Federal Reserve Bank of Philadelphia

POLICYMAP

# Measuring and Understanding Home Repair Costs

## A National Typology of Households†

By Eileen Divringi*, Eliza Wallace**, Keith Wardrip*, and Elizabeth Nash**

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† The views expressed here are those of the authors and do not necessarily represent the views of the Federal Reserve Bank of Philadelphia, the Federal Reserve System, or PolicyMap.

* Federal Reserve Bank of Philadelphia

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## ABSTRACT

To provide a new measure of housing quality, we present a cost-based index of home repair needs based on housing problems reported in the American Housing Survey (AHS). Using the most recent available AHS data, our analysis estimates the national aggregate cost of addressing reported housing deficiencies at $126.9 billion in 2018, with an average repair cost among households with repair needs of roughly $2,920. To enhance our understanding of households with repair needs and identify groups that may be particularly vulnerable to housing disrepair, we use cluster analysis to develop two typologies: one for owner-occupied units and another for renter-occupied units. Our findings suggest that home repair needs are more acute for low-income renters and homeowners but are also present among middle- and upper-income households. Among renters, extremely low-income households in single-family units typically had the costliest repair needs. These were also the most likely renter households to have children present. Among homeowners, low-income older adults who were long-term occupants of their units had the costliest average repair needs. The total cost of addressing repairs reported by low-income households, who may find it financially difficult to make the necessary repairs or move to a higher-quality unit, was $50.8 billion in 2018.

## INTRODUCTION

Ensuring access to adequate quality living quarters has long been a goal of federal housing policy. The Housing Act of 1949 famously called for "a decent home and suitable living environment for every American family…" (42 U.S. Code § 1441). Although the safety and quality of housing in the United States improved immensely during the 20th century (Kutty 1999, Holupka and Newman 2011, Jacobs, et al. 2009), households and neighborhoods across the country continue to struggle with substandard conditions and disrepair (De Leon and Schilling 2017). Inadequate housing is linked with an increased risk of injury and the development of chronic physical and mental health issues (Krieger and Higgins 2002, Evans, Wells, and Moch 2003, Jacobs, et al. 2009), presenting particularly acute hazards for children, older adults, and individuals with disabilities (Evans, Saltzman, and Cooperman 2001, Newman 2003). Injuries and illness related to inadequate housing are estimated to contribute billions of dollars in direct and indirect health-care costs annually (Federal Healthy Homes Work Group 2013) and impose additional societal costs related to lost economic productivity and lower quality of life (Trasande and Yinghua 2011, Gould 2009).

Much of the policy discussion around housing issues in the United States centers on housing affordability, which is a widespread challenge for many low- and moderate-income households (JCHS 2018a). However, both affordability and quality are increasingly understood as interlinked components of housing insecurity (Routhier 2019), as low-income households may sacrifice one to attain the other. For renters, substandard conditions in the lowest-cost units can have detrimental effects on residents' health and safety and may contribute to residential instability (Krieger and Higgins 2002, Rauh, Chew, and Garfinkel 2002, Culhane, Lee, and Wachter 1996). Low-income homebuyers may find that the only financially attainable homes are older or in relatively poor condition (Boehm and Schlottmann 2008a). Further, the costs of major or unanticipated repairs can threaten the financial sustainability of low-income homeownership (Van Zandt and Rohe 2011), undermining the comfort, security, and wealth-building potential that motivates many to purchase a home. In distressed neighborhoods, severe disrepair is a common precursor to abandonment, with potentially harmful repercussions for local quality of life (Hillier, et al. 2003).

Measuring the scope and magnitude of housing repair needs is fundamental to developing effective policy and programmatic solutions. There have been several recent efforts to measure and summarize housing quality (Eggers and Moumen 2013b, Emrath and Taylor 2012, Newman and Holupka 2017), although the most widely used measure by far is the composite indicator of housing adequacy available in the AHS. This measure identifies units as "adequate," "moderately inadequate," or "severely inadequate" based on the presence of one or more housing problems[1] and is discussed in the influential *Worst Case Housing Needs* report provided by the U.S. Department of Housing and Urban Development (HUD) biennially to Congress (Watson, et al. 2017). Recent work has called into question the conceptual basis for these categories (Newman and Garboden 2013, Eggers and Moumen 2013a), but another significant drawback is the difficulty of translating these categories into actionable, policy-relevant information. Accordingly, we present a new measure that weights each housing problem reported in the AHS by the average cost of a reasonable repair. In addition to providing a more nuanced scale of disrepair, this cost-based index enables us to estimate the unit-level costs of addressing substandard conditions that can be aggregated to various geographic levels. Based on housing conditions reported in the most recent AHS, we estimate that the total cost of repairs to the national housing stock would have been $126.9 billion in 2018.[2]

