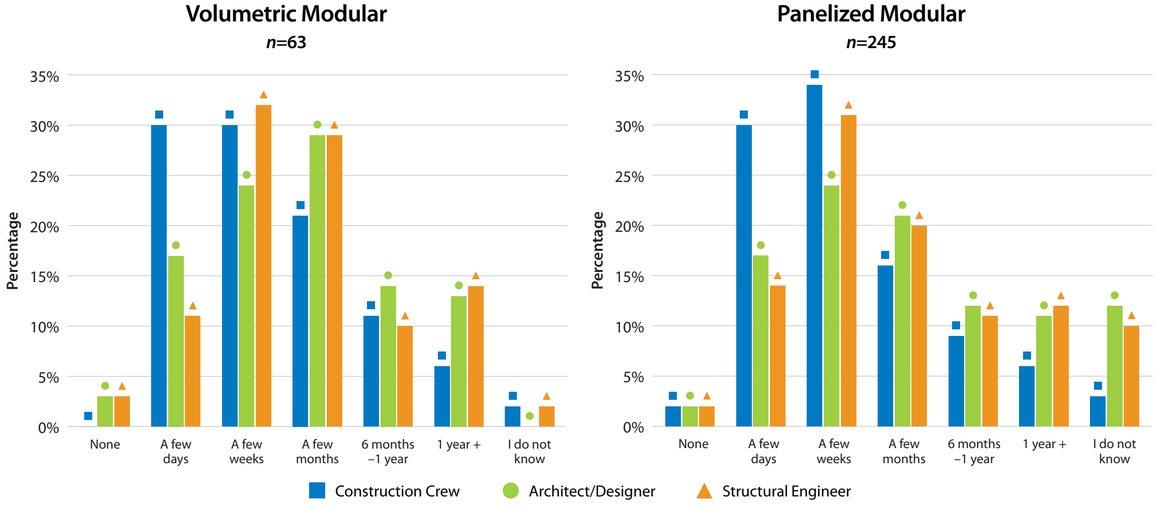


Figure 24. Comparison of training time needed by profession to implement volumetric modular (Left) and panelized (right) projects

The perception of how well prepared the current construction workforce is to support a significant increase in the adoption of modular construction methods differed greatly between contractors and manufacturers. Manufacturers were much more likely than contractors to rate the construction workforce as "well" or "very well" prepared to implement panelized and volumetric modular projects (Figure 25).

When survey responses are analyzed separately, contractors and manufacturers show a stark difference in perceptions regarding how much training is needed for an experienced construction crew that is new to modular construction to successfully implement a panelized or volumetric modular project on a jobsite, as shown in Figure 26.

Responses from manufacturers trended toward a few weeks to a few months to sufficiently train construction crews to implement modular construction projects, while responses from contractors indicate that it would take only a few days of training.

When manufacturers were asked how much training they believed experienced construction workers needed to effectively transition to a modular factory, over three-quarters (83%) indicated that a "moderate amount, a lot, or a great deal" of training would be needed. The remaining 17% thought that "little to none" would be required.

While manufacturers believe contractors are better prepared than contractors view themselves, manufacturers also believe (more so than contractors) that more training is necessary for contractors to come up to speed on their products.

How well prepared is the current on-site construction workforce to support a significant increase in the adoption of these construction practices?

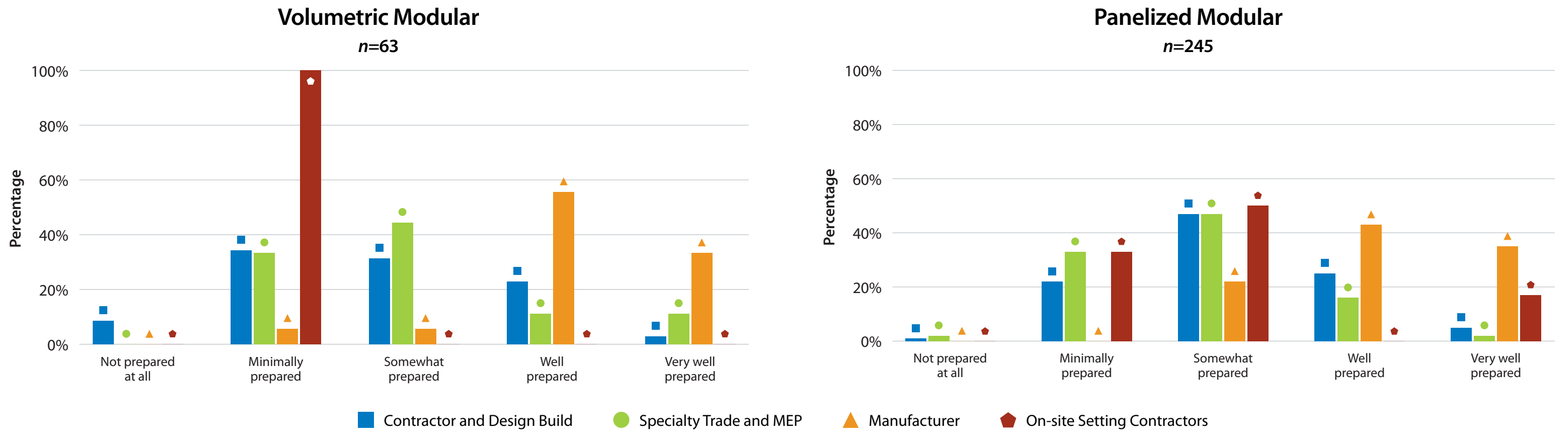
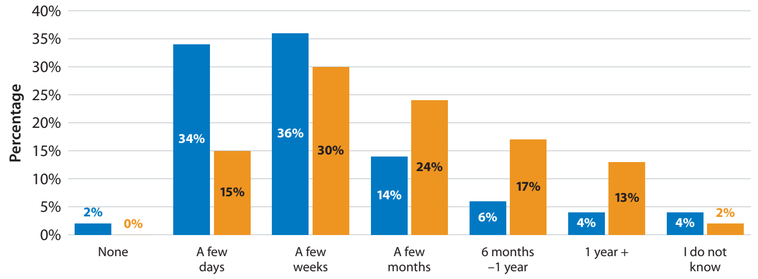


Figure 25. Perceptions of workforce readiness to adopt volumetric modular (Left) and panelized (Right) products

Amount of training required for a construction crew to implement panelized modular projects



Amount of training required for construction crew to implement volumetric modular projects

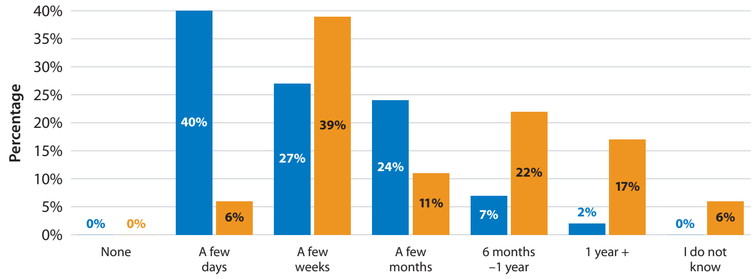


Figure 26. Contractor and manufacturer responses to training needed for construction crews to implement panelized and volumetric modular projects

4.4.2 Training Tools and Delivery Methods

When asked to describe the tools and education needed to help train the workforce, the top four responses across all groups were hands-on or on-the-job training, education or degrees in construction, certifications, and management skills or training. In general, hands-on experience was seen as critical, highlighting the need for more hands-on learning opportunities and vocational programs for upskilling and creating new workforce pipelines. Many contractors highlighted a lack of existing training opportunities, pushing them to create in-house training options or provide mentoring programs that can provide guidance and allow hands-on time working with products in the field.

In interviews and in open-ended survey responses, contractors explained relying on local unions, trade schools and workers' organizations to build construction skills. Others rely on manufacturer trainings.

