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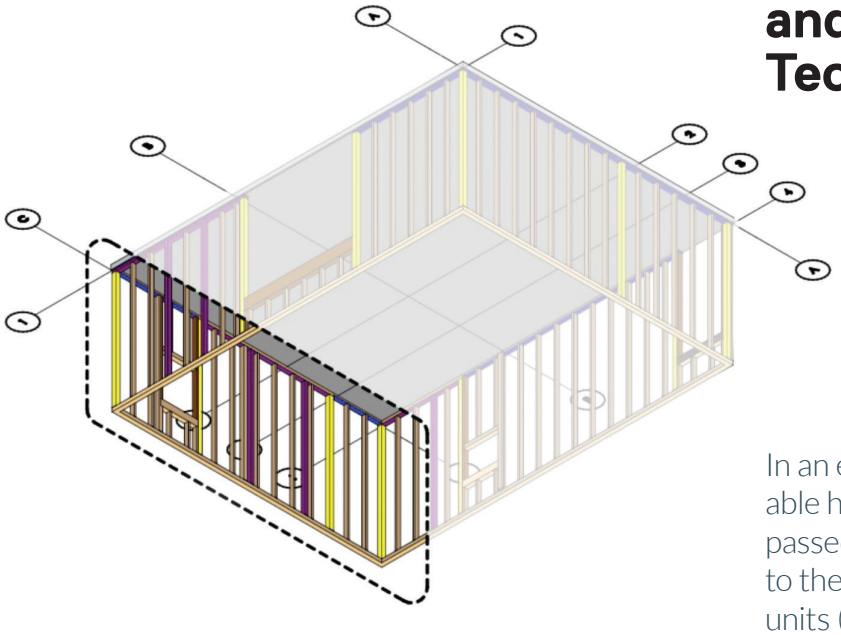


In an effort to address California's affordable housing shortage, lawmakers recently passed statewide legislation removing barriers to the development of accessory dwelling units (ADU). Not since the postwar suburban housing boom has such a significant new market for residential production been created in Los Angeles and, more broadly, across the entire state. Simultaneously, new digital technologies are overcoming constraints in finance models, design processes, and construction practices that restrict ADU production. Through interviews conducted with emerging ADU service providers in Los Angeles, this paper identifies how digital technologies and regulatory change are enabling emergent forms of practice and production for addressing a significant housing shortage. Specifically, it asks what role digital technologies may play in facilitating the mass production of affordable housing in the post-suburban city.

◁ Opening figure. IKEA-style set of instructions. (Credit: Christian Návar, Modative)

△ Figure 1. (Left) Finished Housing, Lakewood, California, 1950, Gelatin silver print. (Right) Framing, Lakewood, California, 1950, Gelatin silver print. (Photographer: William A. Garnett. Courtesy of The J. Paul Getty Museum, Los Angeles, © Estate of William A. Garnett)

Introduction

In September of 2016, the California legislature passed Assembly Bill 2299 (California State Assembly 2016) in coordination with Senate Bill 1069 (California State Senate 2016). Effective January of 2017, the legislation was co-authored by cityLAB-UCLA (D. Cuff and J. Blumenfeld) after a decade of urban research. It significantly eases restrictions on building secondary units, potentially opening up more than eight million single family lots for Accessory Dwelling Unit (ADU) construction (US Census Bureau 2016). The full potential of this new law to create much-needed new housing in the state will depend upon local governments' responses (Brinig and Garnett 2013; Antoninetti 2008) as well as the efforts of ADU service providers adapting to the demands and legal constraints of the market (Chapple et al. 2011). If the protagonists of ADU development and construction are successful, one can anticipate a housing boom similar to that which occurred after World War II, a boom that was spurred by advances in manufacturing and construction. Recent technological advances focus less on physical building technologies and more on digital architectural systems including data management, building information, and online tools. These digital platforms hold the potential to give architecture and its affordability stronger roles in housing production by creating efficiencies in production while accommodating the idiosyncratic nature of contemporary consumer preferences and infill sites.

In the eighteen months after the legislation was passed, a number of service delivery models have arisen to not only meet ADU demand but also create it. Architects, builders, lenders, cities, non-profit housing agencies, venture capitalists, and homeowners are exploring ways to deliver the products this market demands. A mosaic of experiments is taking place. Many of those efforts rest on assumptions that reflect current thinking as well as an optimism about innovative practices, including the notion that data management tools can streamline the design-build process, or that new lending products can be invented to promote affordability and new forms of investment capital can be mobilized. Architecturally speaking, the assumption is that solutions will involve modular, prefabrication, mass production, or building systems strategies, and that these cumulative efficiencies in the design-build process will result in greater affordability or greater profits, as home ownership is a form of income generation or wealth building. Many of these assumptions have paired with optimistic experiments in the past, providing a foundation for investigating how technologically driven disruption may occur.