Although our cost-based index of housing quality has practical advantages over other measures, it tells us little about the types of households that struggle with disrepair. This information is similarly critical for developing and prioritizing policy interventions. Accordingly, we develop typologies of owners

[1] Minor adjustments to the criteria for each category have been introduced over time. Prior to the 2015 AHS, this composite indicator was referred to by the variable name ZADEQ. From the 2015 survey onward, the variable has been renamed ADEQUACY. See the AHS codebook for a description of the classification criteria: www.census.gov/data-tools/demo/codebook/ahs/ahsdict.html.

[2] Here and throughout this report, dollar figures pertain to 2018 dollars.

and renters with repair needs using a hierarchical clustering algorithm based on key household and unit characteristics. The results of this cluster analysis indicate that housing quality issues are more acute among economically disadvantaged households, particularly for renter households where children are present and for older homeowners aging in place. Low-income households residing in older, single-family units are found to have particularly acute repair needs.

The report is divided into the following four sections. The next section provides a brief overview of the methodology used to develop the cost-based housing index and to perform the cluster analyses. Then, we provide a breakdown of national findings using our repair cost–based measure. From there, we describe the typologies that emerged from the cluster analyses for renter- and owner-occupied units. Last, we conclude with a summary of key findings and discuss implications for practitioners.

## METHODOLOGY OVERVIEW

The following section provides an abridged overview of the methodology for the repair cost estimation and cluster analyses. For a detailed explanation of how repair costs estimates were developed and assigned to units in the AHS, see the Technical Appendix to this report.[3] For a detailed explanation of the cluster analyses, see Appendix C included in this report.

### Data

#### *American Housing Survey (AHS)*

The AHS is conducted biennially by the U.S. Census Bureau in partnership with HUD. The 2017 survey, which is used throughout this report, was sent to 85,000 units, combining a nationally representative sample with an intentional oversampling of selected metropolitan statistical areas (MSAs) and HUD-assisted units.[4] The AHS is the most comprehensive source of data on national housing conditions, including detailed information on the demographic and economic conditions of households and the physical characteristics of housing units. Most importantly for this analysis, the AHS includes a battery of survey questions on the physical condition of occupied units in its Housing Problems module, covering topics ranging from sagging roofs to cracked foundations (see Appendix D and the Technical Appendix for more detailed information).

The analysis presented in this report uses the AHS National Public Use File (PUF). The PUF provides anonymized individual responses to the survey, enabling the research team to identify unit-level housing issues. Since the full Housing Problems module is only administered to occupied units, the analysis in this report is restricted to units that were occupied when the 2017 survey was conducted. While the omission of vacant units is likely to substantially understate the national level of housing disrepair (Emrath and Taylor 2012), limiting the analysis to occupied units provides a better representation of the housing stock that is currently in use.

#### *RSMeans Repair Cost Estimates*

To estimate the costs of addressing repair needs identified in the AHS, we worked with Gordian, a firm that specializes in construction cost estimation for the building industry. Gordian maintains the RSMeans database of construction and repair cost estimates for specific construction inputs (e.g., windows, pipes, roofing materials), which include the average cost of labor, materials, and equipment. These estimates assume the use of a professional contractor and factor in appropriate overhead costs. Such estimates are commonly relied upon by construction professionals and are well-suited for our cost-based index. The calculations in this report are based on RSMeans national average data for 2018. For MSA estimates, cost adjustment factors from Gordian (2017) are used to account for regional differences in construction costs.