In interviews, manufacturers describe various approaches to providing hands-on training opportunities. One manufacturer holds a multiday contractor training and certification program for its contractor partners at its facility. Another strategically embeds an in-house project manager in the construction crew during the setting process to familiarize and oversee crews as they learn how to successfully install modular products. Other manufacturers stressed that they have to provide manuals, materials, or in-person training to their contractor partners because they have unique processes associated with the products that may render industry-wide training materials not applicable.

JE Dunn Construction Group, one of the businesses profiled in this paper, indicates that they have developed knowledge management resources that allow their existing workforce to gain exposure to modular construction, which helps them to come up to speed faster. JE Dunn Vice President and National Director of Prefabrication and Manufacturing Stacy Scopano makes these resources known during orientation for new workers, but notes that "even some of our more experienced operators are hitting our internal knowledge centers of [modular] construction. And that is in and of itself its own workforce development effort."

> "Union classes plus on-the-job training seem to be sufficient."
>
> GENERAL CONSTRUCTION/GENERAL CONTRACTOR

In-house, on-the-job training is by far the most used training method. While most of the contractors surveyed report relying on in-house job training, some indicated that this business-as-usual approach to training alone may not be sufficient. Across contractor types, many expressed the need for more than in-house learning. Some cited a need for a diverse mix of training through continuing education, on-site training, manufacturer-led training sessions, and union group training (Figure 28).

Figure 27. A hands-on MEP pod training module at United Association (UA) Local 296—The Pipefitters Union in Boise, Idaho

Photo by Julia Sullivan, NREL 100884

How does your organization train workers to have the necessary skills to work with volumetric/panelized modular projects?
***n*=262**

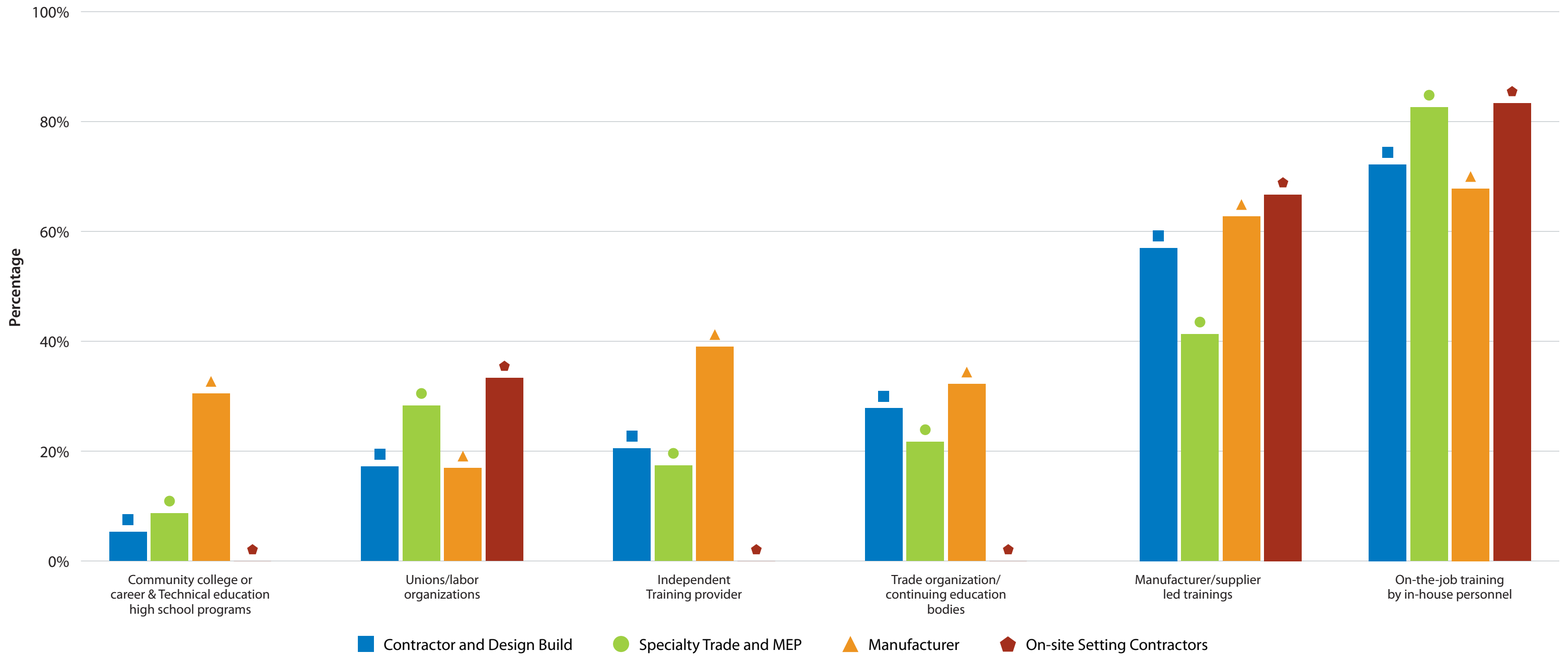


Figure 28. Types of worker training methods used

4.4.3 Training Modular Construction Manufacturing Workers

Many manufacturers indicated they provide cross-training to their employees across disciplines for greater flexibility in staffing. This means a drywaller can fill in on framing, insulation, or other tasks when needed. Many manufacturers referenced having programs intentionally designed to provide cross-training so employees would be capable of performing all major skills on the factory floor. Manufacturers who hire people with a construction background expect a moderate amount of training to effectively transition them from a conventional construction job to a modular construction factory job, as indicated in Figure 29.

Just over 20% of manufacturers surveyed indicated very little to no training is necessary for transitioning from a conventional construction job to a modular construction factory. Over half indicated a moderate amount of training would be needed, and 21% indicated a lot of training is necessary to make the transition.

One contractor mentioned that the carpenters' union training was critical training to their company's work with panelized or volumetric modular construction, highlighting the success that unions can have in this growing industry. Unions that can provide cross-training and help with worker recruitment were also perceived as providing valuable services to survey respondents.

> "Manufacturer training and instructions are a must. Perhaps trade union organizations need to have periodic training programs, updates, and certifications as the industry ramps up."
>
> GENERAL CONTRACTOR

How much training do you think experienced trade workers need to effectively transition to a modular factory job doing similar work?
***n*=59**

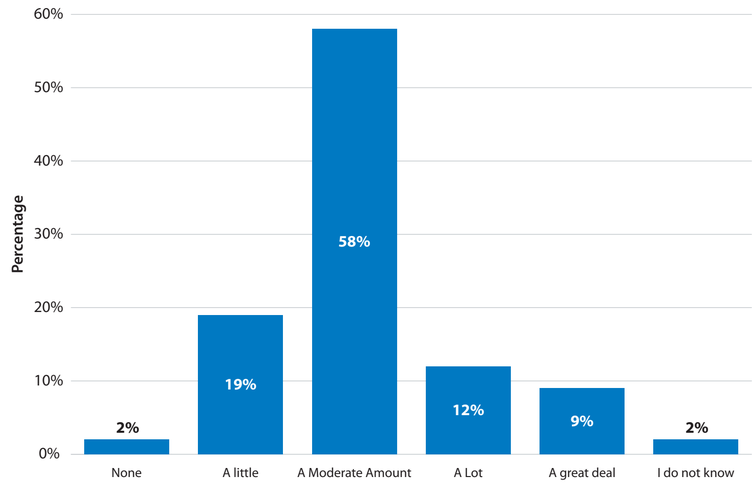


Figure 29. Training needed to transition to a factory

4.5 Union Participation in the Modular Construction Industry

While many of the survey participants indicated not using any unionized labor, there were respondents from each respondent group that indicated using 100% unionized labor on projects, with specialty trade and MEP contractors leading all groups at 29.6% (see Table 2), followed by set contractors, manufacturers, and general contractors.

Manufacturers had the lowest percentage of responses indicating no use of unions across all respondent types, as shown in Table 2. In fact, 57.6% of manufacturing respondents indicated using some unionized labor, with 39.0% using unionized labor on 50% or more of their projects. This makes manufacturers the most likely of all respondent categories to use a significant amount (50% or more of projects) of unionized labor on their projects.