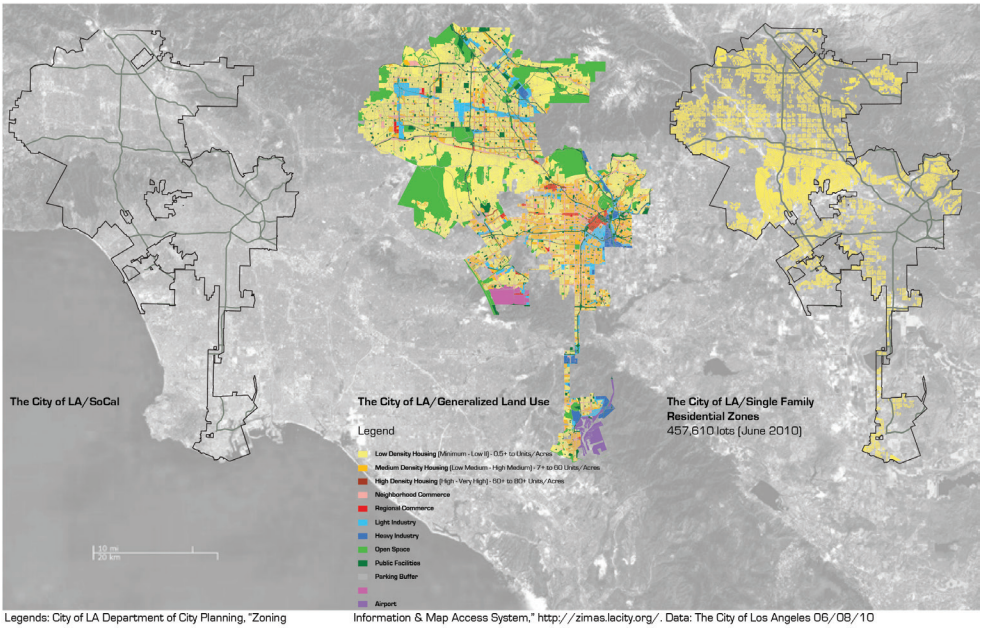
Taken together, these various players are bringing unconventional and innovative tools to the ADU market, sparking new opportunities for designing architectural practices and processes for mass production. Specifically, providers are using digital technologies to overcome constraints in financial models, design processes, and construction practices that have historically restricted ADU production. Consequently, this paper primarily asks what role digital technologies play in facilitating the mass production of affordable housing in the face of intrinsic barriers to the ADU development process. Further, it poses a series of related secondary questions: Where are the hurdles in the commissioning, finance, design, planning, construction, or occupation of backyard housing? What are the specific kinds of digital tools being employed, and how do they compare to more conventional approaches to ADU housing production? How does technology augment—or further complicate—the effectiveness of emerging models of ADU implementation? To answer these questions, three different models for one-stop-shop service provision are analyzed as case studies to determine the effectiveness of their respective approaches. These case studies are discussed in both historic and contemporary contexts related to the Californian ADU market.

This preliminary evaluation of the emerging industry suggests that new information management platforms are helping

SINGLE FAMILY RESIDENTIAL ZONING

Twelve categories of land-use regulations are adopted in the city of Los Angeles. Of these twelve categories, the single-family residential zone restricts the use of metropolitan space to dwelling only. Emerging in 1904 as a device feasible of controlling the lay of the land, the incorporation of single-family residential zoning in the city of LA has gradually increased. In June 2010, the single-family residential zone consisted of 457.610 lots. Scattered all over Los Angeles, these properties are allowed a limited number of units, leaving major areas of land un-built. Incorporated in LA's metropolitan grid, this underutilized land stock provides an asset viable to be utilized for supporting continuous urbanization.

The rationale of the grid, laid out in the 1920s for real estate purposes, gave form to an immense field, characterized in the '70s by Reyner Banham as the Plains of Id. Today, when the grid has been filled up with a sprawling body of low-rise building mass, the topographical variations of the plains, however, have morphed its Cartesian form and thus dissolved its rigidity. The flexibility of the grid stands in stark contrast to the uniformity of the zone, where local significance and site-specific characteristics are suppressed by a set of deterministic codes.



Legends: City of LA Department of City Planning, "Zoning Information & Map Access System," http://zimas.lacity.org/. Data: The City of Los Angeles 06/08/10

△ Figure 2. Single family zoning in Los Angeles. (Source: Cuff et al. 2010, *Backyard Homes LA*)

to overcome some barriers to the production of secondary units, even as conventional delivery prevails. This investigation plays a role in the wider goal of identifying how ADU production may be increased to address the housing shortage and affordability challenges faced by localities within Los Angeles.

Historic Context

In California and elsewhere, ADUs have materialized in different forms specific to historical and cultural purposes. In the nineteenth century, second units in the US were most closely associated with housing for domestic help and low-wage labor (Jackson 1985; Mukhija et al. 2014). Maintaining an ADU provided benefits to families, whether it served as a family-run rental business or as living space (granny flats or in-law units) for elderly parents (Antoninetti 2008). ADUs proved to be an economically viable housing model for households, as they could be produced with simple construction techniques and inexpensive, unskilled labor. By the 1930s, serious ADU regulation at both the federal and local level began to restrict production. Fearing that unpredictable rental incomes from second units would lead to increased insurance rates for home buyers, the Federal Housing Administration discouraged ADU development via mortgage underwriting. In Los Angeles, efforts to preserve the physical and cultural distinctiveness of emerging single-family suburban neighborhoods led to zoning regulations (Gellen 1985). Apartment development concentrated in growth zones was encouraged as a more productive form of economical housing, despite being misaligned with the available capital, budgets, development expertise, and lifestyle preferences of the potential occupants in Los Angeles. Consequently, regardless of zoning restrictions, thousands of illegal ADUs were constructed, prompting concerns for health and safety due to building code noncompliance (Cuff et al. 2010). Fieldwork in Los Angeles has shown that, in some neighborhoods, more than three quarters of residential lots have illegal ADUs today (Cuff et al. 2010).

ADU advocates and urban studies scholars have argued that new rules easing the construction of legal ADUs would have several benefits relative to current demographic and economic challenges. In addition to meeting safety concerns through code compliance, additional secondary units would provide much-needed subsidiary earnings for low-income households (Liebmann 1990; Chang 2011) and would support the needs of the elderly to live in proximity to their caregivers (Liebig et al. 2006). Affordable housing advocates point to the potential for ADUs to increase the overall supply of housing without promoting sprawl while using existing urban infrastructure (Greater Minnesota Housing Fund 2001).

AB 2299 and the Market for ADUs

Cities and counties in California are scrambling to adapt to the new ADU legislation that doubles allowable density in the single-family residential zone by incentivizing infill. Assembly Bill 2299 defines an ADU as "an attached or a detached residential dwelling unit which provides complete independent living facilities for one or more persons. It shall include permanent provisions for living, sleeping, eating, cooking, and sanitation on the same parcel as the single-family dwelling is situated" (California State Assembly 2017). The law stipulates that an ADU may be rented but not sold separately from the primary residence. Additionally, an ADU can be a detached structure (while still located on the same lot), attached to (or part of) the primary residence, or a garage conversion. The floor area of an ADU cannot exceed 50 percent of the existing living area, nor shall it exceed 1,200 square feet (although the legislation continues to be refined through modifications).