We used the most current data available at the time of the analysis to understand both the extent of housing disrepair (the 2017 AHS data) and the costs associated with addressing it (the 2018 RSMeans data). Rather than deflating repair costs to 2017, we report the 2018 values because, using the best unit-level information available, this approach conveys our most up-to-date understanding of the resources required to repair the nation's occupied housing stock.

### Repair Cost Index

Our approach to developing the repair cost index adapts that of Eggers and Moumen (2013b), who constructed a unit-level housing quality index based on a weighted count of housing quality issues identified in the AHS. However, instead of weighting by perceived severity, our index weights by the cost of the associated repairs. Summarized at the unit level, the index provides an approximation of the total costs of addressing substandard conditions reported by households.

To estimate discrete repair costs, we developed a master list of variables from the AHS that identified problems related to the physical condition or equipment of occupied units. Next, we incorporated variables that provided useful context for understanding and remediating the housing problem,[5] creating a set of housing problem scenarios. This list of scenarios was

[3] Available at: www.philadelphiafed.org/-/media/community-development/publications/special-reports/home-repair-costs-technical-appendix.pdf.

[4] For more details on the AHS sample, see *2017 AHS Integrated National Sample: Sample Design, Weighting, and Error Estimation* available at www.census.gov/programs-surveys/ahs/tech-documentation/def-errors-changes.html.

[5] For instance, the cost of repairing a heating system will depend on whether the household is heated by a furnace or baseboard units. See the Technical Appendix to this report for further details.

shared with consultants at Gordian, with whom we worked to define appropriate, cost-effective repairs. The consultants then estimated costs for these repairs based on national averages.

We merged the data set of repair cost estimates from Gordian with the 2017 AHS PUF and assigned repair costs to units based on reported housing issues and context variables. To avoid assigning redundant costs, we identified and adjusted for scenarios in which the repairs were likely to overlap (e.g., if a household reported both a sagging roof and a roof leak, only the cost of replacing the roof was assigned). Once the reported housing problems were assigned corresponding repair costs, estimates could be aggregated at the unit, MSA,[6] regional,[7] and national level using survey weights provided in the AHS PUF.

The cost-based index presented in this report offers some practical advantages over many other available housing quality measures. First, by leveraging a broader array of housing quality-related items included in the AHS, the cost-based index provides a more nuanced and conceptually grounded alternative to HUD's widely used composite measure. Preliminary internal validation tests confirm that the cost-based index has the expected association with other measures of housing quality.[8] Last, although there are numerous potential ways to define index weights,[9] the cost of repairs provides a concrete, objective basis and offers valuable summary-level information for policymakers and public officials.

Despite these advantages, our cost-based index has some important limitations. First, our repair cost index likely understates the magnitude of repair needs for multifamily housing. Many of the cost estimates supplied by Gordian assume the repair applies to a single-family home. In many cases, these costs are likely to be comparable in different unit contexts (e.g., repairing a crack in an interior wall), although for others, there may be substantial differences (e.g., repairing a 10th-story window). Furthermore, AHS respondents in multifamily housing are not asked most questions pertaining to structural housing issues (e.g., issues related to roofs, foundations, exterior walls, or building systems). As a result, we are unable to capture the need for more extensive repairs to larger residential buildings. Additionally, the AHS does not collect information on housing deficiencies that are unlikely to be observed in residents' everyday lives, such as lead exposure, water contamination, and indoor air quality issues. Local and national regulatory factors may also significantly affect the cost of repairs. For example, nonresident property owners or government agencies can encounter costly lead removal requirements when renovating units built before the lead paint ban went into effect in 1978.[10]

Finally, a core challenge of translating AHS housing problem variables into repair costs is the lack of contextual information on building materials and the magnitude of reported issues. For example, the survey does not provide information on roofing or exterior wall materials, the size of holes in interior walls or flooring, or the number of windows that are boarded up or broken. In these situations, we made conservative but reasonable assumptions (see the Technical Appendix for details). For these reasons, our cost-based index should be understood as an approximate measure of the costs to mitigate the repair needs that are reported by AHS respondents.

*"Measuring the scope and magnitude of housing repair needs is fundamental to developing effective policy and programmatic solutions"*

## Cluster Analysis

Cluster analysis is the umbrella term for a variety of exploratory techniques used to classify objects into meaningful groups based on a predefined set of criteria (Everitt, et al. 2011). In the private sector, this type of analysis is commonly used to identify

[6] The AHS National PUF enables users to tabulate statistics for the 15 most populous MSAs.

