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Article

Expanding Housing-Production Capacity in Appalachia: Participatory Pathways for Industrialized Off-Site Construction (IOC)

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Abstract

Appalachia faces a housing challenge that is not only a shortage of affordable units, but also a regional housing-production capacity problem shaped by workforce availability, financing, regulation, market awareness, technology readiness, and institutional coordination. This study examines how participatory stakeholder workshops can identify and prioritize regional constraints and strategies for using industrialized off-site construction (IOC) to expand housing delivery capacity in Appalachia. The study used a three-step qualitative methodology: a regional context review, seven participatory design workshops across Appalachian locations, and internal and external validation of workshop-derived themes. A total of 129 stakeholders participated, representing construction, manufacturing, modular construction, education, workforce development, economic development, local government, finance, and related sectors. Workshop data were analysed through structured prompts, affinity clustering, PICK chart prioritization, independent re-clustering, and Cohen's κ reliability testing. Findings identified five common conditions shaping IOC's regional potential: Education & Training, Policy & Regulation Framework, Marketing & Awareness, Financing & Funding, and Technology & Innovation. Marketing and awareness emerged as a near-term entry point, while workforce, policy, financing, and technology conditions required longer-term coordination. The study contributes a replicable participatory process for diagnosing regional housing-production constraints and positioning IOC as a context-dependent pathway for improving housing delivery, affordability, and access.

Keywords: affordable housing; housing-production capacity; industrialized off-site construction; Appalachia; participatory design; regional housing strategy

Introduction

Appalachia's housing challenge is not only a matter of affordability or housing supply. It is also a regional housing-production capacity problem. In this study, housing-production capacity refers to a region's ability to deliver needed housing by aligning workforce availability, construction capacity, financing mechanisms, policy and regulatory processes, market acceptance, and technology readiness (Buitelaar & de Kam, 2009; Taşan-Kok & Özogul, 2021). This framing matters because housing delivery does not depend on a single constraint. It depends on how labor, institutions, capital, construction methods, and local demand interact within a regional housing system.

The United States continues to face linked housing and labor shortages. Construction labor constraints affect the pace, cost, and feasibility of residential development, with implications for housing availability and affordability (Howard et al., 2024). The Associated Builders and Contractors (ABC) estimates that the United States requires approximately 8 million construction workers to meet current demand, leaving a shortfall of roughly half a million workers compared with current employment levels (ABC, 2024). At the same time, recent analyses indicate that the United States is

underbuilt by about 3.8–3.85 million homes (Khater et al., 2021; Kingsella & MacArthur, 2022). Meeting additional housing demand would require about 400 000 additional workers each year beyond the existing workforce (National Association of Home Builders (NAHB), 2024). These conditions are especially relevant for Appalachia, where housing needs, demographic shifts, economic restructuring, and workforce limitations intersect in ways that constrain local housing delivery (Jones et al., 2023; Larussa, 2023). Within this context, industrialized off-site construction (IOC) has gained attention as one possible pathway for expanding housing-production capacity. IOC is a construction system in which standardized building components or modules are manufactured in controlled factory settings before final assembly on site. It combines industrial principles such as standardization, mechanization, digital coordination, and quality-controlled production with site-based assembly to expand and stabilize housing delivery capacity (Blismas et al., 2006; MBI, 2022). However, IOC is not treated in this study as a stand-alone technical solution. Its usefulness depends on whether regional workforce systems, regulatory processes, financing structures, market awareness, and technology readiness can support its adoption.

IOC represents more than a technical alternative to conventional construction. It shifts the locus of work from the construction site to the factory floor, which changes how workforce skills are organized, how construction tasks are sequenced, how design and procurement decisions are coordinated, and how inspection and quality control are performed (Lessing, 2006; Lu, 2009). These operational changes have implications that extend beyond the construction process itself. They also affect who participates in the construction labor market, how housing supply chains are structured, and how local institutions support or constrain housing delivery (Pan & Sidwell, 2011; Rahman, 2013). For this reason, IOC adoption cannot be evaluated as a stand-alone construction decision. It must be understood as part of a broader change in how a region produces housing. Because housing-production capacity is shaped by local systems, stakeholder knowledge is needed to understand where constraints are most severe and which actions are most feasible. Regional actors, including builders, educators, housing organizations, local officials, workforce-development agencies, lenders, manufacturers, and community partners, often hold practical knowledge about barriers that are not visible in broad housing or construction data alone. Participatory design methods are useful for examining how local stakeholders define problems, connect housing and workforce issues, and prioritize possible strategies, especially when challenges are multi-stakeholder and context-dependent (Sanoff, 2000; Steen, 2013). In this study, participatory workshops were used not simply to collect opinions, but to diagnose how Appalachian stakeholders understand regional housing-production constraints and the conditions under which IOC may support housing delivery.

Existing research documents housing and labor challenges in Appalachia (Jones et al., 2023) and identifies potential benefits of IOC (Blismas et al., 2006). However, these bodies of work rarely examine how rural and small-metro regions translate IOC into locally grounded housing-production strategies through participatory stakeholder processes. Studies of IOC adoption barriers identify issues such as regulation, financing, market acceptance, supply-chain readiness, and institutional coordination, but provide limited evidence on how regional actors themselves identify and prioritize these conditions for housing delivery capacity (Pan & Sidwell, 2011; Rahman, 2013). This gap matters because housing strategies developed for larger metropolitan or more mature industrialized construction markets may not transfer directly to Appalachian communities, where housing systems are shaped by post-industrial transitions, limited construction capacity, aging housing stock, uneven market demand, and varying familiarity with IOC. This study addresses that gap by examining seven participatory stakeholder workshops conducted across Appalachian locations. The study asks: How can participatory stakeholder workshops identify and prioritize regional housing-production constraints and strategies for using IOC to expand housing delivery capacity in Appalachia? To answer this question, the study is guided by three research objectives:

- RO1: Examine regional housing, workforce, economic, and construction-capacity conditions across selected Appalachian workshop locations.

- RO2: Use participatory design workshops to identify stakeholder-perceived constraints and opportunities related to housing-production capacity.
- RO3: Identify and prioritize locally grounded strategies through which IOC may support regional housing delivery systems.

This study contributes to housing research in three ways. First, it reframes IOC adoption as part of a broader regional housing-production capacity problem rather than a purely construction-technology issue. Second, it provides empirical evidence from participatory workshops across Appalachia, showing how regional stakeholders connect housing delivery with workforce development, institutional conditions, financing, market awareness, and technology readiness. Third, it offers a replicable participatory process for translating local expertise into prioritized implementation strategies. The paper positions IOC not as a universal solution, but as a context-dependent pathway that may support housing delivery, affordability, and access when aligned with regional capacity, institutional readiness, and community needs.