While local jurisdictions can make relatively minor changes relative to their circumstances, in effect every house in California can now add a rental unit (whether within or adjacent to an existing dwelling) "by right," that is, without any special planning review. This has unlocked building opportunities because the law removes critical barriers: no additional parking is needed if the house is near transit (broadly defined); no new setbacks can be required; only minimal fees can be levied; and a range of outdated restrictions are removed (for instance, L.A.'s "passageway law," an artifact of old fire protection practices that inadvertently prevented secondary units). Prohibitive constraints were identified by the academic teams at UCLA and UC Berkeley that coauthored the legislation.

This housing market is distinct in several ways: Units are small by current residential standards, ranging from 350–1200 square feet; sites are typically infill behind existing single-family houses; two houses rather than one occupy a single lot with some form of shared relationship between two households. Vast postwar suburban expansion occurred during the most exaggerated housing boom in the history of the United States, when approximately 5 million houses were built between 1945–50 (Figure 1). In California today where less than half the number of units needed are built each year (California Department of Housing and Community Development 2018), ADU legislation has unlocked over 8.1 million single family lots overnight for legal secondary units (U.S. Census Bureau 2016). It is difficult to overestimate this confluence of circumstances on the building industry and its extended service sectors. As most of these secondary units will be built out of sight either behind or within existing housing the entire boom may not be visible from the street, instead resulting in very little disruption to the existing character and perceived density of established neighborhoods. Unlike watching new suburbs unfurl over formerly agricultural landscapes, or residential towers rising from center cities, the ADU revolution will not be visualized.

ADUs and California's Affordable Housing Crisis

The ADU legislation has begun to boost much-needed housing production that averaged less than 80,000 new homes annually over the last 10 years, far below the 180,000 homes needed annually (Brown et al. 2018). Low production contributes to rising costs, compounding the pressure faced by low- to moderate-income residents. Among the 6 million renter households in California, over half pay more than 30 percent of their income toward rent, and nearly 30 percent (1.7 million households) pay more than 50 percent of their income toward rent (Brown et al. 2018).

The affordability crisis has led policy makers and housing advocates at the state and local level to adopt an all-hands-on-deck approach to increasing the state's housing stock. Making it easier to permit and build ADUs is one of many strategies aimed at boosting housing production through infill development. The ADU market is not intrinsically focused on affordability except insofar as the product is a relatively small, rental unit. When compared to conventional modes of housing production, ADUs are inherently more affordable because they use existing land, buildings, and infrastructure. In cities like Los Angeles, where single-family zoning accounts for over 80% of residentially zoned land (Mukhija et al. 2014), there is a strong incentive to facilitate the development of backyard homes (Figure 2). Figure 3 visualizes the backyard space potentially available to ADU construction in the Palms neighborhood of Los Angeles.

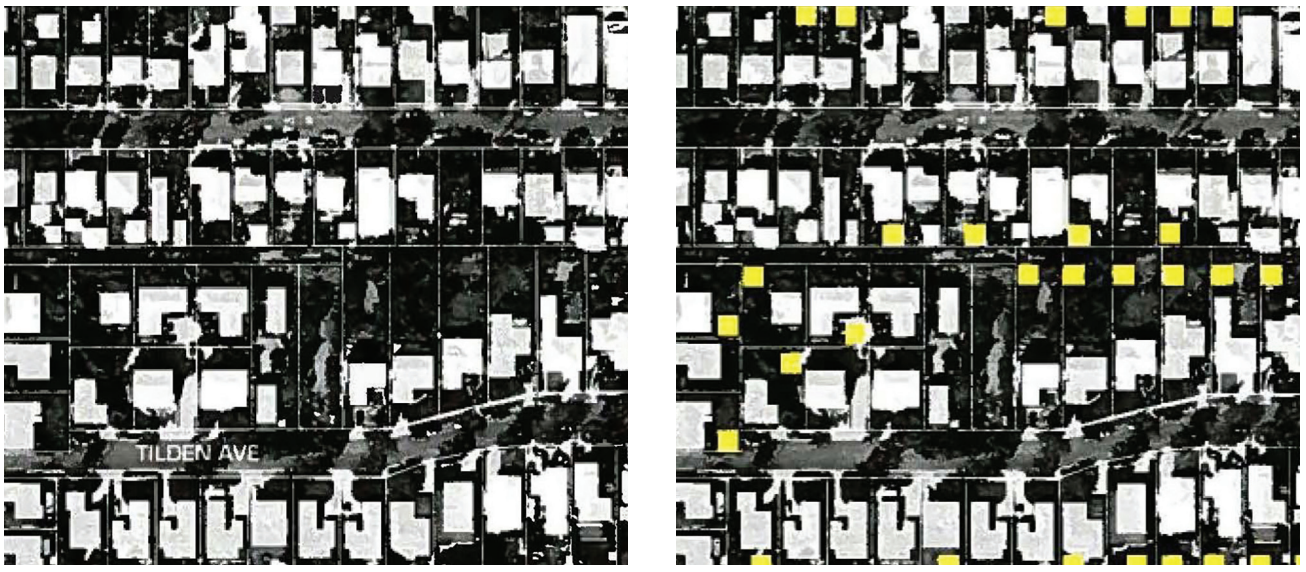
McKinsey & Company estimates that if just five percent of homeowners in California converted a spare bedroom or garage into a new unit, and one out of every hundred single-family homes added a new, detached, or attached dwelling unit, up to 800,000 new housing units could be added to the state's housing stock (Woetzel et al. 2016). The significance of this number is apparent in the call of California's 2018 prospective gubernatorial candidates for what was considered an exorbitant half-million new units of housing for each of the next seven years (Dillon 2018).

Since the California ADU law opened backyards for legal residential construction eighteen months ago, thousands of building permits have been issued. In 2017 alone, nearly 2000 applications for ADUs were filed in the City of Los Angeles, an increase of nearly 25 times the number of permits issued in 2016 (Garcia 2017). To meet demand, ADU service providers are deploying a range of online platforms intended to assist user navigation of complex zoning and permitting processes, determine site feasibility, predict costs, and to program spaces in the secondary unit. Open records of municipal databases populate such platforms with everything from zoning specifics to local construction costs. Analytical, generative, and managerial digital tools range in sophistication, but all negotiate with the idiosyncratic built environment in which no two sites are alike.