[7] Here and throughout this report, regions refer to the groupings of states and the District of Columbia defined by the Census Bureau as census regions. For details, see www2.census.gov/geo/maps/general_ref/pgsz_ref/CensusRegDiv.pdf.

[8] Following the lead of Newman and Garboden (2013), we evaluated the convergent validity of our cost index by assessing its correlation with residents' rating of their unit on a scale from one (worst) to 10 (best). The resulting Pearson correlation coefficient was -0.21 ($p < 0.001$), indicating that higher estimated repair costs were associated with lower unit ratings. See the Technical Appendix for additional internal validity tests.

[9] Newman and Holupka (2017) offer several alternatives.

[10] See www.epa.gov/lead/renovation-repair-and-painting-program for details. Although the AHS has included questions pertaining to lead exposure risk in certain survey years, these questions are not included in the regular Housing Problems module. As a result, we were unable to identify units for which lead remediation costs are likely to be incurred. Gould (2009) estimated that the national cost of lead paint remediation in high-risk units would be between $1.2 billion and $11.0 billion.

key customer segments and inform marketing strategy (Punj and Stewart 1983). In the public and nonprofit sectors, cluster analysis has been used to construct informative typologies of target populations for social services (Kuhn and Culhane 1998, Ross and Holmes 2017) and policy-relevant groupings of neighborhoods, cities, and metropolitan areas (Bates 2006, Federal Reserve Bank of Chicago n.d., Erickcek and McKinney 2006), among other applications.

In this report, cluster analyses are used to summarize the large number of observations of households with repair needs into two sets of typologies: one for renter-occupied units and the other for owner-occupied units. This process is fundamentally a classification exercise, intended to delineate useful groupings of these households rather than reveal underlying structures or relationships within the data. By providing a quantitatively grounded, multidimensional characterization of households with repair needs, these typologies can help inform policy and programmatic responses.

The first step of the cluster analysis was to compile a list of potential clustering variables based on a review of the relevant housing quality literature. Using a hierarchical clustering algorithm,[11] we systematically examined cluster solutions yielded by numerous permutations of these variables. The final combinations of clustering variables were selected for both theoretical and pragmatic reasons. First, for each typology, the clustering variables had an established relationship with the experience of housing disrepair in the housing quality literature. Second, these combinations of variables were among the relatively few that yielded highly differentiated cluster solutions that were well-suited to our analytical goals. For a more in-depth description of the cluster analysis methodology, see Appendix C.

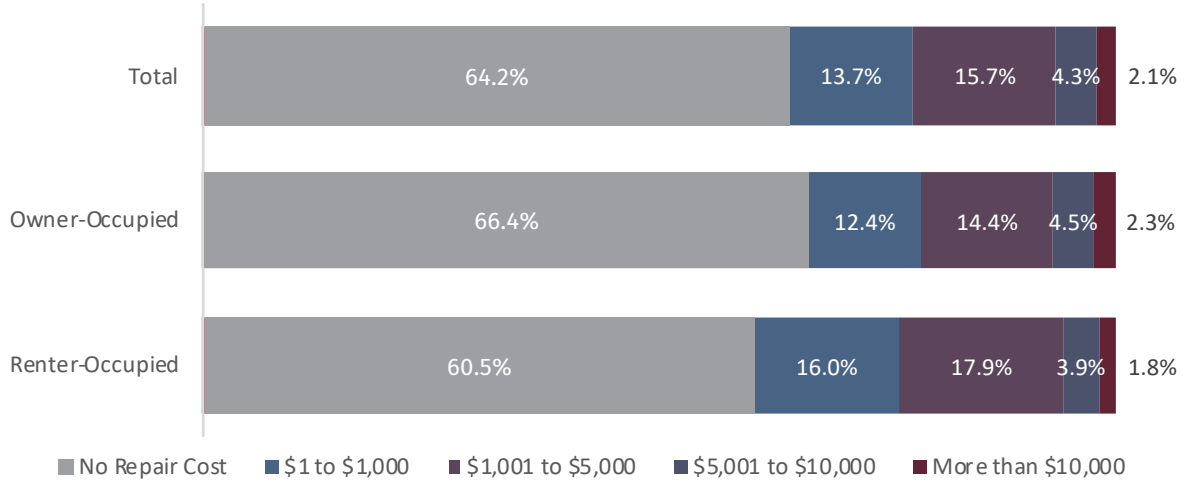
[11] "Hierarchical" clustering is an agglomerative method that begins with each observation in a separate cluster. The algorithm then merges nearest neighbors in a stepwise fashion until all observations are part of a single cluster. A cluster solution is selected from the intermediate merges using quantitative and practical criteria. See Appendix C for details.