The literature review revealed that there are examples where unions can play a critical role within the modular construction industry. The Northern California Carpenters Regional Council (NCCRC) represents 37,500 members in northern California. The NCCRC has embraced modular manufacturing and has forged partnerships with modular factories via a "wall-to-wall contractor" model. Two such factories are Factory OS and RAD Urban, where NCCRC leads workforce training across disciplines, from carpentry to electrical and plumbing, and employees in turn are covered by the union (MBI 2018).

One manufacturer from an urban area revealed that many of the localities and states within his company's service territories are taking notice of the practice of importing prefabricated panelized or volumetric modular products from out of state, made with nonunion labor. It could be a prime opportunity for local unions to find pathways to replicate models like the NCCRC model.

One predominant opinion relayed by survey respondents was that "less work in [the] field cuts the need for union workers." Several general contractors said they would be unlikely to build with union labor, but others said "union or training" is a must.

Unions have expertise in workforce training and could scale their ability to train larger pools of workers and expand membership. Simultaneously, they could play a critical role in recruiting workers to factories, which also struggle with worker recruitment. Furthermore, they can provide their union members with locally based work opportunities in factories between site-based projects. Many specialty trade workers reiterated the need for more training by manufacturers and suggested in write-in responses that there could be a role for unions in working on training and recruitment for manufacturers.

What percentage of your projects use unionized labor?

Table 2. Use of Unionized Labor by Survey Respondent Group

	Contractor and Design-Build	Specialty Trade Contractors	Manufacturer	On-Site Set Contractors
None	45.4%	51.6%	33.9%	66.7%
1–49%	32.8%	14.1%	18.6%	0%
50–75%	6%	1.6%	25.4%	0%
76–99%	10.4%	3.1%	3.4%	16.7%
100%	4.9%	29.6%	10.2%	16.7%
I do not know	0.5%	0%	8.5%	0%

United Association Local 296 Plumbers & Pipefitters

In an interview with UA Local 296 Plumbers & Pipefitters—the pipefitters union in Boise, Idaho—it became clear that modular and panelized solutions do not necessarily reduce union jobs. Many consider Boise to be the "Modular Mecca" due to its large volume of modular manufacturing, supplying products locally and to locations as far-flung as Alaska. While manufacturers are not currently employing union members in any of these factories, they do not see unions as a threat. In fact, unions are teaching many of the crosscutting skills needed in factories to deploy modular solutions, such as welding, computer-aided design, rigging, HVAC, heat pumps, energy management, piping, and controls.

What's more pressing than getting into factories at present is keeping pace with demand. From 2023 to 2025, UA 296 is expected to grow from 965 to 3,000 members. Solutions that allow them to expedite work help alleviate the rising demand for their services in a way that allows them to do more work while still providing union wages and educational and professional benefits. In Boise, the second largest market for pipefitters is in hospitals. Training Director Michael Parker showed off the shop's MEP pod training unit while discussing UA 296 members' recent completion of a multistory hospital with similar products. "In hospitals, pipefitters are making critical connections that literally save lives," Michael Parker said. "Both the factory and field know that premanufactured components need skilled craftsmen to make sure they're connecting correctly."

4.6 Worker Recruitment

Contractors and manufacturers who responded to our survey universally pointed to workforce challenges related to recruiting and hiring workers, worker retention, lack of job performance, and shortages of skilled trade workers.

The top three workforce challenges reported by survey respondents include:

- Rising labor costs
- Difficulty finding skilled trade workers
- Difficulty attracting workers or competition.

Figure 30 delineates each respondent group's opinions on the severity of their company's difficulty with hiring skilled trade workers. Many modular construction manufacturers tend to employ people with construction backgrounds, as shown in Figure 31, and most manufacturers state that construction experience is important, shown in Figure 32. In fact, nearly three-quarters of manufacturers surveyed noted that construction experience was somewhat or very important for new employees, while 10% were neutral and 19% felt it was not very important or not important at all.