Methodology

Although data shows an increase in ADU planning permits since the introduction of the new regulation, there has not yet been a significant increase in ADU completion (measured by Certificates of Occupancy granted), which suggests that further roadblocks exist for ADU development. Anecdotes about the struggles of building an ADU abound, yet no systematic analysis of barriers has taken place—even while legislative revisions are being proposed to address presumed hurdles. Since the introduction of California Assembly Bill 2299 in January 2017, where are the misalignments in emerging service delivery models for the commissioning, finance, design, planning, and construction of backyard ADU housing?

Complementing evidence that ADU permits have increased dramatically, valuable insight can be gained from the challenges experienced in achieving approval, the reasons for the discrepancies between planning and occupancy approval rates, and an analysis of the design and construction innovations. To grasp insights about the inexperience, uncertainty, and variability in ADU services, interviews were conducted with three "one-stop-shop" providers who emerged in the eighteen months since the adoption of the law. Conducted in May and June 2018, the interviews commenced with the same fixed lines of inquiry based on research questions posed in the introduction before opening to a more candid and exploratory discussion to discover unexpected issues and areas of importance in the



△ Figure 3. Projective vision of 38 ADUs to 82 existing homes in Palms. (Source: Per-Johan Dahl & cityLAB-UCLA)

emerging industry. Interviews, both by phone and in person, were conducted in order to gather in-depth qualitative information from the perspectives of the different experts on each team. The interviews were critical to understanding the barriers negotiated by the providers and the ways that digital technology has been deployed to overcome the challenges of the ADU development process.

Just how to meet the potential demand for ADUs in Los Angeles is currently a kind of "Wild West" of ad hoc experimentation among builders and architects, who engage with lenders, investors, and property owners. Small contractors drive trucks with signs announcing "We Build ADUs Call 213-555-5555," and young architects launch websites featuring photorealistic images of modular ADU systems that have yet to be built. Among the wide-ranging attempts to restructure service delivery to meet new ADU demand, this research is directed to comprehensive service providers who organize the development process holistically. Of particular interest are providers that incorporate multidisciplinary teams of architects, lenders, and builders, due to their expert knowledge about specific constraints. Furthermore, only collectives that had successfully delivered at least one ADU solution were included to enable an assessment of their strategies in practice.

Three very different comprehensive providers were strategically chosen as case studies to represent a cross-section of the housing market and the professions actively engaging in the scaling up of backyard housing production. The first collective, led by nonprofit urban design firm LA-Más and community development financial institution Genesis LA (GLA), is exploring alternative housing and lending models for low-to-moderate income and immigrant households within Los Angeles. Secondly, with a particular focus on meeting the needs of Los Angeles' Hispanic population, general contractors Garage Conversion Improvements (G.C. Improvements) and their supporting financial partners, including Ygrene Works, Hero, and CaliforniaFIRST, were interviewed. Finally, the architecture firm Modative, a consumer market provider servicing middle- to upper-market clients, offers additional services in development, real estate and construction; Modative also has a venture capital partner, United Dwelling. A comparison of the services provided by the three organizations studied is provided in Table 1.

The interviews generated six transcripts, one from a primary interview conducted by the research team with the service provider and one additional transcript of preliminary G.C. Improvements or follow up (LA-Más and Modative) questions with team members. Transcripts were assessed to identify commonalities and distinctions in the experiences of the three providers relative to the attributes of their respective businesses as comparatively outlined in Table 1. Interview outcomes include the identification of three distinct challenges for ADU production and successful facilitative tactics for mass producing ADUs in the post-suburban city.

Results

The interviews revealed that the complexity of idiosyncratic site and market conditions has led to three distinct challenges for ADU mass production across five stages.

Challenge 1: Uncertainty

The current ADU market presents greater uncertainty than other long-established housing models. Local jurisdictions are still adjusting their zoning codes in response to the statewide legislation. There is no industry agreement as yet for assessing and appraising the value of an ADU, and service provision remains unregulated. As a result, lenders offer conventional finance models that do not meet the needs of homeowners seeking to build an ADU. Standard mortgage financing has yet to adapt to adding secondary units to existing lots. For example, ADU construction

has the potential to convert a single family property into income-generating property, changing the lending model. However, since lenders do not consider future rent in their income equations, homeowners may not qualify for the needed construction sum; building a secondary unit requires mortgage refinancing of the principal residence (the entire property), which generally has undesired financial implications (higher tax rates, changes in mortgage interest rates, etc). Where financing is being offered, it is often via fifteen to thirty-year profit sharing commitments between investor-lenders and homeowners. This arrangement places risk on economically vulnerable households, as it relies on the stability of emerging and unregulated service providers and the growth of rental income and property values within the often volatile housing market. Further, as no two homeowners seeking finance are identical (each has varied equity in their property, assessed values, employment status, income levels, credit ratings, and liquid assets), it is difficult to develop standardized finance options for the emerging market. Without developed financial tools, new ADU implementation is limited to property owners with the economic means to self-finance, leaving those without the means with no feasible path forward.

Challenge 2: Variability

A second distinct challenge to ADU facilitation is the variability among projects. Unlike the tabula rasa greenfield sites that underwrote economically efficient postwar housing, ADU development occurs lot-by-lot as infill within the established residential fabric. Per the legislative change, land open for ADU construction now exists in most California backyards; however, each opportunity is constrained by the location and composition of existing buildings, landscaping and infrastructure connections, and the existing policies and forces that govern them. These include levels of municipal regulation and codes, highly paid and union-fortified workforces, social expectations, individual aspirations, self-interest, and a culture of customization. This form of construction is similar to major building additions, which proceed idiosyncratically, house by house.

Refined prototypical models are championed as one means to create efficiencies of mass production in the housing sector. However, variability, uncertainty, and inexperience reflect a misalignment between the complex realities of the contemporary housing industry and the processes developed to serve it. A viable path to implementation cannot be addressed through designing housing typologies in isolation. Scaling ADU production currently requires negotiating the tangled network of site requirements, design, lending, and construction with an emphasis on coordination. Although architects are focused on ADU design innovations and lenders are seeking ADU financial innovations, no single actor will be an effective agent of industry change if operating in isolation.

Challenge 3: Inexperience

The third challenge concerns the inexperience of homeowners acting as developers for the first time. Most homeowners have no experience with architects and other building professionals, planning regulations and processes, or project management. Even professionals with development experience (such as qualified builders, architects, designers, and real estate agents) may not have an understanding of the particular ADU compliance requirements. Consequently, the realization of ADU development is hampered by noncompliance delays, associated increased costs and, in some instances, complete termination of the development process due to frustration or insufficient resources.