## NATIONAL FINDINGS

Nationally, 35.8 percent of occupied housing units reported at least one repair need in the 2017 AHS (Table 1). However, there was considerable variation in the magnitude of repair needs across these units. Nearly two-fifths of households with repair needs had estimated total repair costs under $1,000. The distribution of repair costs was heavily right-skewed, with the average estimated repair cost ($2,920) exceeding double the median ($1,449) for units with any repair need. As shown in Figure 1, a relatively small share of occupied housing units reported extensive repair needs, while a substantial share indicated more moderate-cost issues.

As shown in Table 1, echoing previous research, we find that housing quality issues were generally more severe or more common for those in poverty, single parents, and renters (Holupka and Newman 2011, Rosenbaum 1996, Kutty 1999, Jacobs, et al. 2009, Emrath and Taylor 2012, Raugh, Landrigan, and Claudio 2008). Householders of color were generally more likely than non-Hispanic white householders to report at least one housing problem; Native American householders experienced particularly acute disrepair, with median and average repair costs that considerably exceeded those of other

**FIGURE 1. DISTRIBUTION OF OCCUPIED HOUSING UNITS BY ESTIMATED REPAIR COST AND TENURE**




Sources: Authors' analysis of 2017 AHS PUF and 2018 RSMeans data from Gordian.

## TABLE 1. NATIONAL REPAIR COST ESTIMATES BY UNIT AND HOUSEHOLD CHARACTERISTICS

| | Percent with Repair Needs | Number with Repair Needs (Millions) | Repair Costs | | |
|---|---|---|---|---|---|
| | | | Aggregate (Billions) | Median | Average |
| All Occupied Units | 35.8% | 43.4 | $126.9 | $1,449 | $2,920 |
| **Tenure** | | | | | |
| Owner-Occupied | 33.6%* | 26.0 | $81.8 | $1,449 | $3,142* |
| Renter-Occupied | 39.5%* | 17.4 | $45.0 | $1,355* | $2,587* |
| **Ratio of Income to Poverty Level** | | | | | |
| Less than 100% | 42.9%* | 7.3 | $25.4 | $1,556* | $3,482* |
| 100-199% | 38.6%* | 8.3 | $25.4 | $1,449 | $3,063 |
| 200% or Above | 33.6%* | 27.9 | $76.1 | $1,426 | $2,730* |
| **Race/Ethnicity of Householder** | | | | | |
| Asian or Pacific Islander† | 31.3%* | 1.9 | $4.3 | $1,219* | $2,249* |
| Black or African American† | 39.6%* | 6.2 | $19.2 | $1,502 | $3,069 |
| Hispanic or Latino (Any Race) | 39.9%* | 6.6 | $18.8 | $1,449 | $2,859 |
| Native American† | 47.7%* | 0.5 | $2.5 | $2,570* | $5,010* |
| White† | 34.1%* | 27.5 | $80.0 | $1,449 | $2,914 |
| Other/Two or More Races† | 48.0%* | 0.7 | $2.1 | $1,430 | $2,770 |
| **Household Type** | | | | | |
| Married Couple | 33.5% | 19.8 | $57.5 | $1,449 | $2,904 |
| With Children | 37.7%* | 9.2 | $27.0 | $1,449 | $2,942 |
| Single Female Householder | 39.1%* | 14.3 | $42.0 | $1,449 | $2,932 |
| With Children | 46.8%* | 4.3 | $13.8 | $1,599* | $3,186* |
| Single Male Householder | 36.2% | 9.3 | $27.4 | $1,449 | $2,934 |
| With Children | 42.7%* | 1.4 | $4.1 | $1,449 | $2,871 |
| **Structure Type** | | | | | |
| Manufactured Home | 45.5%* | 3.1 | $11.0 | $1,743* | $3,587* |
| Single-Family Home | 35.3% | 30.3 | $98.2 | $1,502* | $3,240* |
| Small Multifamily (2–9 Units) | 35.7% | 5.0 | $9.0 | $1,200* | $1,783* |
| Large Multifamilty (10+ Units) | 34.0%* | 5.0 | $8.7 | $1,095* | $1,727* |
| **Year Built** | | | | | |
| 1939 or Earlier | 45.4%* | 7.5 | $24.1 | $1,556* | $3,200* |
| 1940–1969 | 40.1%* | 12.5 | $38.6 | $1,449 | $3,087* |
| 1970–1999 | 34.6%* | 17.4 | $50.3 | $1,449 | $2,894 |
| 2000 or Later | 25.7%* | 6.0 | $13.7 | $1,333* | $2,292* |
| **Location** | | | | | |
| Metropolitan Area | 35.4% | 36.4 | $102.1 | $1,449 | $2,804* |
| Nonmetropolitan Area | 37.9%* | 7.0 | $24.8 | $1,502 | $3,519* |
| **Census Region** | | | | | |
| Northeast | 35.5% | 7.7 | $19.8 | $1,355* | $2,552* |
| Midwest | 34.8% | 9.4 | $27.9 | $1,449 | $2,958 |
| South | 36.5% | 16.6 | $51.3 | $1,449 | $3,094* |
| West | 35.7% | 9.7 | $27.9 | $1,449 | $2,878 |