Background

This section situates the study within three areas of scholarship relevant to the research question: regional housing-production systems, IOC as a shift in housing delivery, and participatory approaches to diagnosing local housing constraints. The purpose is not to review IOC technologies in detail, but to explain why IOC must be examined through the housing systems that shape production capacity, affordability, workforce development, regulation, financing, and market acceptance.

Regional Housing-Production Systems and Appalachian Constraints

Housing delivery is shaped by more than aggregate demand or unit shortages. It depends on the capacity of local and regional systems to coordinate land, labor, capital, regulation, infrastructure, market confidence, and production methods. Prior housing research shows that local housing production is affected by governance structures, institutional fragmentation, and the coordination of public and private actors (Buitelaar & de Kam, 2009; Taşan-Kok & Özogul, 2021). This systems perspective is especially important for regions where housing needs intersect with workforce limitations, uneven investment, and constrained development capacity.

In Appalachia, these issues are visible across communities with older housing stock, affordability constraints, repair needs, and uneven access to adequate housing (Jones & Spencer, 2018; Jones et al., 2023). Housing constraints are also connected to regional economic development. In many communities, limited housing availability affects workforce recruitment and retention, while workforce shortages constrain the ability to build, repair, and maintain housing. This means that housing need cannot be separated from the systems that produce housing. Workforce constraints are particularly pronounced. In the past decade, the broader Appalachian region lost approximately 50 thousand mining jobs and 10 thousand skilled manufacturing jobs (Appalachian Regional Commission, 2022). Aging trends in the construction workforce add to these pressures, with roughly 30 per cent of Central Appalachia's construction and industrialized construction workforce aged 55 or older (Henderson, 2023). These workforce shifts shape regional housing-production capacity by limiting the local labor base available to build, repair, and adapt housing, while also reflecting longer-term economic restructuring across the region.

The seven workshop locations reflect this broader regional pattern. They include post-industrial cities, rural and small-metro communities, growth corridors, and places with older housing stock and shifting employment bases. Across these locations, housing constraints are linked to local labor markets, economic restructuring, population change, and uneven production capacity. Full location-by-location housing and workforce indicators are provided in Supplementary Tables S4 and S5. Table 1 combines the housing and workforce context across the seven workshop locations.

Together, this context supports the framing of Appalachia’s housing challenge as a regional housing-production capacity problem. Expanding housing supply requires more than identifying land or demand. It requires coordination among workforce pipelines, financing mechanisms, regulatory processes, construction capacity, infrastructure, and local market demand.

Table 1. Regional housing and workforce context across workshop locations (Data USA, 2022).

Location	Population trend	Housing snapshot	Key housing challenge	Economy and workforce drivers
Bluefield, WV	Declining	Median home ~\$113,900; median year built 1950	Insufficient affordable housing; aging inventory	Declining economy; healthcare, education, retail, manufacturing
Huntington, WV	Declining	Median home ~\$129,600; median year built 1950s	Aging stock; infrastructure deficit	Declining economy; education, trade/transport/utilities, government, hospitality
Knoxville, TN	Increasing	Median home ~\$314,700; median year built 1980s	Affordability; low inventory; market uncertainty	Growing economy; manufacturing, healthcare, technology, tourism
Marietta, OH	Declining	Median home ~\$161,600; median year built 1950s	Investment pressure; older homes	Growing economy; healthcare, social work, retail, education
Morganton, NC	Increasing	New housing stock entering the market	Affordable options not keeping pace with growth	Growing economy; manufacturing, healthcare, hospitality
Pittsburgh, PA	Declining	Median home ~\$158,900; median year built 1950s; largely energy-inefficient	Aged, energy-inefficient stock	Recovering from prior industrial decline; education, healthcare, hospitality
Prestonsburg , KY	Stagnant	Median home ~\$172,000; median year built 1970s	Old, less sustainable stock; concentrated poverty	Declining economy; healthcare, social work, hospitality, food industry

IOC as a Shift in Housing Delivery Systems

IOC is relevant to this study because it changes how housing production is organized. Rather than relying entirely on conventional site-based construction, IOC shifts some building activities into controlled off-site or factory settings before final assembly on site. Prior research associates off-site and industrialized approaches with potential gains in productivity, schedule reliability, quality control, safety, and cost predictability (Blismas et al., 2006; Pan & Sidwell, 2011). However, these benefits depend on the surrounding system in which IOC is introduced.

This shift affects more than construction technique. Moving work from the site to the factory changes labor requirements, production sequencing, design coordination, procurement timing, inspection processes, transportation logistics, and capital needs. It can create new workforce pathways and make construction work more predictable, but it also requires coordination among manufacturers, builders, regulators, lenders, educators, and housing organizations (Lessing, 2006; Rahman, 2013). In this sense, IOC should be understood as a housing-delivery system shift rather than simply a technical alternative to conventional construction.

For Appalachia, this distinction matters because the region’s housing challenge is shaped by local capacity. IOC may help address production constraints only if it fits regional workforce systems, regulatory pathways, financing structures, supply chains, and community expectations. If those conditions are weak or misaligned, IOC may remain technically possible but difficult to implement.

The relevant question is therefore not whether IOC is generally beneficial, but how regional actors understand the constraints and conditions that would allow IOC to contribute to housing delivery.

Participatory Approaches to Regional Housing-System Diagnosis

Because housing-production capacity is shaped by local institutions, markets, and workforce systems, participatory methods are useful for examining how stakeholders understand regional constraints. Participatory design and related design-thinking approaches are commonly used for problems that are multi-actor, context-dependent, and socio-technical in nature (Sanoff, 2000; Steen, 2013). These methods allow researchers and practitioners to elicit local knowledge, compare stakeholder perspectives, and move from problem identification toward prioritized action.

In this study, participatory workshops were used as a diagnostic method for regional housing-production systems. The workshops did not treat IOC as a predetermined solution. Instead, they asked stakeholders to describe current housing and workforce conditions, identify opportunities and concerns, and prioritize strategies that could strengthen housing delivery capacity. This approach is important because regional actors often understand constraints that may not appear clearly in secondary data, including local permitting practices, workforce gaps, financing concerns, public perception, institutional readiness, and coordination barriers.