Stage 1: Predesign

The lack of homeowner experience results in a number of predesign and procurement challenges, including a lack of awareness of ADU typologies, questions regarding the necessity of hiring professional assistance throughout the process, and the potential risks and benefits for the household. All interviewed parties engaged directly with homeowners to offer ADU services, either via knocking on doors or via social media (Facebook and YouTube), online forums (BiggerPockets), and their respective company websites that provide information (including cityLAB UCLA's *Building an ADU* brochure (Figure 4) geared toward a lay audience). A number of ADU feasibility tools, which also serve a didactic purpose of informing property owners about the overall process, are being developed by both government and service providers to assist in the predesign phase.

Stage 2: Finance and Lending

A number of significant problems for ADU production tied to financing were identified, such as insufficient household savings or capital, poor credit history, "unstable" employment status for those with casual or gig economy-based jobs, and difficulty in assessing the value of ADU development. These challenges have prompted the invention of online calculator tools as well as new lending products. Some individual property owners minimize the financial uncertainty by working with an operator, like those interviewed here, who can predict and absorb costs across the whole development process. To accurately estimate and convey the cost of a potential project for clients, and to assist in assessing finance conditions, ADU developer G.C. Improvements makes use of several online tools that assist in calculating realistic project costs (including maintenance and loan repayments, as well as potential rental income for loans over a ten-, twenty-, or thirty-year period). The unique lending circumstances associated with ADUs mean that tailored financing plans need to be invented (Figure 5). The model adopted by both Modative and G.C. Improvements is similar to an investment, enabling homeowners with low savings, insufficient equity within their existing homes, poor credit ratings, or unstable employment status to construct an ADU through a long-term, rent-sharing arrangement with a lender-investor. Unlike loans based on refinancing existing mortgages to cover the construction of the ADU, which require immediate monthly repayments, homeowners are given twelve months to make the first repayment, at which point the ADU construction is complete and the property is typically generating sufficient revenue to cover monthly payments and generate a small profit. However, in order for the lenders to recoup their initial capital outlay, homeowners must share rental income with the financier, who owns a ten-to-thirty-year ground lease on the ADU property. A ground lease is an agreement whereby a tenant is permitted to develop a piece of property during an agreed-upon period of time stipulated