Sources: Authors' analysis of 2017 AHS PUF and 2018 RSMeans data from Gordian.

Note: Medians and averages are calculated for units with estimated repair costs > $0. Repeated median values reflect the costs of common individual repairs or combinations of repairs.

* Denotes statistically signficant difference from all occupied units at p <0.10 level. Only calculated for share of units with repair needs, median repair cost, and average repair cost.

†Non-Hispanic or Latino

householders ($2,570 and $5,010, respectively). Single female householders with children — a household type that research suggests is particularly disadvantaged in the private housing market (Desmond 2016, Holupka and Newman 2011) — were also more likely to report housing problems (46.8 percent) and relatively costly repair needs (an average of $3,186).

Repair needs were somewhat more common among units in nonmetropolitan areas (37.9 percent of units) than in units in metropolitan areas (35.4 percent).[12] Average repair costs were also somewhat higher for units in nonmetropolitan areas ($3,519, compared with $2,804 in units in metropolitan areas). A likely contributing factor is that manufactured housing, which is concentrated in rural areas (Housing Assistance Council 2010), was associated with an especially high prevalence of repair needs (45.5 percent) and average repair cost ($3,587). As anticipated, the prevalence and magnitude of repair needs were also strongly associated with a unit's age. Units built before 1940 were nearly 20 percentage points more likely to have at least one repair need than units built in 2000 or later.

As shown in Table 2, the most commonly reported repair needs pertained to structural issues and leaks and mold.[13] A slight majority of aggregate repair costs were associated with structural repairs, which tend to be relatively costly. Reflecting the skewed distribution of repair costs, the majority of units with