The conceptual logic of the study is therefore straightforward: Appalachia’s housing challenge reflects a regional production-capacity problem; IOC represents a possible shift in housing delivery systems; and participatory workshops provide a method for identifying how local actors understand and prioritize the conditions needed for that shift to support housing outcomes.

Methodology

This study used a qualitative participatory research design to examine how regional stakeholders identify and prioritize housing-production constraints and IOC-related strategies in Appalachia. The methodology consisted of three steps that correspond to the three research objectives. Step 1 reviewed regional housing, workforce, economic, and demographic conditions across the workshop locations (RO1). Step 2 used participatory design workshops to collect and analyse stakeholder input on regional housing-production constraints, IOC-related opportunities, and locally grounded strategies (RO2 and RO3).

Step 3 validated the resulting themes through internal inter-rater reliability testing and an external advisory review. Participant composition is summarized in Figure 2, and Figure 1 summarizes the methodological workflow.

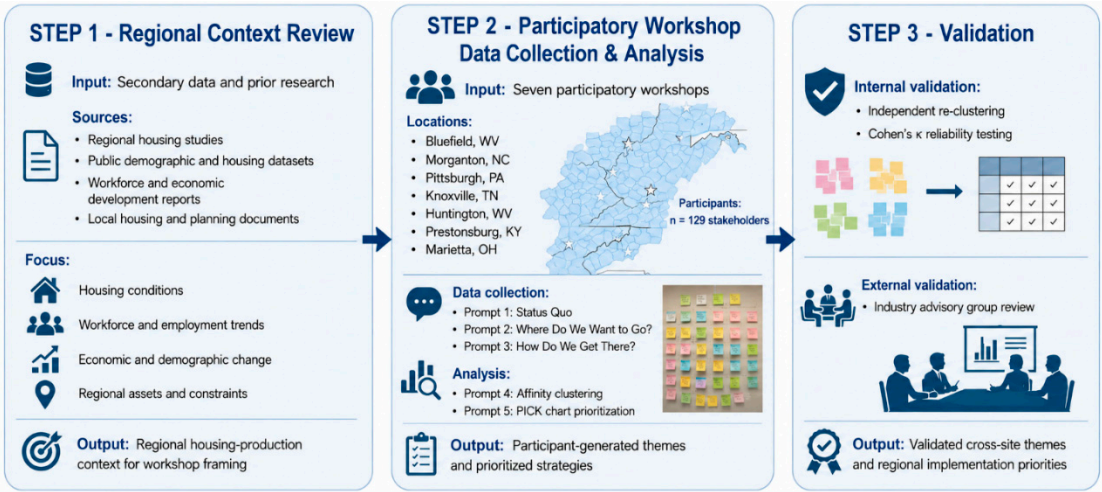


Figure 1. Methodology workflow.



Figure 2. Distribution of industry background of workshop participants (n=129).

Step 1: Regional Context Review

The first step reviewed secondary data and prior research to establish the housing, workforce, economic, and demographic context of the selected Appalachian workshop locations. This review was not designed as a standalone systematic literature review. Instead, it provided the regional background needed to frame the participatory workshops and interpret stakeholder responses. Sources included regional housing studies, public demographic and housing datasets, workforce and economic development reports, and local housing or planning documents relevant to the workshop locations (Data USA, 2022; Jones et al., 2023; Mather, 2004).

The review focused on four areas: local housing conditions, workforce and employment trends, economic and demographic change, and regional assets or constraints relevant to housing delivery. Housing indicators included affordability, housing-stock age, supply constraints, and condition-related concerns. Workforce and economic indicators included employment sectors, labor availability, industrial transition, manufacturing capacity, and education or training infrastructure. The purpose was to understand how each workshop location was positioned within the broader Appalachian housing-production system before engaging stakeholders. This regional context review informed the workshop framing and supported the interpretation of stakeholder-identified constraints and strategies.

Step 2: Participatory Workshop Data Collection and Analysis

Seven participatory design workshops were conducted across Appalachia. Workshop locations included Bluefield, West Virginia; Morganton, North Carolina; Pittsburgh, Pennsylvania; Knoxville, Tennessee; Huntington, West Virginia; Prestonsburg, Kentucky; and Marietta, Ohio. These locations were selected as accessible regional workshop sites that could draw together relevant personnel, resources, and institutional networks within the Appalachian region. The research team also consulted community colleges and economic development groups to confirm that the selected locations functioned as regional convening points for housing, workforce, education, construction, and economic development stakeholders.

A total of 129 stakeholders participated in the workshops (Supplementary Table S3). Participants were recruited based on their leadership and professional roles in sectors relevant to housing-production capacity and IOC-related delivery systems. These sectors included construction, manufacturing, modular and prefabricated construction, economic development, local government, zoning, planning, code enforcement, education, finance, and workforce development. Local convening partners supported participant identification and recruitment. Figure 2 summarizes the distribution of participant backgrounds across the workshops.

All data collection procedures were developed in accordance with university human subjects’ protocols (protocol #23-1369). Participants were briefed on the purpose and societal benefits of the research initiative. Participation was voluntary, and individual responses were not collected with personal identifiers. Attendance was recorded for workshop management purposes, but individual sticky-note responses were not linked to participant identities.

At the beginning of each workshop, facilitators introduced IOC using the working definition presented in the Introduction. This ensured that participants shared a general understanding of IOC before discussing regional constraints and opportunities. The workshops then used five structured prompts.

Prompts 1-3 generated stakeholder input on current conditions, future opportunities, and practical strategies. Prompts 4-5 organized and prioritized those strategies through participant-led clustering and PICK chart analysis. Table 2 summarizes the prompt structure and analytical purpose.

Table 2. Workshop prompt structure.

Prompt	Purpose	Participant task	Analytical use
Prompt 1: Status Quo	Identify current regional conditions	Participants described the status quo of housing and workforce in their region, including education, infrastructure, and technology conditions, as well as related challenges and opportunities.	Established baseline housing-production constraints and regional assets.
Prompt 2: Where Do We Want to Go?	Identify future opportunities and concerns	Participants considered how IOC could take advantage of opportunities or address concerns in their region.	Identified perceived IOC opportunities within local housing systems.
Prompt 3: How Do We Get There?	Generate practical strategies	Participants proposed IOC-related strategies connected to the needs and opportunities identified in Prompts 1 and 2.	Produced locally grounded strategy statements for clustering.
Prompt 4: Affinity clustering	Organize strategies into themes	Participants grouped similar strategies from Prompt 3 into common thematic areas.	Produced participant-generated thematic clusters.
Prompt 5: PICK chart prioritization	Prioritize themes by impact and ease of implementation	Participants placed themes on a PICK chart according to perceived impact and implementation difficulty.	Identified perceived feasibility, impact, and sequencing of strategies.