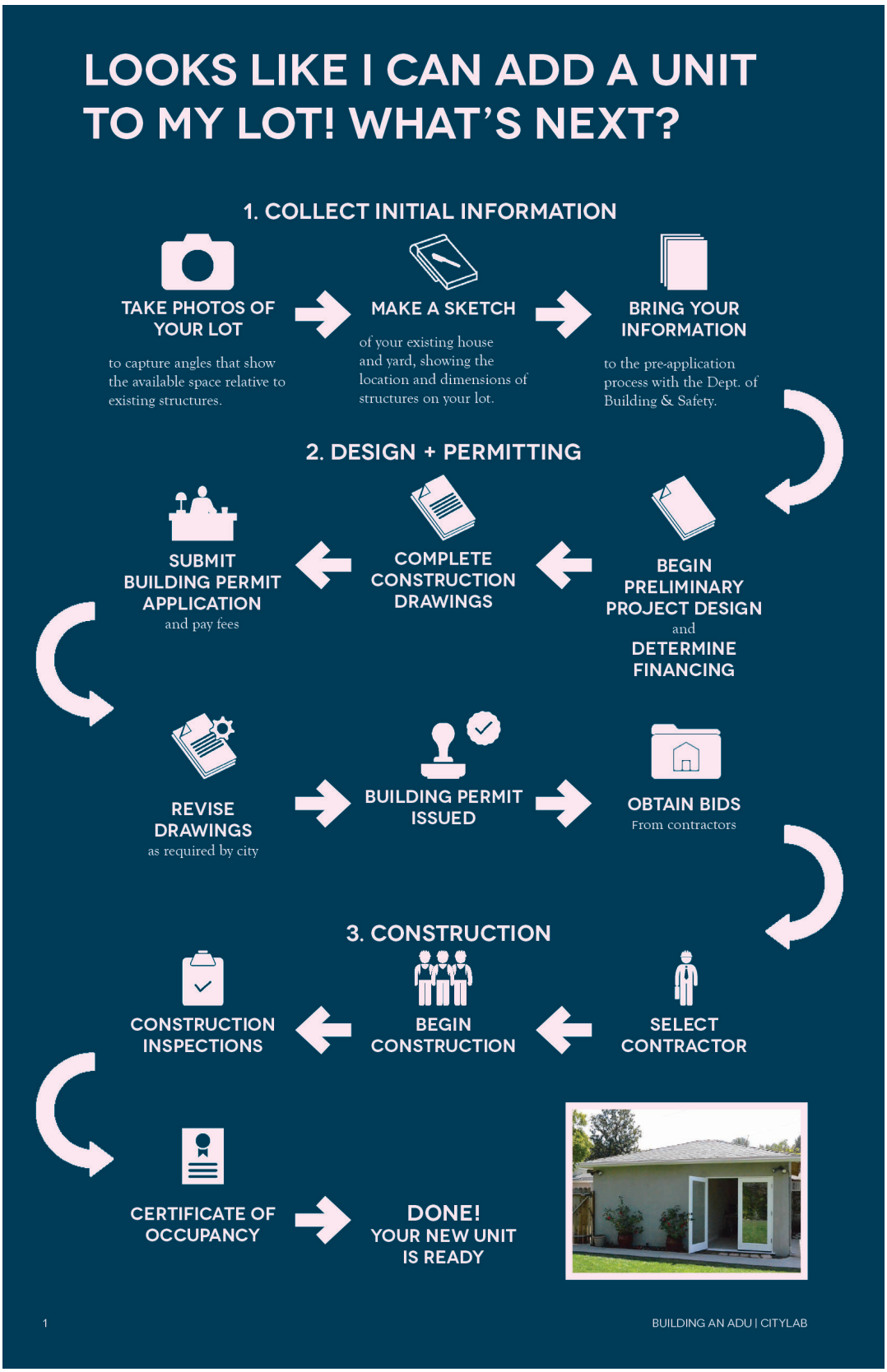
Table 1. Service Delivery Comparison

Services	LA-Más	Garage Conversion Improvements (G.C. Improvements)	Modative
Organization type and target client	Nonprofit; focus on low-income homeowners	For profit; focus on low-to-moderate income households	For profit; focus on middle-to-upper income homeowners
Primary disciplinary foundation	Urban designers	Building contractors	Architects
Year founded	2012	2015	2006
Office location	Frogtown, CA	Reseda, CA	Culver City, CA
Size	5–10 office staff plus advisory council	20–25 office staff plus construction teams with a foreman and 4–5 crew members	10–15 office staff
New (attached and detached) ADU development	Yes	Yes	Yes
Garage conversion or retrofit	Yes	Yes	Yes
Predesign	Provides predesign and client has limited options for customization	Allows clients to choose materials and some configurations of interior elements	Using IKEA-style predesigned kits; allows limited customization of finishes but not structure or layout components
Finance & lending	Partners with Self-Help Federal Credit Union and Genesis LA	Partners with Ygrene Works, Hero, CaliforniaFIRST	Partners with United Dwelling
Permitting	In-house	Contracts with third party	In-house

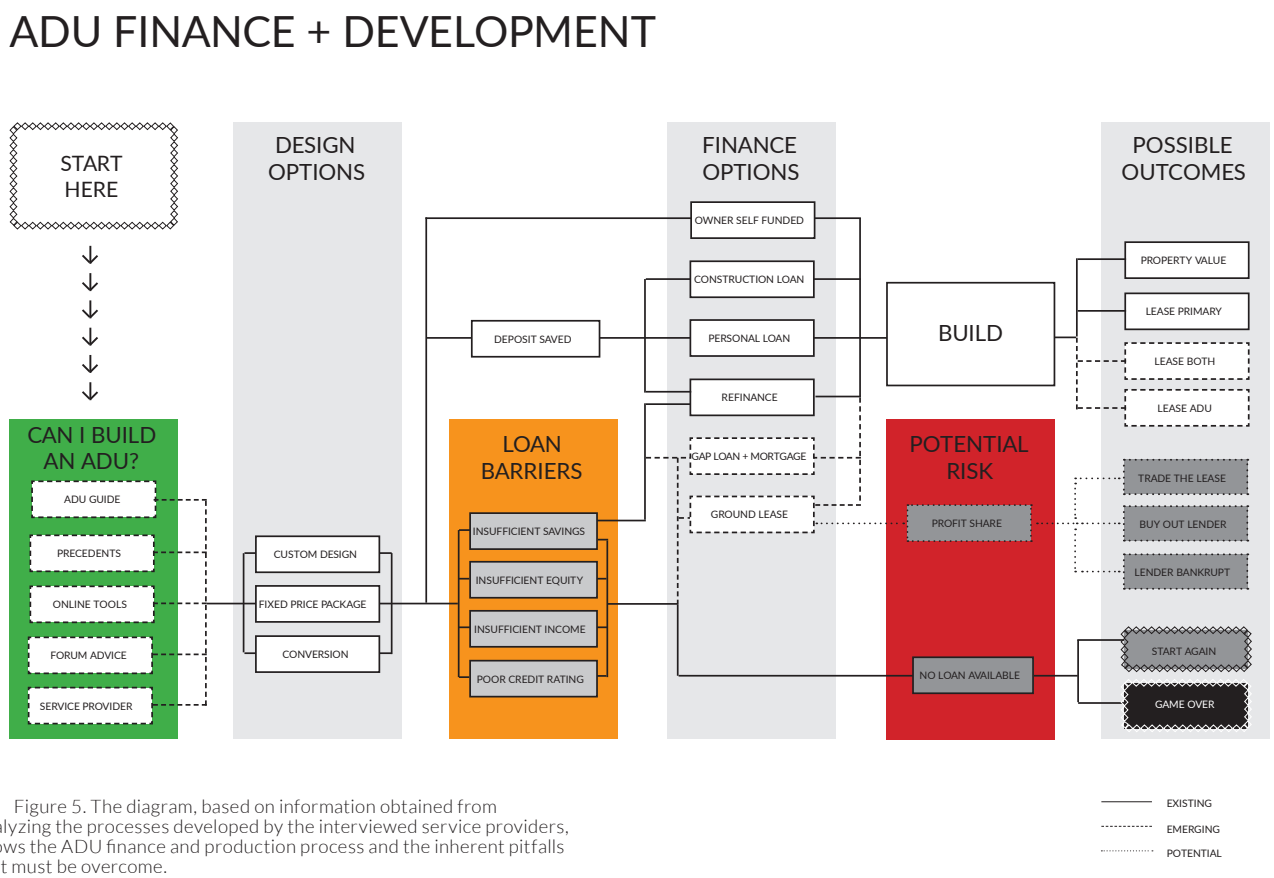
by the lease. At the end of the lease, the land and all improvements return to the owner of the property. This model poses considerable risk to homeowners considering building an ADU on their property, since lender equity is tied up for long periods of time in an unstable property market, which in turn requires them to generate increased revenue over time to expand their operations. An alternative approach is the guarantee-based finance model tested by GLA and LA-Más for the City of LA's ADU Pilot Project. GLA provided a gap loan to guarantee the cost of construction before owners transitioned to a traditional mortgage with a credit union. This hybrid approach avoids the risk and commitment associated with the long-term ground lease profit share arrangement. All interviewed providers are developing proof-of-concept prototypes to reduce current uncertainties.

Stage 3: Regulation, Codes, and Planning Processes

Each of the three parties interviewed stated that standards in the approval process were needed and that they have plans to lobby for these changes. Although AB2299 removes some significant regulatory constraints and reduces uncertainty through clarification and simplification of laws, the participants identified many parameters that slow or prohibit ADU production. For example, service providers report that planning and building departments are inconsistent in the time taken (between three and six weeks) to process similarly compliant applications. Furthermore, the same scheme presented to different individuals within the same planning department can result in diverse and conflicting outcomes and recommendations. This is particularly frustrating for companies attempting to provide consistent, streamlined services with as many as sixteen inspections over the life of the



◁ Figure 4. Page from cityLAB's "Building an ADU" guidebook. (Source: cityLAB-UCLA, citylab.ucla.edu/adu-guidebook).