**TABLE 2. PREVALENCE OF REPAIR NEEDS BY REPAIR CATEGORY**

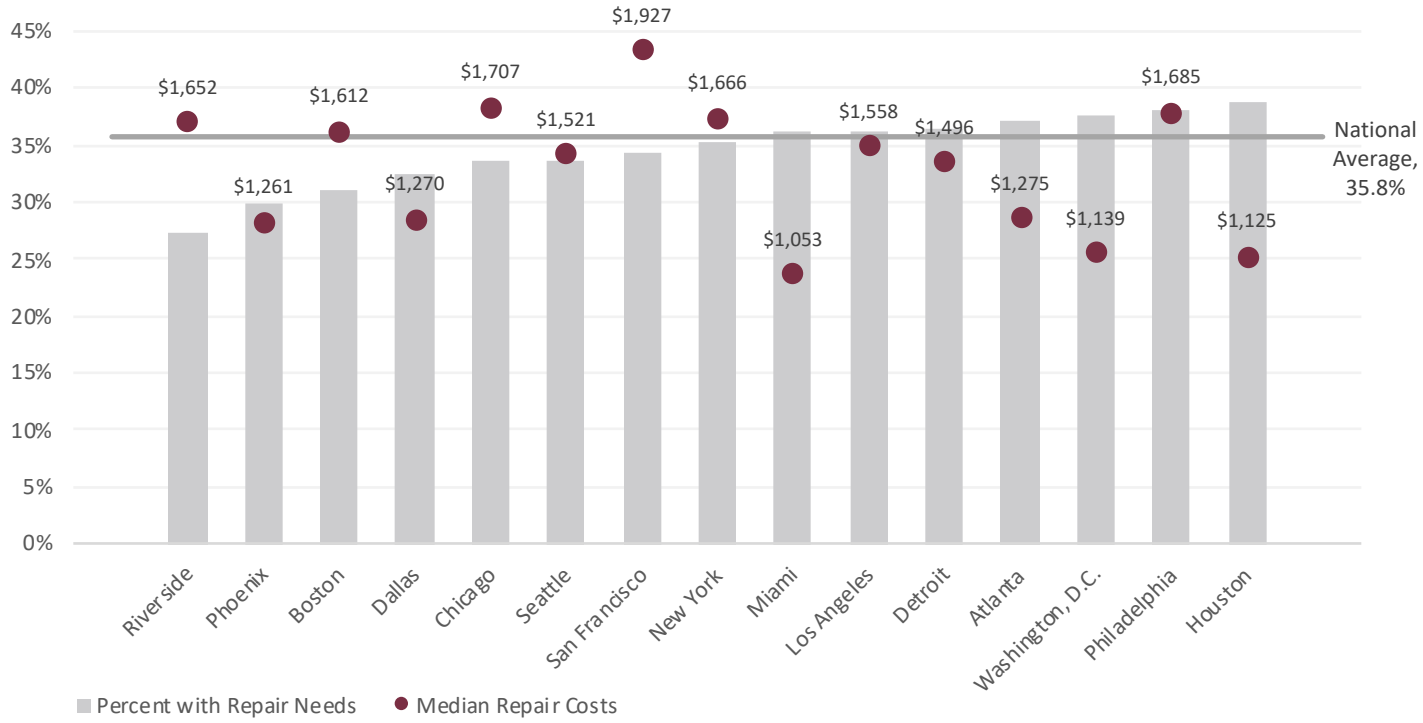
| | Share of Units Reporting Issue* | Share of Aggregate Costs |
|---|---|---|
| Electrical | 15.4% | 7.0% |
| Heating | 14.0% | 4.3% |
| Leaks and Mold | 46.7% | 25.0% |
| Pests | 13.8% | 2.2% |
| Plumbing | 10.9% | 4.7% |
| Structural | 44.0% | 56.8% |

Sources: Authors' analysis of 2017 AHS PUF and 2018 RSMeans data from Gordian.
* For units with repair costs >$0. Column does not sum to 100% because units may report housing problems in more than one category.

[12] Unfortunately, the 2017 PUF does not allow users to break out metropolitan areas into their component central city/noncentral city geographies, although prior research suggests that disrepair is more common among central city units (Emrath and Taylor 2012, Kutty 1999).

[13] For an overview of the types of housing problems reported in each of these categories, see Appendix D.

**FIGURE 2. PERCENT OF HOUSEHOLDS WITH REPAIR NEEDS AND MEDIAN REPAIR COSTS BY MSA**




Sources: Authors' analysis of 2017 AHS PUF and 2018 RSMeans data from Gordian. Cost estimates adjusted for regional variation using zip code–level location factors from Gordian (2017).
Note: Medians are calculated for units with estimated repair costs > $0.

repair needs reported only one housing problem (58.6 percent) and just over one-fifth reported two problems (22.3 percent). Less than 6 percent of units with repair needs reported five or more problems. The most commonly reported housing issues among units with repair needs were cracks or holes in walls or ceilings (15.2 percent),[14] roof leaks (14.0 percent), cracked or crumbling foundations (11.4 percent), and signs of roaches at least weekly in the past 12 months (10.2 percent).