For Prompts 1-3, participants wrote responses on sticky notes and placed them around a visual facilitation structure organized around a blue triangle. Prompt 1 asked participants to describe the status quo of housing and workforce in their region, including education, infrastructure, technology, challenges, and opportunities. These responses were placed below the triangle to represent current regional conditions. Prompt 2 asked participants how IOC could take advantage of opportunities or address concerns in their region. These responses were placed above the triangle to represent desired opportunities or future directions. Prompt 3 asked participants to identify practical IOC-related strategies connected to the needs and opportunities raised in the first two prompts. These responses were placed in the center of the triangle to represent strategies for moving from current conditions toward desired outcomes. Figure 3 shows the participatory design process used for Prompts 1-3.

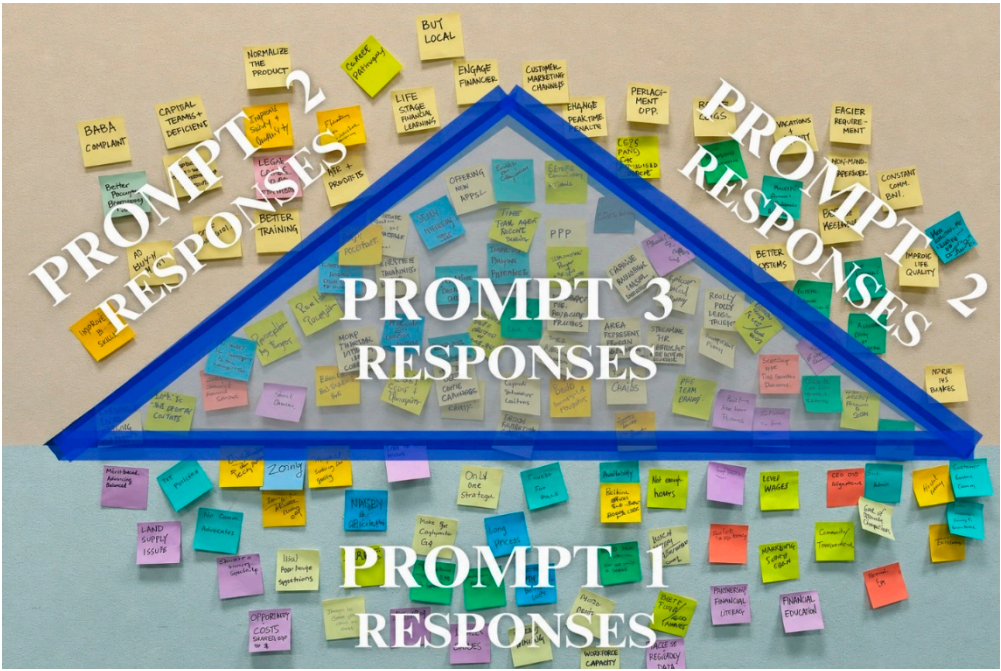


Figure 3. Example of Participatory Design Process, Prompts 1-3.

Prompt 4 used affinity clustering to organize the strategy statements generated in Prompt 3. Participants grouped similar solutions into thematic areas that represented local priorities for strengthening housing-production capacity through IOC. Affinity diagramming originates with Kawakita's KJ method and is commonly used in human-centered design to organize qualitative inputs into meaningful groups and support collective sense-making (Martin & Hanington, 2012; Kawakita, 1991). Figure 4 provides an example of the theme-clustering output.

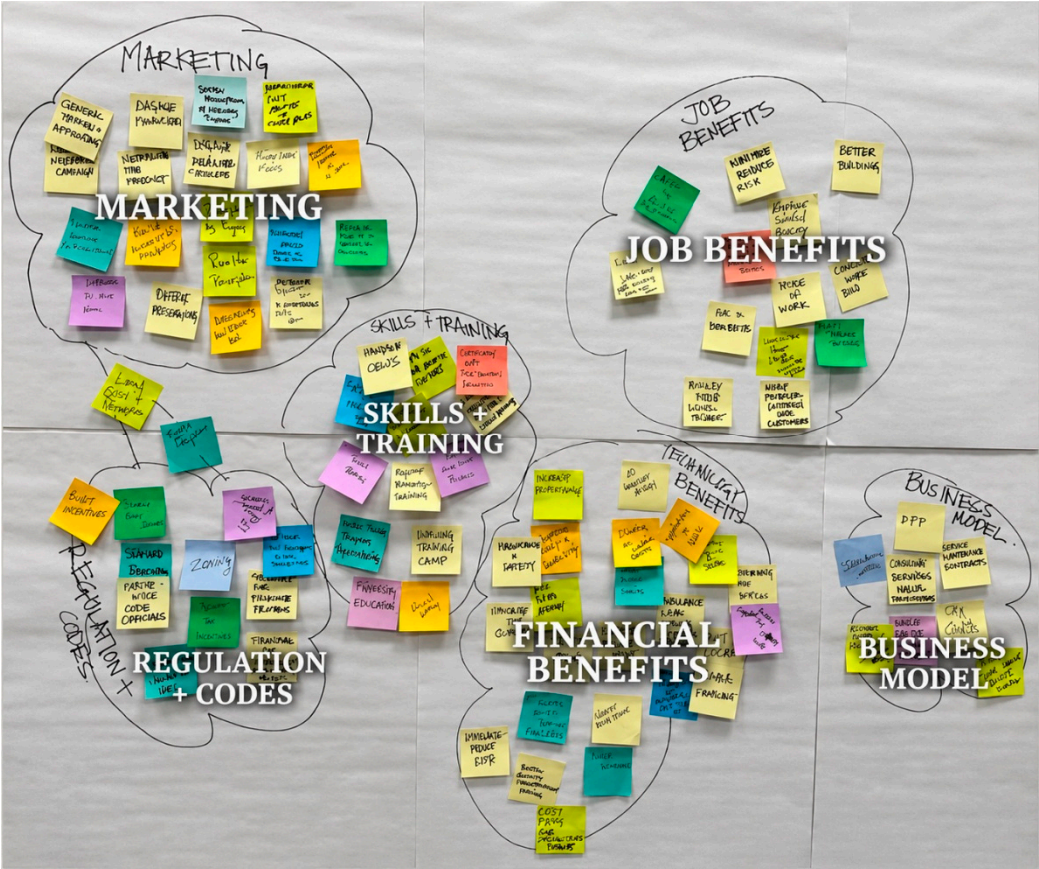


Figure 4. Example of Affinity Diagram - Theme Clustering Output.