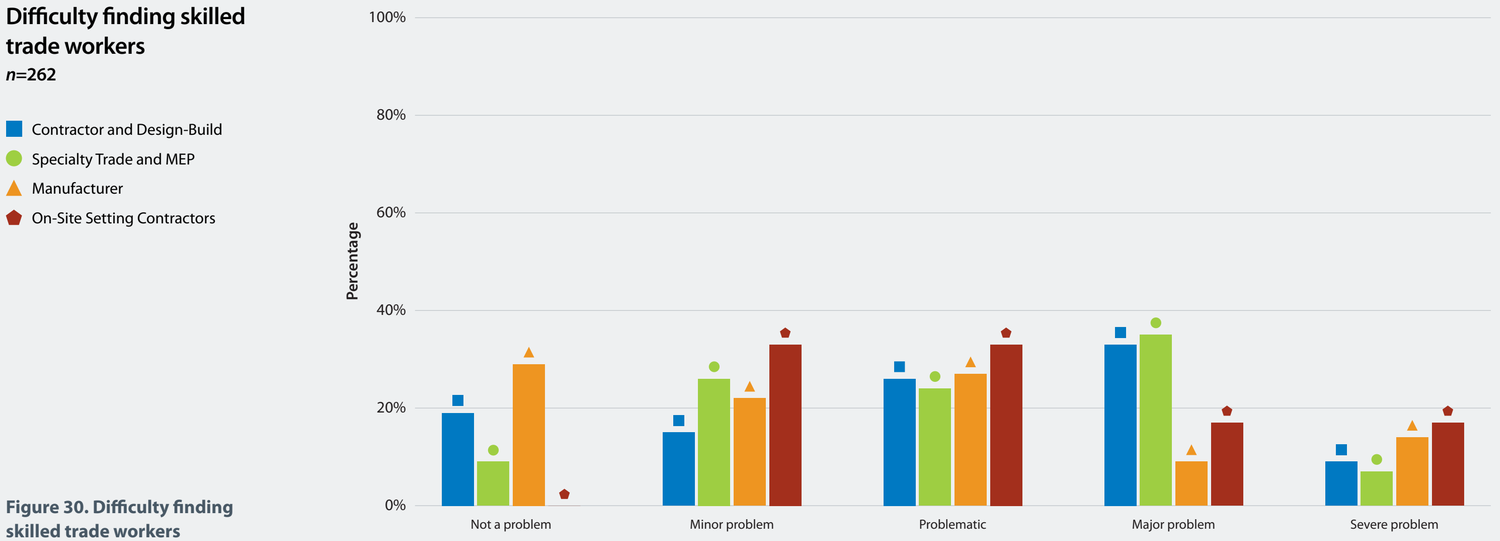


Figure 30. Difficulty finding skilled trade workers

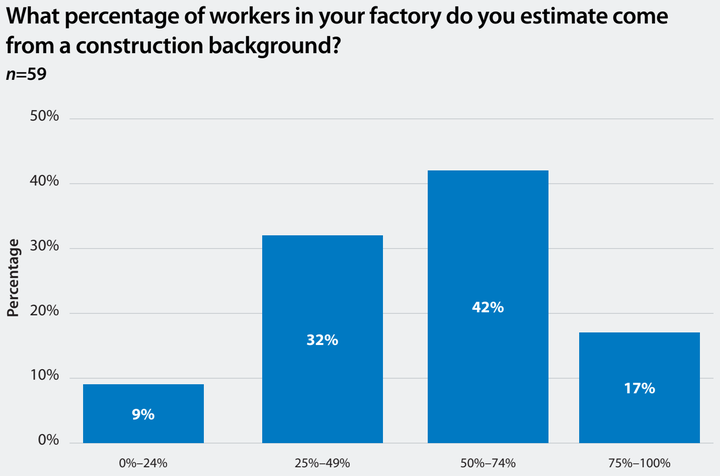


Figure 31. Percentage of modular factory workers with construction backgrounds

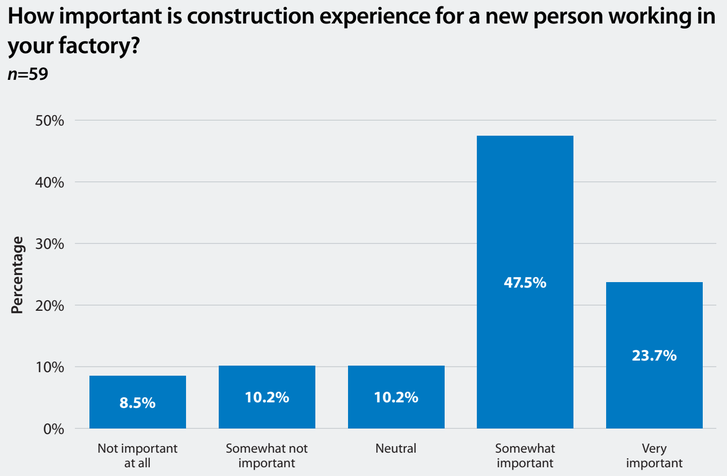


Figure 32. Importance of construction background in factories

As shown in Figure 33, manufacturers most frequently recruited from specialty trade and construction laborer communities. The next highest rank recruiting practice is recruiting from other manufacturers. Other populations include veterans, computer programming professionals, and computer numerical control operators. Manufacturers also indicated recruitment of candidates with business, video game development, and technology backgrounds. Many modular construction manufacturers describe companies as "tech companies" rather than construction or manufacturing companies.

When asked if the adoption of modular construction has enabled companies to expand the applicant workforce to populations who may not have joined a conventional construction company, 57% of contractor and design build firms selected no, 25% selected I don't know, and 19% selected yes (Figure 34).

Recruiting from unconventional construction populations may be an opportunity to mitigate some of the workforce shortage challenges contractors and manufacturers currently face.

Which industries, demographics, or communities do you recruit from when looking for workers who might be well positioned to work with volumetric and/or panelized modular products?

***n*=59,** *This question was only asked to manufacturers*

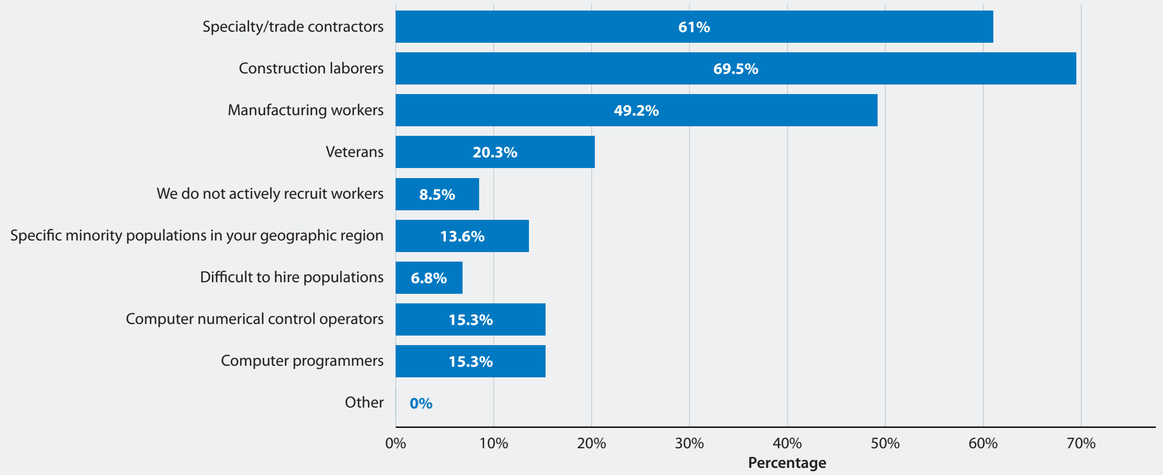


Figure 33. Manufacturers' recruitment pools

Has the adoption of modular construction practices enabled you to expand the applicant pool/workforce to populations who may not have joined a traditional construction company due to physical limitations, employment stability, working location/environment, etc.

***n*=203**

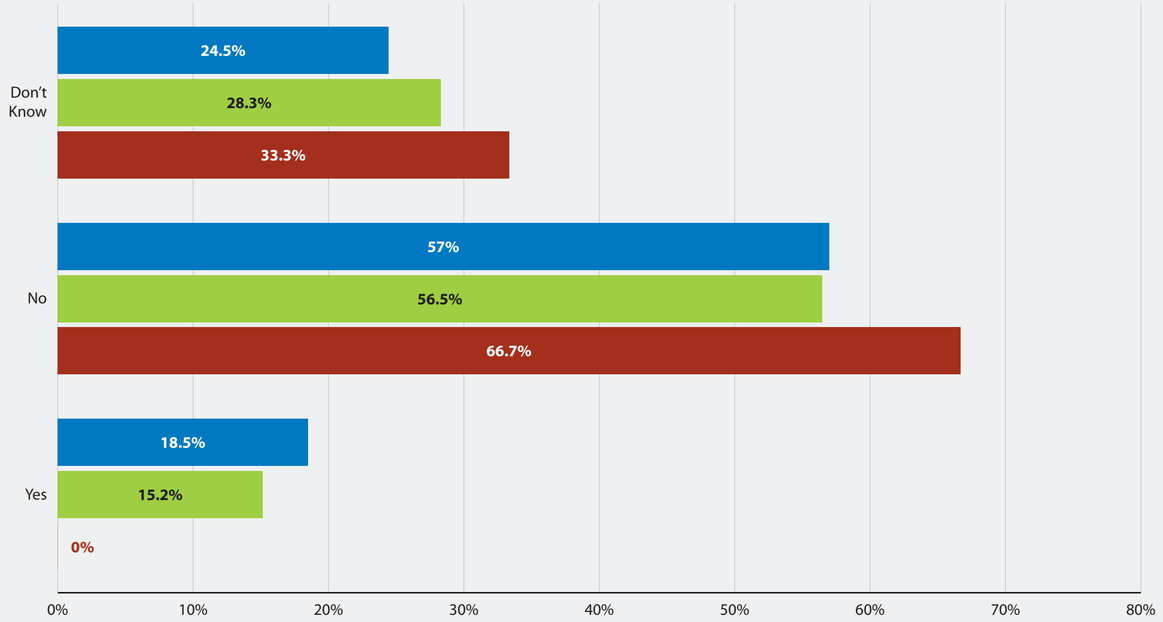


Figure 34. Use of modular construction methods impact on expanding applicant pools—contractor responses

05

Responses From Construction Firms Not Using Modular Construction Methods

The survey had a section for a capped group of 50 respondents who indicated they do not use panelized or volumetric modular products. The intention was to better understand the nonuser perception of these products and why they have elected not to use them. Among the group of 50 nonusers, only 5.6% of specialty trade contractors and 25% of general contractors indicated that their company had considered using panelized or modular building systems or components in the last three years (Figure 35). None of the 50 contractors in the nonuser group indicated that they expect to use volumetric and/or panelized modular construction practices within the next three years (Figure 36).

Has your company considered using volumetric modular or panelized modular products in the past three years?

***n*=50**

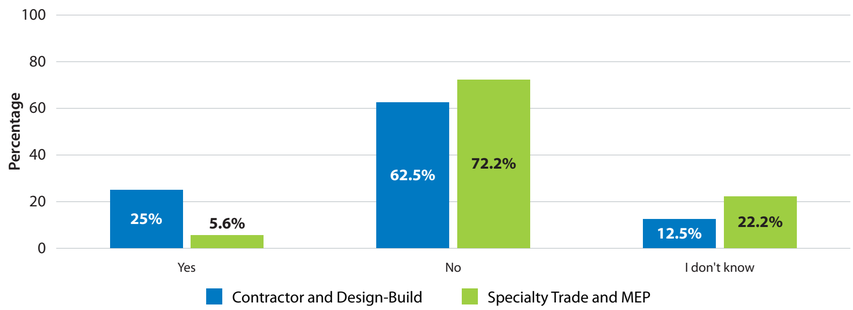


Figure 35. Nonusers' Responses To Whether They Had Considered Using Modular Products

Does your company plan to adopt volumetric modular or panelized modular in the next three years?