△ Figure 5. The diagram, based on information obtained from analyzing the processes developed by the interviewed service providers, shows the ADU finance and production process and the inherent pitfalls that must be overcome.

project—each with a two- to three-week delay when failed. In response, G.C. Improvements is conducting their own pre-assessment inspections with qualified contractors, at their own expense, to reduce the risk of rejection and to establish a reputation with assessors as trustworthy contractors. Given the complications within a single jurisdiction, service providers are focusing their efforts in a single city or region. However, the statewide law is robust enough that local-level modifications are likely to produce similar service provision practices, as was found in Los Angeles.

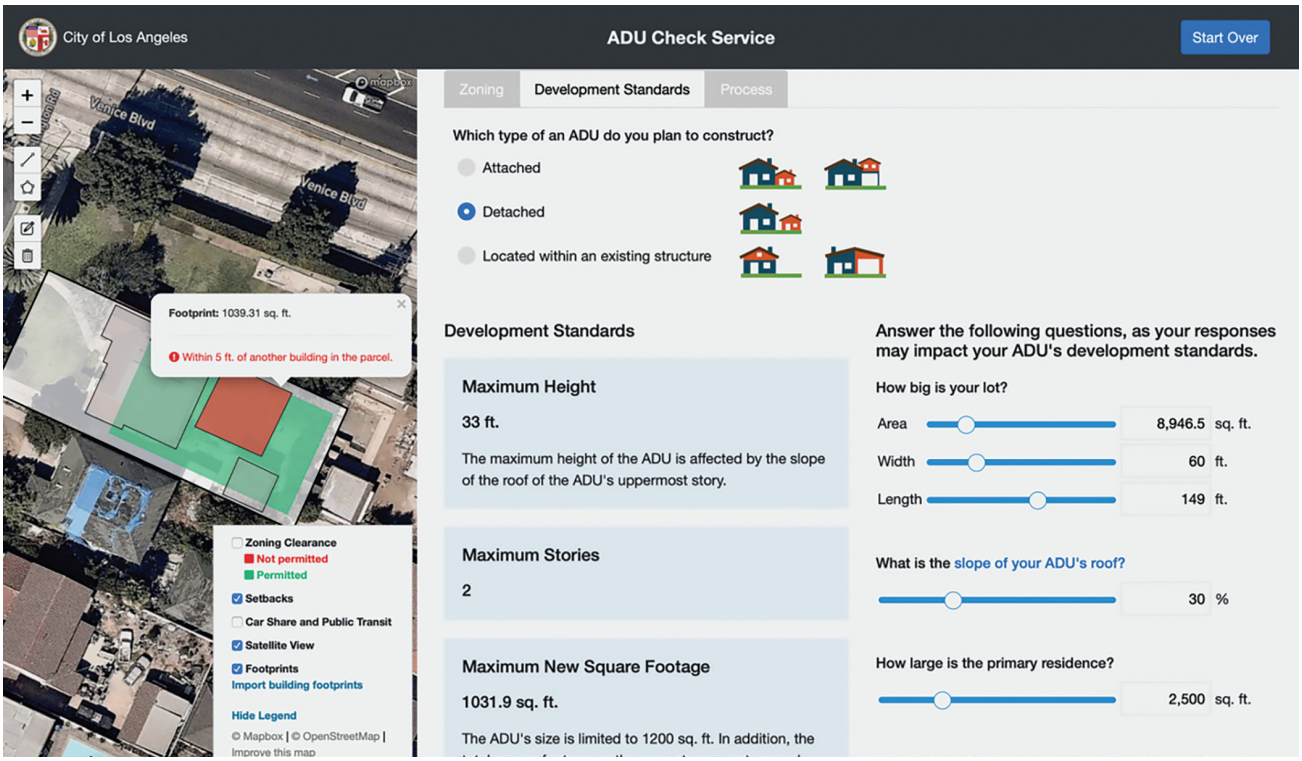
Service providers reported the use of a range of emerging third-party digital tools into their processes, including those that aim to minimize noncompliant ADU applications by compiling the relevant regulatory constraints for a specific property. A good example is the computational platform "San Mateo County ADU Check" from Symbium. This street address-based tool compiles a report of setbacks, parking requirements, maximum size of the ADU, costs, and forms to file related to county regulations (Figure 6). Consequently, the tools are capable of providing a large number of households with accurate and up-to-date information about regulatory and other code-based constraints. Such software is an excellent feasibility tool, but site specifics remain abstract compared to the specificity of ADU design services by a professional architect.

Stage 4: Dwelling Design and Response to Existing Site Conditions

Working within the physical constraints of established sites is identified by service providers as the greatest challenge to introducing efficiencies in the design process. While postwar mass production housing experiments focused on standardization, modularity, and prefabrication, this combination does not work for small backyard infill on suburban lots due to the high variability among properties, in terms of both existing buildings and service connection points. The study's participants found that with no consistency in driveway layout, foundation conditions, or setbacks in the tight backyard sites, prefabricated whole units are impractical at present. In addition, the ingrained culture of customization conflicts with the standardization of dwelling units.

In response, full-service teams have established a number of design approaches in order to introduce efficiencies. Computer modeling is used by Modative to help visualize existing and proposed layout options to preplan utility services. This operation ensures that all services are connected prior to ADU installation, minimizing delays due to noncompliance, avoiding miscommunication with installers, and reducing labor on site.

To address the variation in location of on-site utilities (existing gas, electric, and water services), G.C. Improvements configures internal layouts to ensure that all services are colocated on a single wall that can be easily shuffled to achieve efficiencies for both garage renovations and new building layouts. Similarly, while G.C. Improvements does allow clients to modify materials and some configurations of interior elements, they clearly communicate cost implications and require clients to commit to one of three levels of



△ Figure 6. Online interface for entering lot information. (Source: Symbium, https://symbium.com/services#adu)

finish quality and provide options to suit. Modative also allows limited customization of finishes but does not alter structural or layout components.