Prompt 5 used a PICK chart to prioritize the themes generated through affinity clustering. Participants evaluated each theme according to perceived impact and ease of implementation. Themes considered low impact and easy to implement were placed in the Possible quadrant. Themes considered high impact and easy to implement were placed in the Implement quadrant. Themes considered high impact but difficult to implement were placed in the Challenge quadrant. Themes considered low impact and difficult to implement were placed in the Kill quadrant. The PICK chart is commonly used in process improvement to compare actions by feasibility and expected value (Badiru & Thomas, 2013). Figure 5 provides an example of the prioritization process.

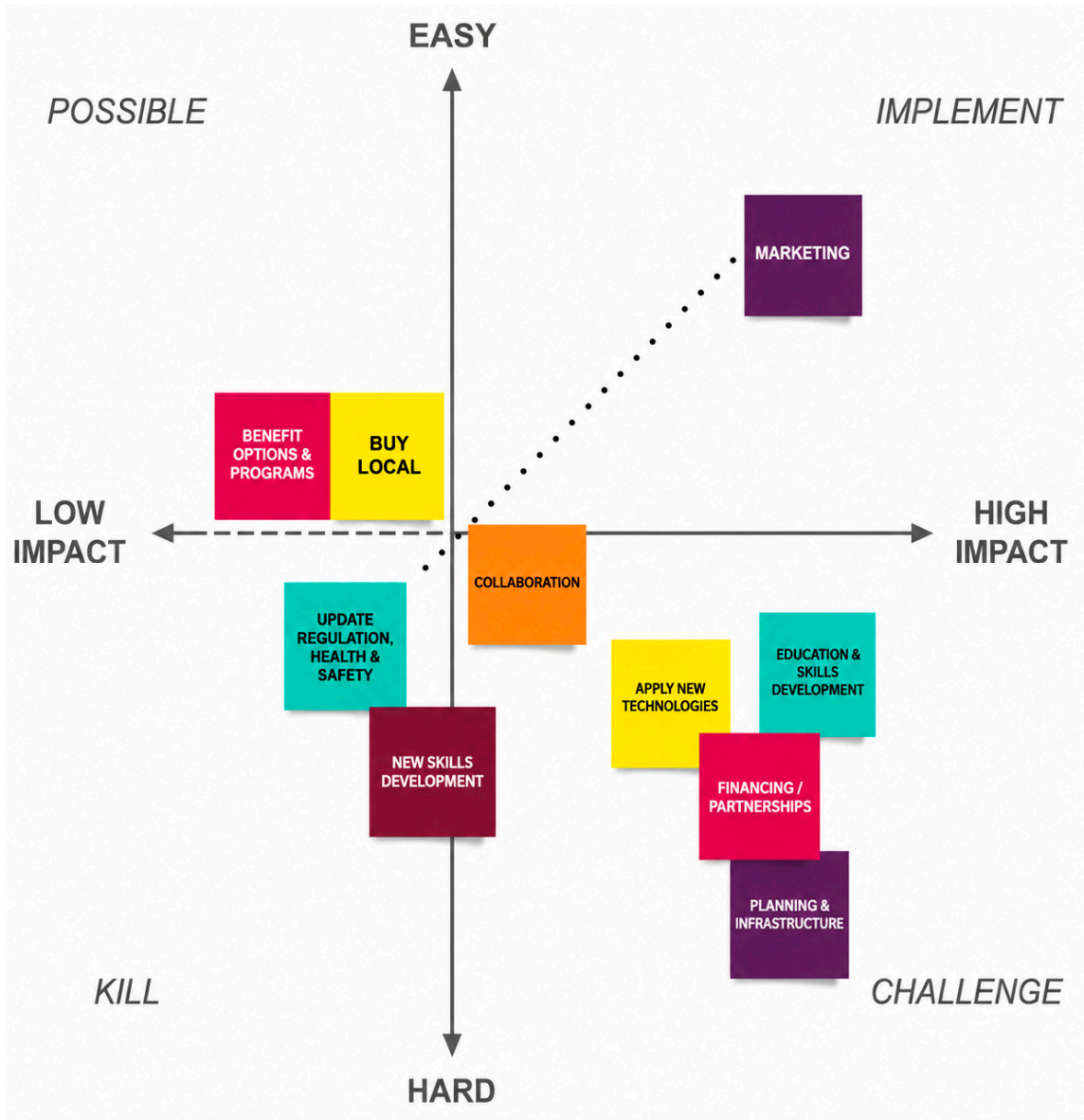


Figure 5. Example of PICK Chart – Prioritizing Themes.

Step 3: Validation

The third step assessed the credibility and consistency of the workshop findings through internal and external validation. Internal validation was conducted through independent re-clustering by the research team. After the workshops, the team reviewed the sticky-note data and independently repeated the clustering process. The independent clustering was then compared with the original

participant-generated clustering to assess whether the thematic structure was stable beyond the workshop setting. Figure 6 illustrates the comparison between participant-generated clustering and independent re-clustering.

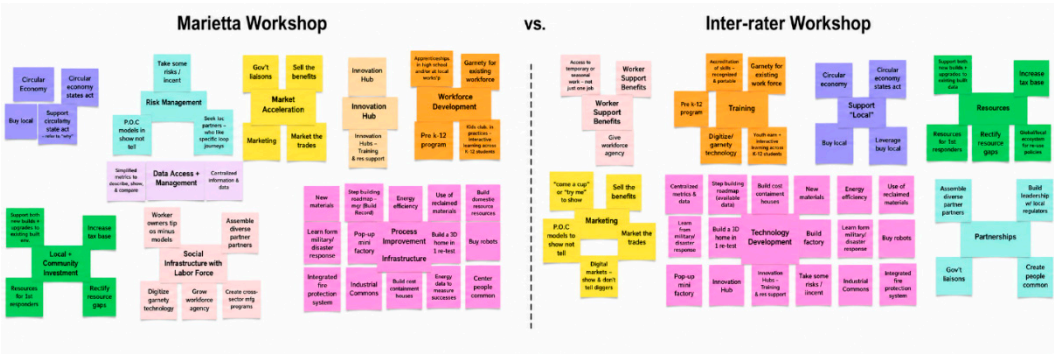


Figure 6. Example of Internal Validation - Theme Re-clustering and Comparison.