***n*=50**

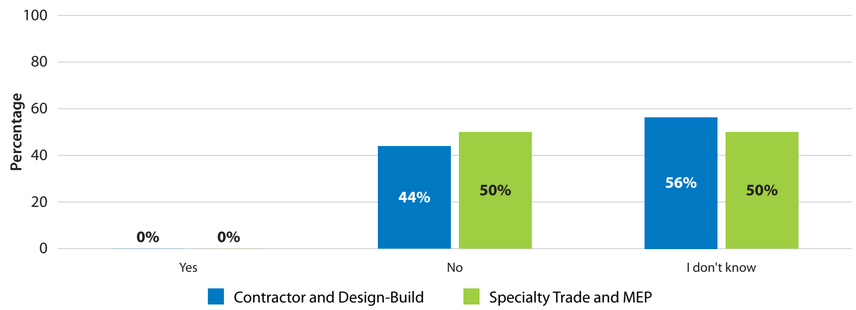


Figure 36. Nonuser Plans To Adopt In The Next Three Years

5.1 Perceptions About Adopting Modular Construction Methods

Respondents selected the top three reasons for not adopting volumetric or panelized modular construction methods. The most common reasons (cited by 91% of the nonuser respondents) were not being familiar with modular construction products and not having workers trained to use them (Figure 37). The third most cited reason (by 39% of nonusers) is lack of demand from developers and/or owners.

These top three reasons were from 14 different response options and demonstrate the need to provide more opportunities for contractor training and exposure. The results also reveal the importance of cultivating developer and owner demand.

Nonuser perceptions about what building types are applicable for panelized and/or volumetric modular systems demonstrate that there is a need for more general awareness about the inroads modular construction methods are making. One respondent indicated that modular construction would only be used in multifamily housing. They did not think it could be used for office buildings or hospitals, but most survey participants who had used modular construction methods are using volumetric and panelized modular methods to construct office buildings and hospitals.

When asked how difficult it would be to use panelized and volumetric modular products if a client required them to do so, 72% of nonusers indicated it would not be very difficult, easy, or very easy while 28% believe it would be difficult or very difficult (Figure 38). Of those who thought it would not be difficult, only three (6% of all responses) indicated that it would be easy or very easy to implement.

When the adoption question is further examined by contractor type, 77.8% of specialty trade contractors compared with 68.7% of general contractors indicated that using panelized or volumetric modular construction methods would not be very difficult or would be easy or very easy to adopt.

When presented with the opportunity to elaborate on the ease of adoption, 80% of the responses pertained to ease of adaptability due to similar methods of construction and erection already in use, crew adaptability, and contractor experience. One respondent wrote "it should be easy to preform, estimating may be a bit tricky."

Those who perceived adoption as being difficult largely attributed it to a lack of experience and the need for training. One respondent wrote "there is a notable learning curve to learning how to implement modularity correctly and efficiently." Several others did not believe modular construction was applicable to their specific trades.

Please indicate why you think your company has not considered using volumetric modular or panelized modular construction in the past three years.
***n*=50**

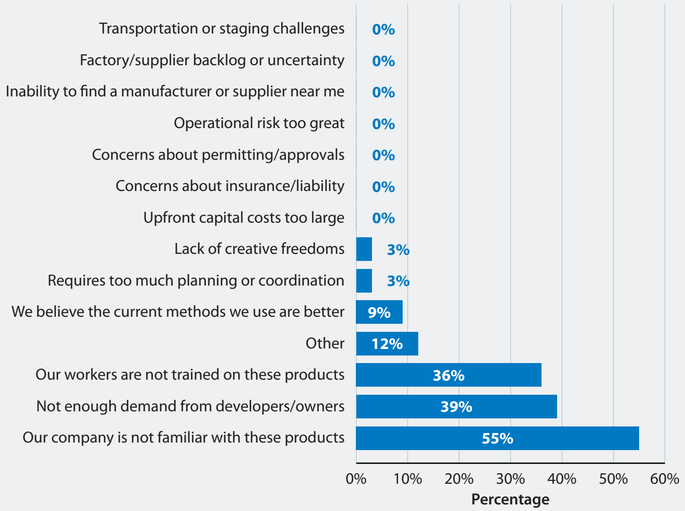


Figure 37. Reasons Nonusers Chose Not To Adopt Modular Construction

If a client were to require you to use volumetric modular or panelized construction practices, how difficult would it be for your company to implement?
***n*=50**

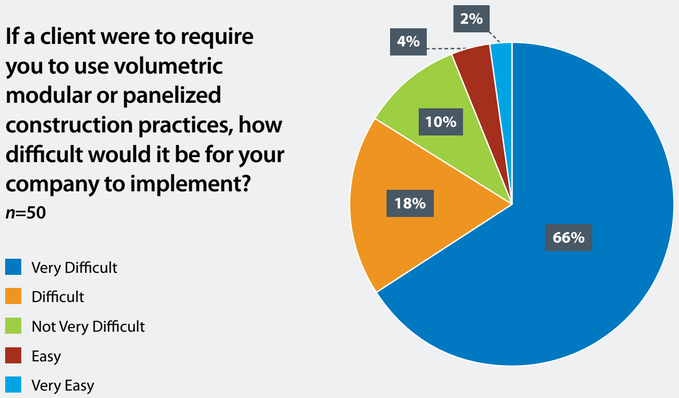


Figure 38. Nonuser Perception About Ease Of Implementation

5.2 Benefits and Drawbacks Cited by Contractors Not Using Modular Construction Methods

Nonusers are aware of the touted benefits of modular construction methods—especially general contractors, who were 2.14 times more likely than specialty trade contractors to associate panelized and/or volumetric modular construction with positive outcomes.

The top benefits indicated by nonusers are (Figure 39):

- Decreases construction costs
- Improves project schedule performance
- Helps deal with skilled labor shortages.

One-third (33.3%) of the nonuser group indicated they do not believe any benefits result from the modular construction methods. Excluding the 10 "none of these" responses, general contractors selected 73 benefits compared to 34 benefits selected by specialty trade contractors.

When asked about potential drawbacks, the top response (46%) was none of these options out of 11 options (Figure 40). Aside from "none of these options," the top-ranking drawback indicated by nonusers are:

- Delayed inspection process
- Lowers project quality
- Increases construction costs.

What benefits do you see potentialy coming from using volumetric modular or panelized modular products?
***n*=50**

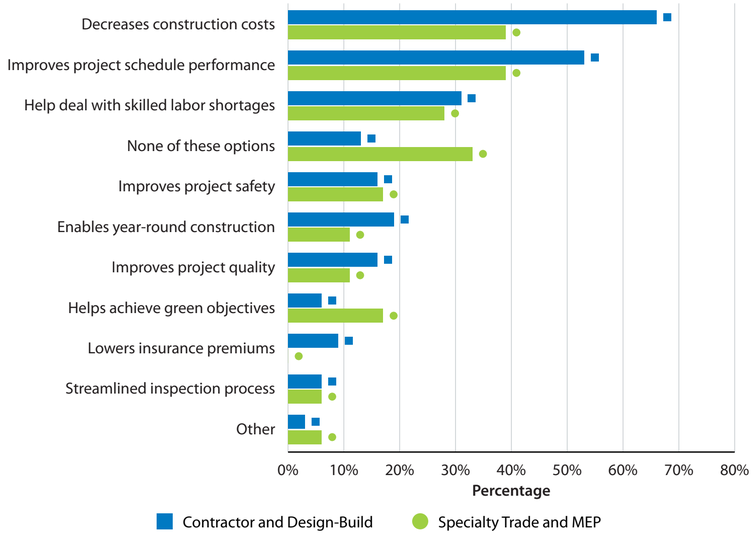


Figure 39. Benefits Nonusers See To Using Modular Construction Methods

What potential drawbacks or risks do you see in using volumetric modular or panelized modular products?
***n*=50**