To minimize the conflict between the homeowner's development aspirations and design efficiency, Modative encourages clients to conceptualize the ADU not as a small customizable house in their yard but as an investment project. However, the participants observed that homeowners are much more receptive to this approach through renderings and more likely to relax expectations for control if the project is a renovation of an existing structure, such as a garage. Modative is also developing an approach that essentially removes the client from the process. Partnering with a venture capitalist, this approach will focus only on detached garage conversions, assembling multiple projects in the same neighborhood. A ground lease will require sharing rental income with the homeowner and allows only superficial initial customization of the rental unit.

Stage 5: Construction and Fabrication

Geographic concentration of development was a consistent aim for all three companies, as they estimated significant labor and administrative efficiencies by treating a single neighborhood as one site. While prefabrication promises to assist in the production of affordable housing, establishing warehouses, labor forces, and the necessary machinery to construct whole units efficiently off-site requires levels of production demand that have not yet materialized. Instead, providers found that greater efficiencies can be achieved by adapting traditional construction practices. The key inefficiency identified was the cost of skilled labor. G.C. Improvements minimized the need for experienced builders by requiring standardized framing systems for detached- to single-story and garage conversions. Modative is developing a hybrid prefabrication and traditional construction technique that shifts ADU construction toward a simplified assembly process. Using detailed modeling in BIM, components are printed 1:1 on paper to make a template, thereby translating construction drawings into IKEA-like instruction manuals that can be easily interpreted by individuals of all skill levels. Due to this simplified approach, companies are able to hire construction teams through Chrysalis, a Los Angeles-based nonprofit organization that assists homeless and low-income individuals find employment, which significantly reduces the cost of construction and provides employment opportunities for those with little to no training or experience.

Reduction of costs were also reported by Modative, who noted that the introduction of construction management software like Procore saved them the estimated full-time equivalent of two additional administrative staff members.

Discussion

Technology utilized by emerging "one-stop-shop" operators is helping overcome impediments to the mass production of ADU development, particularly in three key stages of the development

process: predesign, design, and construction. Technology adopted in the predesign stage primarily focuses on calculation and communication using online platforms to provide translations of complex sets of information, including the visualization and specialization of regulatory information and financial forecasts. The cost of labor, both in the office and in the field, is one of the areas where technology demonstrates the greatest potential for generating efficiencies during the design and construction stages. Tools that facilitate conveying complex information efficiently between expert designers/engineers and nonexpert laborers can also be used in the construction stage. BIM is critical to this process, as it allows for both the virtual visualization and construction of elements, enabling increased efficiencies on site when the templates created are used multiple times.

In different ways, the chosen predesign, design, and construction tools can successfully overcome development complications because they directly address the identified challenges of inexperience, variability, and uncertainty in the emerging ADU market. Effective approaches to achieving systematic efficiencies in time and cost are those that adopt multiple forms of technology throughout the development process. Surprisingly, the most innovative advances towards mass production are achieved through the coupling of traditional low-tech processes with sophisticated digital tools to address specific obstacles, suggesting that mass production solutions in the housing sector may be found in reexamining existing approaches in conjunction with emerging technologies.

Next Steps and Broader Applicability

Further efficiencies in the ADU sector can be gained through technologies that address the unresolved issues, hurdles, and opportunities identified in the initial research. For example, a public database with 3-D models of physical sites could lead to more appropriate prefabricated building modules. As standardized dwelling models and processes continue to be refined, municipal agencies should consider how the approval process could be standardized to support and expedite the construction of compliant dwellings. While the current ADU boom in Los Angeles was spurred by new laws, many of the remaining inefficiencies in the development process are regulatory. As comprehensive service providers enhance their track records, metrics about systematic problems will spur further modification of existing legislation.

Lessons learned from the progress of backyard housing in Los Angeles could have broader applicability and implications in other states and international contexts. In the US, cities in more than a dozen states are encouraging ADUs, from Oregon (Peterson 2018) and Colorado (Castle 2018) to Maryland (Friedman 2018) and New Hampshire (Green 2018). Abroad, Australian consumers' preferred form of residential development is detached dwellings located within single-residence zones (Australian Bureau of Statistics 2012). A recent report issued by the Australian Housing and Urban Research Institute (AHURI) found that since 2009, the production of secondary dwellings on single-family lots has yielded almost six times

◁ Figure 7. Built prototype for backyard Accessory Dwelling Units called the Backyard BIHOME. (Credit: Kevin Daly Architects, UCLA Students, and cityLAB-UCLA. Photograph by Photekt).

more additional units than the construction of affordable rental dwellings incentivized by a government planning initiative targeted at medium- to large-scale developers (Gurran et al. 2018). However, like Los Angeles, the production of backyard housing to date in Sydney and other predominantly suburban Australian cities such as Perth, Adelaide, and Hobart is constrained by planning regulation, homeowners' lack of development experience, and the availability of finance.

ADU lessons will also translate to other housing types. For example, the efficiencies that Modative discovered by developing small-lot subdivision projects became the basis of their ADU construction approach. Similarly, emerging innovative finance options specific to backyard housing may apply to other development activities that are currently restricted by a lack of loan types, such as the expanding DIY home renovation market. By facilitating new mass production approaches to more effectively address housing affordability issues, innovative ADU processes could have implications for multi-family housing.

This research has been conducted at the very beginning of an exploration period for scaling an ADU-led approach addressing housing production issues in Los Angeles. As such, ongoing work is needed to examine and identify the implications of ADU development to critically evaluate its effectiveness. Furthermore, although the current unregulated service provision environment fosters innovation, the same environment may enable predatory activities and detrimental actions. Finally, while the approaches to a scaled residential production identified in this research facilitate an increase in housing stock, they should not be promoted at the expense of architectural quality. It is critical to identify and respond to possible negative impacts on the perception of backyard housing as an appropriate model of development, in order to avoid repeating the mistakes of poor-quality apartment developments in established neighborhoods (that resulted in a reduced acceptance of multifamily housing).

Analyzing the initiatives and processes established by three comprehensive service providers identified that barriers to the mass production of housing are not insurmountable. Just as UCLA's cityLAB addressed restrictive conditions with planning regulation and paired these with a translated guide for homeowners as well as a full-scale prototype (Figure 7), service providers are leveraging technological advances to create processes and products that address the misalignment between ADU housing models and the post-suburban city.

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