Inter-rater reliability was assessed using Cohen’s κ for nominal categories (Cohen, 1960; Viera & Garrett, 2005). Agreement was evaluated at the note level by comparing workshop theme assignments with the independent re-clustering. For each workshop site, Cohen’s κ was calculated from a $k \times k$ contingency table using the formula:

$$\kappa = (P_o - P_e)/(1 - P_e)$$

where P_o represents observed agreement, and P_e represents expected agreement by chance. Each site-level κ value was reported with the corresponding double-coded sample size. The overall agreement value was summarized by combining site-level Cohen’s κ values using sample-size weighting, so that workshop sites with more double-coded notes contributed proportionally more to the overall estimate. The strength of agreement was interpreted using the Landis & Koch (1977) benchmarks. The Cohen’s κ benchmark table used to interpret agreement strength is provided in Supplementary Table S2.

External validation was conducted through an industry advisory group. The research team presented preliminary findings, including regional trends and workshop-derived themes, to advisory group members with experience across industry, education, nonprofit work, government, economic development, research, and related agencies. The composition and organizational roles of the advisory group are provided in Supplementary Table S1. The purpose was to test whether the emerging findings were credible and useful beyond the individual workshop settings. Advisory group feedback focused on priorities that appeared across multiple workshops, including housing delivery, education and training, exposure to IOC, market understanding, and regional coordination. This external validation helped confirm that IOC should not be approached as a one-size-fits-all solution, but as a context-dependent housing-production pathway shaped by local needs, workforce capacity, institutional readiness, and community priorities.

Results

Stakeholder-Identified Housing-Production Constraints and IOC Opportunities

Across the seven workshops, participants described housing and workforce challenges as linked regional problems rather than separate issues. Stakeholders consistently connected housing availability, workforce recruitment, local economic development, and construction capacity. In several locations, participants noted that housing constraints affected the ability to attract and retain workers, while workforce shortages limited the ability to produce, repair, and deliver housing at the pace needed.

Participants identified several recurring constraints across the workshop locations. These included shortages of skilled construction labor, aging or inadequate housing stock, limited attainable housing options, infrastructure gaps, uneven access to training pathways, and limited familiarity with IOC. These concerns appeared across different local contexts, although the emphasis varied by location. Morganton participants highlighted public-private partnerships, specialized training programs, and lower manufacturing costs. Pittsburgh participants emphasized technology, collaboration, and community workforce education. Knoxville stakeholders connected IOC opportunities with process improvement, technology integration, and realistic workforce training. Huntington participants pointed to local materials, technology, funding strategies, vacant industrial sites, and regional alignment as possible assets. Prestonsburg participants emphasized home-buying options, alternative funding, and education and training beginning at the K-12 level. Marietta participants discussed local economic development, workforce development, technology integration, and community investment.

Participants identified IOC as a potential pathway for addressing housing and workforce challenges, but not as a stand-alone solution. Instead, IOC was discussed as one part of a broader regional strategy for improving housing delivery, workforce development, and construction productivity. Participants saw potential for IOC to create more predictable construction processes, reduce labor-intensive site work, support safer and more stable work environments, and connect housing delivery with new training and employment pathways. IOC was also linked to the possible use of regional manufacturing assets, vacant industrial sites, and existing workforce-development institutions.

At the same time, participants identified conditions that would need to be addressed before IOC could support housing delivery effectively. These included public awareness, market acceptance, workforce training, financing, policy and regulatory alignment, technology readiness, and local coordination. Together, these findings show that stakeholders viewed Appalachia's housing challenge as a production-capacity issue. The constraint was not only the need for more units. It was also the region's ability to align workers, institutions, financing, technology, and local market demand around housing delivery.

Common Themes Across the Workshops

The affinity clustering process produced five common themes across the workshop locations: Education & Training, Policy & Regulation Framework, Marketing & Awareness, Financing & Funding, and Technology & Innovation. These themes represent the main areas stakeholders believed would need to be addressed for IOC to support housing-production capacity in Appalachia. The themes are not isolated categories. Each one connects to the broader system of housing delivery and helps explain the regional conditions needed for IOC to become a practical housing-production pathway.

Education & Training focused on workforce pipelines, skill development, K-12 exposure, community college programs, specialized training, and upskilling for IOC-related work. Participants emphasized that workforce development would need to begin before workers entered the construction industry and continue through technical education, employer partnerships, and on-the-job learning.

Policy & Regulation Framework included permitting, codes, inspection processes, public-sector coordination, and institutional alignment. Participants viewed these issues as important because IOC may require different inspection timing, code interpretation, procurement pathways, and coordination between local and state-level actors.

Marketing & Awareness focused on increasing familiarity with IOC among the public, local officials, developers, lenders, workers, and potential homebuyers. Participants suggested that market acceptance would depend on reducing misconceptions, showing successful examples, and explaining how IOC could support local housing and workforce needs.

Financing & Funding included capital access, investment risk, lender confidence, funding programs, incentives, and business models. Participants viewed financing as essential because IOC often requires upfront investment, coordinated capital, and confidence from public and private partners.

Technology & Innovation included digital tools, factory-based production, process improvement, data access, automation, and other innovations that could support IOC implementation. Participants recognized the importance of technology but emphasized that it would need to be introduced in ways that fit local workforce capacity and regional industry culture.

Together, the five themes show that stakeholders understood IOC implementation as a systems problem. Education, policy, awareness, financing, and technology were not treated as separate concerns. They were viewed as connected conditions that would shape whether IOC could support regional housing-production capacity.

Prioritization of Common Themes Through PICK Charts

The PICK chart activity helped participants move from identifying common themes to prioritizing them according to perceived impact and ease of implementation. Across the workshops, participants did not treat all themes as equally actionable in the short term. Figure 7 summarizes the prioritization of the five common themes.