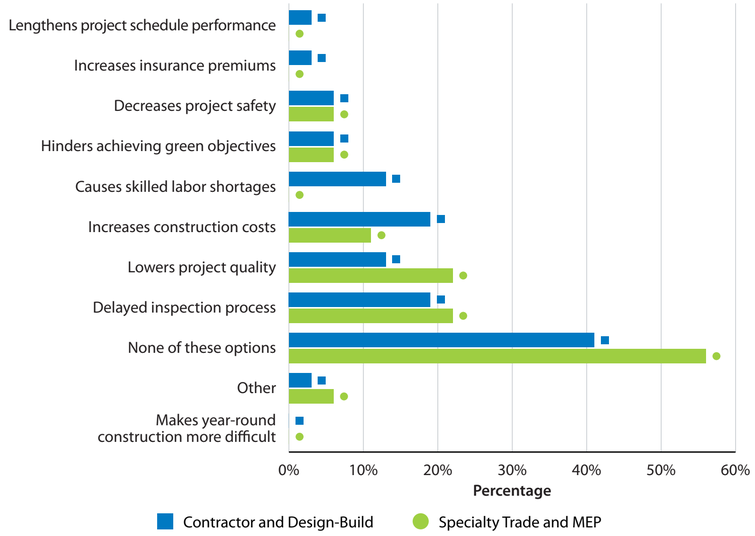


Figure 40. Drawbacks Nonusers See To Using Modular Construction Methods

06

Conclusion

Many of the study participants see a bright future for the modular construction industry, citing that it is one of the most effective ways to address workforce shortages and demand for new construction, especially affordable housing. While many participants believe the number of people needed overall on a construction site will not vary significantly whether implementing a modular construction or conventionally built project, they agree that fewer framing and drywall contractors will be necessary at the jobsite to implement a modular construction project compared with conventional building methods.

Modular construction manufacturers are recruiting people from the construction and specialty trades professions to work in their factories, indicating that these professions will still be in demand with a shift to more modular construction practices and provide an opportunity for workers to be in a controlled factory environment rather than on a jobsite. However, as factories continue to evolve, manufacturers expect structural steel, electrical, and framing work will be automated, signaling a potential decline in demand for these professions.

This study illustrates some key differences in perceptions between modular manufacturers who produce panelized and volumetric modular products and those who implement these projects on-site. Key differences in opinions are related to the construction workforce readiness to adopt modular construction and the amount of training needed to become proficient at implementing modular construction projects. Manufacturers believe the construction workforce is better prepared than contractors view themselves to be and that more training is needed to become proficient in modular construction than contractors perceive. While contractors believe very little training is needed and it does not require many additional skills, contractors who use these products and those who do not both cite a lack of training and familiarity with the products and modular construction practices as a top barrier to adoption, illustrating a need in the industry for more education, training, and awareness.

The training delivery method most used by survey respondents to adapt to modular construction is on-the-job training. Respondents cited the need for a problem-solving mindset, clear communication, organizational understanding, common sense, and open-mindedness as the most in-demand soft skills needed to help workers in the shift to modular construction methods. Important hard skills included understanding detailed drawings; facilitating on-site coordination of transportation and set crews; building information modeling comprehension, and the ability to operate machinery including computer numerical control equipment and ergonomic-assistive equipment like lifts and cranes.

Despite some manufacturers prioritizing the hiring of non-conventional populations in their factories, the survey indicates that most modular construction manufacturers still prioritize recruiting from the construction industry, constraining an already undersupplied workforce pipeline. Because factories require less labor-intensive work, have less variable work environments and enable more structure and regularity, manufacturers could look to non-conventional construction populations, including from those working in technology sectors, and from populations currently underrepresented in the construction sector.

While survey respondents had the opportunity to provide information on wages, benefits, safety, and working conditions, there were not sufficient responses to include any definitive information in this study. More research is needed to understand the nuances of the modular construction industry's impact on workers, including more quantitative data on safety incidents, how wages are being impacted, and how a wider pool of applicants can be attracted to this growing industry.

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APPENDIX A

Methodology Details and Discussion

A.1 Literature Review

A literature review was conducted to establish existing research gaps. An initial scan was performed on 500 existing publications on industrialized and modular construction. This was narrowed down to 30 publications that had the highest relevance based on keywords. The content of these 30 publications can be categorized as follows: industrialization of construction (11), digitalization of construction (8), research specific to volumetric modular (7) and panelized construction (4), and off-site construction skills (5). One of the publications also looked specifically at off-site construction occupations. All the publications about off-site construction skills were published within three years of the literature review, suggesting that this is still an emerging area of study. Furthermore, all focused specifically on the off-site and factory-based workforce, without considering the full ecosystem of how the construction workforce may be impacted or evolve as a result of the increasing adoption of prefabricated building components, systems, and modules. This will be a key focus of later research.

The broader set of 30 publications were reviewed to better understand what elements of modular construction are well represented in the literature. In Table A-1, the frequency of certain key topic areas is quantified across key categories, including social trends, technology trends, broader construction market trends, modular construction benefits, and challenges.

Modular Construction Benefits

While the benefits were the most frequently published, they were not often supported by industry feedback, highlighting the need to use this study to confirm whether these benefits are being realized by contractors.

One of the most frequently published topics was regarding labor shortages in the construction industry and how modular construction could alleviate workforce shortage strains. None of the literature spanned both on-site and off-site or factory workforce impacts and potential skill or occupational transitions.

Table A1. Frequency that topics from literature review were addressed in a review of 30 publications

Social Trends		Technology Trends		Broad Construction Market Trends		IC Benefits		IC Challenges	
Affordable housing	6	Extended reality	2	Labor shortages	13	Cost savings	12	Transportation	5
Workforce housing	3	Bim	2	Supply chain shortages	3	Time savings	15	Distance	2
Training/ education	7	Automation	4	Material costs	4	Waste reduction	9	Site density	3
New/emerging workforce populations	3	3d printing	1	Wage requirements	3	Productivity	15	Site storage	1
Barriers to entry	1	Virtual collaboration	3			Job creation	2		
Gen Y and Z	2					Safety	10		
						Quality	11		

In short, many publications discuss modular construction's benefits and challenges. Only one covered off-site construction occupations and five covered skills needed in off-site construction. Each of these resources specifically looked at the off-site construction workforce/skills, not at the broader workforce across construction, including traditional, on-site, and off-site. These did not cover the benefits and/or drawbacks to the nature of work, and working conditions (except safety).

Other key findings from the literature review include that hiring is indeed a challenge for off-site construction and the industry remains in an early stage, lacking even consistent definitions or terminology across the industry. There is a spectrum to how automated companies are, which significantly affects the type of work and occupations needed in the factory. There is agreement that skills like logistics, planning, digital design, production management, and data-related jobs all showed an increase in importance for off-site construction.

A.2 Survey

The project team iteratively developed survey questions on a digital whiteboard (Canva) to determine survey flow and user-type skip-logic. This process included the pairing of question concepts to the constructs outlined in the research questions. Figure A-1 illustrates the flow logic of the survey. The survey tool was then refined to solidify question formats, language, and response options until the survey was added into the survey platform.

A.3 Survey Recruitment

Two participant groups were targeted in this survey: construction industry contractors and manufacturers of assemblies, panelized systems, modular buildings, or modular components. Survey participants who fell into the former group were members of a national panel of contractors created and managed by Dodge Construction Network (herein referred to simply as "Dodge"). The contractor survey deployed by Dodge leveraged their existing nationwide contractor panel consisting of self-selecting construction industry professionals, general contractors, design-build professionals, and specialty trade contractors. The latter group of manufacturer participants was recruited by an external contractor with a similar self-selecting panel recruiting system. All participants of this national survey were over the age of 18, employed in the United States, and had expertise or experience in the construction industry as a contractor, manufacturer, or off-site construction manufacturer.