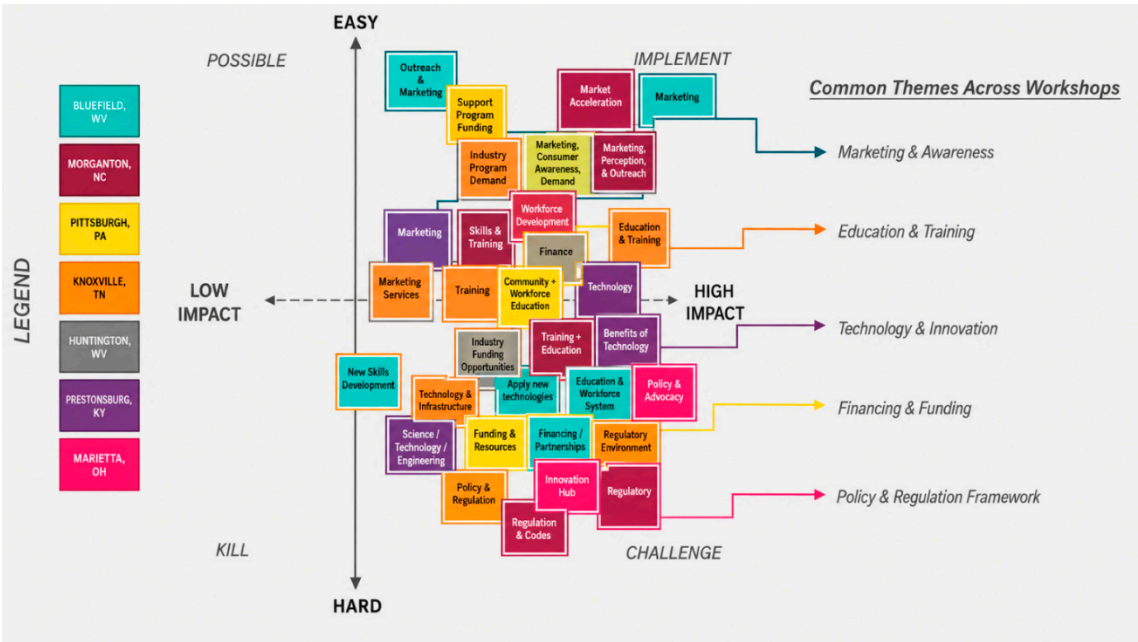


Figure 7. Combined PICK chart revealing common themes.

Marketing & Awareness was generally viewed as high impact and easier to implement than the other themes. Participants saw awareness-building as an immediate step that could reduce resistance to IOC, improve public understanding, and build confidence among local stakeholders. This made awareness-building a near-term entry point for broader IOC implementation.

Education & Training was also viewed as highly impactful, but more resource-intensive. Participants connected this theme to long-term workforce development, technical education, K-12 exposure, community college partnerships, and employer involvement. Because these activities require sustained coordination, infrastructure, and investment, education and training were seen as important but less immediately implementable than awareness-building.

Policy & Regulation Framework was viewed as high impact but difficult to change quickly. Participants recognized that codes, permitting, inspection pathways, and public-sector procedures

could strongly affect IOC adoption. However, these systems were also seen as institutionally complex because they involve multiple agencies, jurisdictions, and decision-making levels.

Financing & Funding was also viewed as high impact but difficult to implement. Participants connected this difficulty to upfront capital needs, lender and investor risk perception, uncertainty around IOC business models, and expectations for quick financial returns. These concerns suggest that financing barriers are not only about the availability of money. They are also about confidence, risk-sharing, and the ability to package investment around a housing-production model that may be unfamiliar to local markets.

Technology & Innovation was viewed as essential to IOC, but participants emphasized that technology should be introduced incrementally. Many Appalachian construction and housing markets remain shaped by traditional practices, limited technical capacity, and cautious adoption cultures. For this reason, participants suggested that digital tools, factory processes, automation, and data systems should be matched with workforce training and local readiness rather than introduced as stand-alone upgrades.

Overall, the PICK chart findings show a practical implementation sequence. Awareness-building may be a near-term starting point, while education, policy, financing, and technology require longer-term coordination. This suggests that IOC implementation in Appalachia may depend less on promoting a single technology and more on building the regional conditions that allow the technology to work.

Reliability of Thematic Clustering

The internal validation process assessed whether the workshop-generated themes were stable when independently re-clustered by the research team. Agreement between workshop theme assignments and independent re-clustering was assessed using Cohen’s κ at the note level for each workshop site. The overall agreement was then summarized using a sample-size-weighted value across the seven sites.

Table 3. Summary of inter-rater Cohen’s κ calculation.

Location	n	Observed agreement, P_o	Expected agreement, P_e	Cohen’s κ	Strength of agreement
Bluefield	50	0.82	0.19	0.78	Substantial
Morganton	43	0.65	0.23	0.55	Moderate
Pittsburgh	55	0.84	0.17	0.80	Substantial
Knoxville	61	0.90	0.16	0.88	Almost perfect
Huntington	47	0.85	0.24	0.80	Substantial
Prestonsburg	72	0.90	0.18	0.88	Almost perfect
Marietta	32	0.84	0.29	0.78	Substantial

Across the seven workshops, Cohen’s κ values ranged from 0.55 to 0.88. Morganton showed moderate agreement, while the remaining six sites showed substantial to almost perfect agreement. The overall sample-size-weighted Cohen’s κ was 0.80, indicating substantial agreement across the full dataset. These results suggest that the thematic structure was not only generated during the workshops but was also reasonably stable when reviewed independently.

The external validation process reinforced and extended the workshop themes. Advisory group members confirmed that the five common themes captured the conditions they viewed as most important for IOC adoption in Appalachia, while emphasizing that prioritization would need to reflect local housing markets, workforce capacity, and institutional readiness. The group also noted that awareness-building and workforce-training pathways could function as practical near-term entry points, while financing structures and policy alignment would require longer-term coordination across public, private, and educational actors. This external feedback supported the interpretation that IOC should not be introduced as a one-size-fits-all solution, but as a housing-

production pathway shaped by local needs, workforce capacity, institutional readiness, and community priorities.

Discussion

The findings show that stakeholders did not understand Appalachia's housing challenge as only a shortage of units or as a narrow construction-technology problem. They described housing delivery as a regional production-capacity issue shaped by workforce pipelines, financing, regulation, market awareness, technology readiness, and institutional coordination. This supports the central argument of the study: IOC may contribute to housing delivery only when it is aligned with the local systems that produce, regulate, finance, and accept housing.

The pattern across the five themes is not a checklist of separate issues but a system of interdependent conditions in which each theme shapes the feasibility of the others. Awareness influences financing because lenders, public agencies, and residents need a basic understanding of off-site construction before they will commit capital, write favorable policy, or accept new housing forms. Workforce training enables technology adoption because factory processes, digital tools, and automation cannot operate without a skilled labor base. Policy frameworks shape financing because permitting predictability, inspection pathways, and procurement rules affect lender risk and investor confidence. The five themes therefore describe not five parallel problems but a connected set of regional conditions that move together. IOC's contribution to housing delivery depends less on improving any one condition and more on whether enough of them can advance in coordination.

The PICK chart prioritization adds a temporal dimension to this interdependent pattern. Stakeholders did not view IOC adoption as something that could be unlocked through a single near-term action. They identified an entry point through awareness building and a longer arc through workforce, policy, financing, and technology coordination. The pattern reflects something inherent to housing-production capacity: most of the conditions that shape housing delivery sit in institutional structures, capital systems, and workforce pipelines that change slowly. Only awareness, which depends primarily on information and communication, moves at a faster pace. This sequencing implies that regional IOC strategies should treat early-stage awareness not as preparation for a more important set of actions, but as the precondition that allows slower institutional changes to take root.

These findings matter for housing affordability and access because construction efficiency alone does not guarantee better housing outcomes for residents, renters, first-time buyers, or low-income households. IOC can support affordability only if regional systems reduce delivery uncertainty, expand skilled labor capacity, improve financing pathways, and build trust in the quality and suitability of off-site housing. For example, workforce training can reduce production bottlenecks, but it can also connect housing strategy to local employment and economic development. Clearer policy and regulatory pathways can reduce uncertainty for builders, manufacturers, lenders, and public agencies. Marketing and awareness can help address misconceptions that off-site housing is lower quality, temporary, or disconnected from community needs. Financing and funding mechanisms can determine whether IOC supports attainable housing or remains limited to market-rate development. Technology and innovation can improve quality control and production reliability, but only when local workers, firms, and regulators have the capacity to use them effectively. In this sense, the five themes are not merely implementation concerns. They are conditions that shape whether IOC can contribute to more attainable, reliable, and locally acceptable housing delivery.

The findings also connect to international debates on industrialized and off-site construction. In Finland, research on industrialized timber and modular construction links adoption to sustainability goals, quality improvement, and production capacity, while also identifying barriers related to fragmented operating models, uneven code interpretation, contractor capability, and financing risk (Ilgin & Karjalainen, 2024; Kinnunen et al., 2025). In Japan, the longer-established prefabricated housing sector shows how regulation, factory production, product standardization, and firm-led quality systems can co-evolve to support delivery performance (Chau et al., 2024; Noguchi, 2003). In

China, prefabrication has been promoted through national policy to improve productivity, quality, safety, and environmental outcomes, but adoption remains constrained by cost concerns, incentive design, technical capacity, and uneven market acceptance (Jiang et al., 2018; Qi et al., 2020). These examples show that the Appalachian themes are not isolated local concerns. Training, regulation, awareness, finance, and technology recur across industrialized housing contexts.

At the same time, Appalachia should not be read as a smaller version of Finland, Japan, or China. The value of international comparison is not to claim that these housing systems are directly transferable, because that would oversimplify the institutional, economic, and market differences that shape adoption. Rather, comparison shows that similar implementation pressures are shaped by different institutional, economic, and market conditions. Appalachia's IOC conditions are embedded in rural and small-metro housing markets, post-industrial economic transitions, limited local construction capacity, older housing stock, and uneven familiarity with off-site housing. This regional specificity matters because strategies developed in mature industrialized construction systems may not work where lenders are unfamiliar with IOC, workforce pipelines are thin, local governments have limited inspection capacity, or residents have limited exposure to off-site housing models. The contribution of this study is therefore not a universal IOC roadmap. It is a participatory process for identifying the local configuration and sequencing of IOC implementation conditions within a specific regional housing system.

These findings extend prior work on regional housing-production systems by showing how stakeholders in a post-industrial, rural and small-metro context translate abstract capacity dimensions into concrete implementation conditions. Where existing literature emphasizes that local housing production depends on coordinated governance, institutional capacity, and the alignment of public and private actors (Buitelaar & de Kam, 2009; Taşan-Kok & Özogul, 2021), the workshop findings specify which dimensions of regional capacity local actors identify as most consequential for adopting a particular delivery pathway. This adds empirical grounding to the regional-systems view of housing production and demonstrates how participatory methods can operationalize that view for specific delivery innovations such as IOC.

This point shifts IOC adoption from a construction-sector question to a housing-system question. The workshops show that stakeholders did not simply ask whether IOC could build housing faster. They asked what training, policy support, financing, public awareness, and technology conditions would be needed for IOC to work in their communities. This makes the study relevant beyond Appalachia because the participatory process can be adapted in other regions to diagnose housing-production constraints, compare stakeholder priorities, and identify feasible starting points for action. The use of structured prompts, affinity clustering, PICK chart prioritization, independent re-clustering, and advisory group review provides a transparent process that can be replicated and compared across regions.

The study has limitations. The findings reflect seven Appalachian workshop locations and should not be treated as statistically representative of all Appalachian communities or IOC markets. Participants were primarily institutional, professional, and industry stakeholders, so end-user perspectives from renters, first-time buyers, and low-income households were limited. The findings also capture perceived priorities rather than the outcomes of completed IOC projects. Although independent re-clustering and Cohen's κ testing strengthened confidence in the thematic structure, some interpretation is inherent in qualitative clustering. Future research should apply this protocol in other regions, include more resident and end-user voices, and connect workshop priorities to cost, schedule, permitting, workforce, financing, and post-occupancy outcomes. Longitudinal studies of pilot IOC projects would be especially useful for testing whether the priorities identified through participatory workshops translate into measurable housing-production gains.

Conclusions

This study reframes Appalachia's housing challenge as a regional housing-production capacity problem rather than only a shortage of affordable units. Through seven participatory stakeholder

workshops, the study identified five common conditions shaping IOC's potential role in housing delivery: Education & Training, Policy & Regulation Framework, Marketing & Awareness, Financing & Funding, and Technology & Innovation. The findings show that IOC is not a universal technical solution, but a context-dependent housing-production pathway whose value depends on regional workforce systems, institutional readiness, financing structures, market confidence, and community acceptance.

The study contributes to housing research by showing how participatory methods can translate local stakeholder knowledge into prioritized regional strategies. It also demonstrates that industrializing housing production requires more than adopting factory-based construction methods. It requires understanding the regional systems that make housing delivery possible. For Appalachia and similar regions, the central question is therefore not simply whether IOC can build housing faster, but whether regional actors can create the conditions for IOC to support attainable, reliable, and locally grounded housing outcomes. For policymakers and regional housing actors, this means that IOC adoption strategies should begin by diagnosing local conditions rather than importing technology models from elsewhere. For researchers, the participatory protocol provides a transparent and comparable method for studying how regional housing systems adapt to delivery innovations.

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