Survey Procedure

Research data were collected through two separate national survey panels via Forsta, a survey platform. The contractor panel group's survey collected data between Nov. 14, 2023, and Dec. 14, 2023, with three reminder prompts sent on Nov. 20, Nov. 27, and Dec. 11. The manufacturer panel group's survey collected data between Nov. 29, 2023, and Dec. 18, 2023, with three reminder prompts seven days apart from one another.

The panels used for this research are proprietary, were created and are managed by Dodge's construction industry insights research team, and consist of established construction industry members, which are leveraged for market research in the construction industry. Previously, participants opted to be a member of a research panel with Dodge or one of their collaborators, using a double opt-in procedure. Participants were able to decline answering questions at will, for any reason.

Data Cleaning

Data were cleaned by the Dodge project partners. All personally identifying information was removed from the dataset, including the open-ended responses to collect contact information for incentive delivery. After the survey data were cleaned, they were formatted for analysis in SPSS, a commonly used data analysis tool in statistical research projects, to analyze quantitative data. Identifying information was retained separately from cleaned research data by Dodge and was used to deliver participation incentives to survey takers in the week after data collection. This personal identifying information used for incentivization was then deleted from the study data.

Survey Data Analysis

After the data cleaning process, the researchers worked with Washington State University's Social & Economic Sciences Research Center to analyze the data. Frequency and descriptive statistics were pulled for all survey questions. User groups delineated by participant type (e.g., general construction or general contractors and design-build firms, specialty trade contractors, and on-site set contractors) were further separated from the data to determine differences in participant type and industry perceptions.

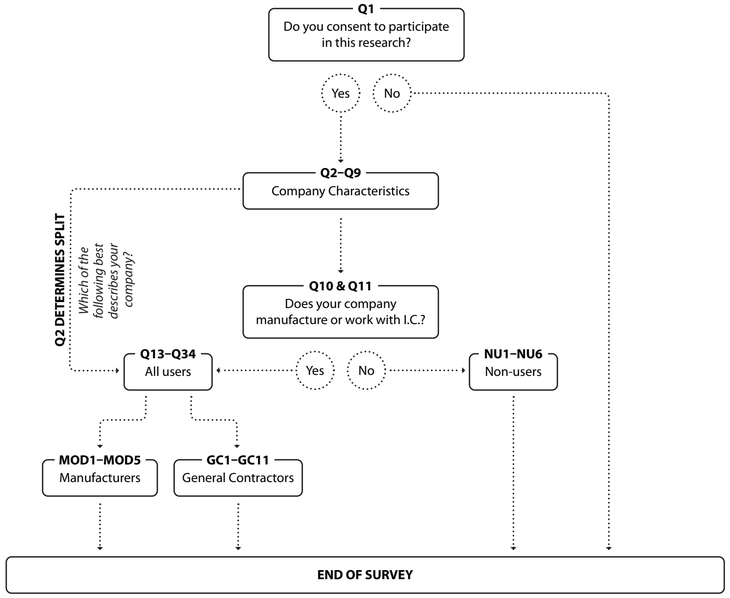

Figure 41. Survey flow logic, which illustrates which participant groups received which category of questions.

APPENDIX B

Survey Participant Company Questions

Question	Details	Count	%
Which of the following best describes your company?	General construction/General contractor	166	53.2%
	Design-build firm	17	5.4%
	Specialty trade contractor	64	20.5%
	Manufacturer or supplier of modular or panelized construction products	59	18.9%
	On-site installation or set contractor	6	1.9%
What parts of the value chain does your company directly serve? (Select all that apply)	Design	62	--
	Manufacturing	73	--
	Transportation	28	--
	Setting	60	--
	Construction	268	--
	Commissioning/Permitting	34	--
Which of the following job functions/ departments best describes your job role?	Human Resources Professional	7	2.2%
	Executive/Director	103	33%
	Supervisor/Manager, (e.g., Project Manager, Safety Manager, etc.)	148	47.4%
	Administrative Staff	19	6.1%
	Tradesperson/Laborer/Worker	12	3.8%
	Other	23	7.4%
What geographic markets does your company serve (over the last three years)? (Select all that apply)	**NORTHEAST:** Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont	66	--
	SOUTH: Alabama, Arkansas, Delaware, District of Columbia, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and West Virginia	140	--
	MIDWEST: Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin	108	--
	WEST: Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming	92	--
	Outside of the U.S.	3	--

Question	Details		Count	%
Please indicate in which sector(s) do you work? (Select all that apply)	Single family detached / attached up to 4 units		97	--
	Multifamily (5+ units)		117	--
	Hospitality/Healthcare		149	--
	Public Sector/Education		176	--
	Office/Retail		183	--
	Other		54	--
Does your company manufacture or work with EITHER of the following two product categories? (Select all that apply)**	Volumetric Modular (e.g., 3D modules in the form of pods; bathroom modules; temporary modular; mechanical pods; etc.)		63	--
	Panelized modular systems (e.g., wall panels; mechanical/electrical/ plumbing (MEP)-integrated walls; structurally insulated panels (SIPS); cross-laminated timber (CLT); wall assemblies; curtain walls; flat packed construction assemblies; precast/prestressed concrete walls; etc.)		245	--
	No, we do not use / make any of these products		50	--
In the past 3 years, how many projects using the following types of products has your company completed?	Volumetric Modular Products	1–4	26	--
		5–9	15	--
		10 or more	19	--
		I don't know	3	--
	Panelized Modular Products	1–4	98	--
		5–9	59	--
		10 or more	79	--
		I don't know	9	--

* Note: this question was used to sort users of modular construction products from nonusers (NU questions). We know from this question that ALL NU question respondents were construction contractors or specialty trade contractors. There were no nonuser participants in the manufactur ing or on-site setting groups.

APPENDIX C

Literature Review Summary

Citation	Full Citation	Citation Type	Type	Relevance
Wang et al. 2018	Wang, Peng, Peng Wu, Jun Wang, Hung-Lin Chi, Xiangyu Wang. 2018. "A Critical Review of the Use of Virtual Reality in Construction Engineering Education and Training." International Journal of Environmental Research and Public Health. https://www.mdpi.com/1660-4601/15/6/1204	Journal Article	Digitalization	Digitalization
Welk 2022	Welk, Hannah. 2022. "Time, Cost Savings Increase Modular Construction Interest." Los Angeles Business Journal. https://labusinessjournal.com/real-estate/time-cost-savings-increase-modular-construction-in/	News Article	Volumetric	Modular Workforce
Black & Veatch 2022	Black & Veatch. 2022. "Black & Veatch Selects Avatour to Optimize Remote Project Collaboration." Black & Veach - Press Release. https://www.bv.com/news/black-veatch-selects-avatour-optimize-remote-project-collaboration	Press Release	Digitalization	Digitalization
Warren 2022	Warren, Brent. 2022. "Modular Home Factory, Apartments Planned for Value City Site." Columbus Underground. https://columbusunderground.com/modular-home-factory-apartments-planned-for-value-city-site-bw1/	News Article	Volumetric	Modular Workforce
Mahoney 2022	Mahoney, Kellyane. 2022. "Autodesk Launches Microgrants and Scholarship Award to Support Students Entering Construction Trades." Autodesk. https://adsknews.autodesk.com/stories/make-it-real-microgrants	Press release	Volumetric	Workforce
Star Equity Holdings 2022	Star Equity Holdings, Star. 2022. "KBS Builders Wins $4.2 Million Contract to Manufacture Workforce Housing on Nantucket." Star Equity Holdings. https://www.globenewswire.com/news-release/2022/06/16/2463878/11704/en/KBS-Builders-Wins-4-2-Million-Contract-to-Manufacture-Workforce-Housing-on-Nantucket.html	Press Release	Volumetric	Modular Workforce
HercuTech 2022	HercuTech. 2022. "Arizona-Based HercuTech Disrupting Building Industry with Game-Changing HercuWall™ Technology." PR Web. https://www.prweb.com/releases/arizona_based_hercutech_disrupting_building_industry_with_game_changing_hercuwall_technology/prweb18762073.htm	Press Release	Panelized	Modular Workforce
HercuTech 2023	HercuTech. 2023. "HercuFit Program: Train, Compete, Win." HercuTech. https://hercutech.com/hercufit/#1601664372216-e7a3405f-8781	Company Webpage	Panelized	Modular Workforce
Alaska Business 2022	Alaska Business. 2022. "Modular Buildings: Roofs over Remote Sites." Alaska Business Magazine. https://www.akbizmag.com/magazine/modular-buildings/	News Article	Volumetric	Modular
Chatzimichailidou 2022	Chatzimichailidou, Mikela. 2022. "Using BIM in the safety risk management of modular construction." Safety Science. https://www.sciencedirect.com/science/article/pii/S0925753522001916	Journal Article	Volumetric	Modular
ABB 2021	ABB. 2021. "ABB Robotics advances construction industry automation to enable safer and sustainable building." ABB. https://new.abb.com/news/detail/78359/abb-robotics-advances-construction-industry-automation-to-enable-safer-and-sustainable-building	Press Release	Modular Broadly	Modular Workforce
Berg 2023	Berg, Nate. 2023. "Could this inflatable factory reinvent construction?" Fast Company. https://www.fastcompany.com/90835778/could-this-inflatable-factory-reinvent-construction	News Article	Modular Broadly	Modular
Smith et al. 2023	Smith, Ryan, Ivan Rupnik, Tyler Schmetterer and Kyle Barry. 2023. "Offsite Construction for Housing: Research Roadmap." HUD. https://www.huduser.gov/portal/portal/sites/default/files/pdf/Offsite-Construction-for-Housing-Research-Roadmap.pdf	Research Roadmap	Modular Broadly	Modular Workforce
Van Sante 2022	Van Sante, Maurice. 2022. "Lagging productivity in construction is driving up building costs." ING. https://think.ing.com/articles/lagging-productivity-drives-up-building-costs-in-many-eu-countries	News Article	Digitalization	Workforce
Modulous 2022	Modulous. 2022. "Construction tech firm Modulous raises $11.5 million to help developers, architects, and general contractors build net-zero modular homes without a factory." Modulous. https://www.modulous.com/news-media/modulous-announces-series-a-fundraise	Press Release	Digitalization	Modular Workforce
Copley et al. 2022	Copley, Jason and Michael Schwartz. 2022. "Five Barriers to Bringing 3D-Printed Construction to the Philadelphia Area." Cohen Seglias. https://www.cohenseglias.com/news-article/five-barriers-to-bringing-3d-printed-construction-to-the-philadelphia-area/	News Article	Digitalization	Modular Workforce
Wong Chong 2021	Wong Chong, O. 2021. "Logic Representation and Reasoning for Automated BIM Analysis to Support Automation in Offsite Construction." Automation in Construction. https://par.nsf.gov/servlets/purl/10275270	Research Paper	Digitalization	Modular

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Jiang et al. 2022	Jiang, Yishuo, Ming Li, Daqiang Guo, Brave Wu and Ray Y. 2022. "Digital twin-enabled smart modular integrated construction system for on-site assembly." Computers in Industry. https://www.sciencedirect.com/science/article/pii/S0166361521002013	Research Paper	Digitalization	Modular Workforce
Wong and Loo 2022	Wong, Rosana and Becky Loo. 2022. "Sustainability implications of using precast concrete in construction: An in-depth project-level analysis spanning two decades." Journal of Cleaner Production. https://reader.elsevier.com/reader/sd/pii/S0959652622040586?token=546AC527D6209860705E614251AF85DBA3415F6A04032FAB276152F97223D861E1082F7061FD0BAF2808162114EBBB5D&originRegion=us-east-1&originCreation=20230308183247	Research Paper	Panelized	Modular Workforce
Assad et al. 2022	Assad, Rayan, Islam El-adaway, and Kim Needy. 2022. "The Impact of Offsite Construction on the Workforce: Required Skillset and Prioritization of Training Needs." Journal of Construction Enigneering and Management. https://ascelibrary.org/doi/abs/10.1061/%28ASCE%29CO.1943-7862.0002314	Research Paper	Modular Broadly	Modular Workforce
Ginigaddara et al. 2020	Ginigaddara, Buddhini, Yinbin Feng, and Srinath Perera. 2020. "An Evaluation of Offsite Construction Skill Profiles." Journal of Financial Management of Property and Construction. https://www.emerald.com/insight/content/doi/10.1108/JFMPC-08-2020-0057/full/html	Research Paper	Modular Broadly	Modular Workforce
Nazir et al. 2020	Nazir, Falaq, David J. Edwards, Mark Shelbourn, and Igor Martek. 2020. "Comparison of modular and traditional UK housing construction: a bibliometric analysis." Journal of Engineering and Technology. https://www.emerald.com/insight/publication/issn/1726-0531	Research Paper	Volumetric	Modular
Mohammadi and Grosskopf 2017	Mohammadi, Arefeh and Kevin R. Grosskopf. 2017. "Project IMPACT: A Case Study of Developing a Manufactured Construction Workforce through Contextualized Training." 53rd ASC Annual International Conference proceedings. http://ascpro0.ascweb.org/archives/cd/2017/paper/CERT119002017.pdf	Research Paper	Panelized	Modular Workforce
Podder et al. 2022	Podder, Ankur, Kenny Gruchalla, Nicholas Brunhart-Lupo, Shanti Pless, Mauro Sica and Paola Lacchin. 2022. "Immersive Industrialized Construction Environments for Energy Efficiency Construction Workforce." Frontiers in Virtual Reality. https://www.frontiersin.org/articles/10.3389/frvir.2022.781170/full	Research Paper	Modular Broadly	Modular Workforce
Ganiron Jr and Mohammed Almarwae	Ganiron Jr, Thomas U., and Mohammed Almarwae. 2014. "Prefabricated Technology in a Modular House." International Journal of Advanced Science and Technology. http://article.nadiapub.com/IJAST/vol73/4.pdf	Research Paper	Modular Broadly	Modular
Attouri et al. 2022	Attouri, Emma, Zoubeir Lafhaj, Laure Ducoulombier, and Bruno Lineatte. 2022. "The current use of industrialized construction techniques in France: Benefits, limits and future expectations." Cleaner Engineering and Technology. https://reader.elsevier.com/reader/sd/pii/S2666790822000416?token=F35C4C0AF804B6E45C62899640CDFB71EFD004FC668440BEEBE1C969C20E547AE7B254EC3C2F078D59A89F3468CFBFA1&originRegion=us-east-1&originCreation=20230310185447	Research Paper	Modular Broadly	Modular
Ginigaddara et al. 2019	Ginigaddara, Buddhini, Srinath Perera, Yingbin Feng, and Payam Rahnamayiezekavat. 2020. "Skills Required for Offsite Construction." CIB World Building Congress. https://www.arataumodular.com/app/wp-content/uploads/2022/07/Skills-Required-for-Offsite-Construction.pdf	Research Paper	Modular Broadly	Modular Workforce
Assad et al. 2022	Assad, Rayan, Kim Needy, Islam El-adaway. 2022. "Quantification of the State of Practice of Offsite Construction and Related Technologies: Current Trends and Future Prospects." Construction Engineering and Management.	Research Paper	Modular Broadly	Modular Workforce
Cheng et al. 2023	Cheng, Zhuo, Shengxian Tang, Hexu Liu, and Zhen Lei. 2023. "Digital Technologies in Offsite and Prefabricated Construction: Theories and Applications." Buildings. https://www.mdpi.com/2075-5309/13/1/163	Research Paper	Digitalization	Modular
Rotimi et al. 2022	Rotimi, Funmila, Firas Majthoub Almughrabi, Don Amila Sajeevan Samarasignhe, and Chathurani Silva. 2022. "Specific Skill Requirements within Prefabricated Residential Construction: Stakeholders' Perspectives." Buildings. https://www.mdpi.com/2075-5309/12/1/43	Research Paper	Modular Broadly	Modular Workforce

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