## Large Metropolitan Areas

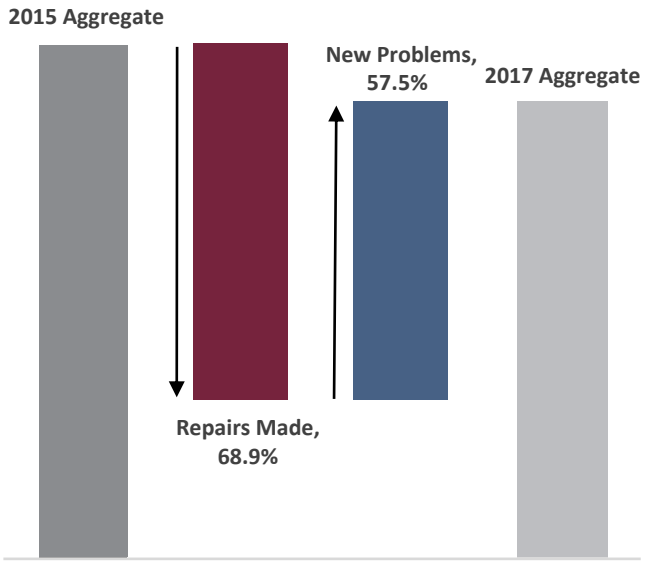
Across the 15 largest MSAs, the prevalence of home repair needs ranged from a low of 27.3 percent in the Riverside, CA region to 38.8 percent in the Houston MSA (Figure 2).[15] By and large, the prevalence of repair needs in these metropolitan areas was in line with, if not substantially below, the overall national rate. Median repair costs, adjusted for regional differences in construction costs, were considerably more variable. The highest estimated costs were associated with regions that have relatively old housing stock (Philadelphia and Boston), relatively high construction costs (San Francisco), or both (Chicago and New York). In 14 of the 15 MSAs, the prevalence of repair needs was higher among renter-occupied units than owner-occupied units. In the New York MSA, the share of renter-occupied units reporting at least one housing problem (42.7 percent) was more than 14 percentage points higher than that of owner-occupied units (28.3 percent). Additional MSA-level summary statistics are provided in Appendix A.

## Change from 2015 to 2017

Thus far, we have discussed household repair needs as a snapshot of the conditions when the 2017 survey was conducted. However, since the AHS is a panel survey that enables us to follow the same housing units over time, it is worth briefly discussing the dynamics of home repair needs. The current panel of AHS units was first surveyed in 2015, offering us a two-year interval across which changes in unit-level repair needs can be observed. Figure 3 summarizes the net change in aggregate repair costs based on changes in unit-level estimates but holds the costs of specific repairs constant at their 2018 values.

Although it is expected that some portion of repair needs would be addressed over the two-year period and that new ones would arise, the magnitude of the churn illustrated by Figure 3 is notable.[16] The red bar reflects the overall decline in total repair costs for units that had lower estimated costs in 2017 than 2015; the blue bar reflects the overall increase in repair costs for units that had higher estimated repair costs in 2017 than 2015, including units that recorded repair needs in 2017 but not in 2015. More than two-thirds of the aggregate costs of repairs in 2015 were addressed in this two-year period, and new repair costs equivalent to 57.5 percent of the 2015 aggregate emerged. The share of aggregate repair costs that were addressed exceeded the costs of new problems that emerged, leading to a decline in aggregate repair needs between the two survey years. This decline is substantial but understandable in the context of a strengthening housing market (JCHS 2018a). Further, there has been a considerable uptick in home improvement investment in both the rental and owner-occupied stock since the end of the Great Recession. A recent study estimates that $424 billion was spent on improvements, maintenance, and repairs in 2017 alone,

**FIGURE 3. PERCENT CHANGE IN AGGREGATE REPAIR NEEDS FROM 2015 TO 2017**




Sources: Authors' analysis of 2015 and 2017 AHS PUF and 2018 RSMeans data from Gordian.
Note: The percent decrease in repair needs ("Repairs Made") is calculated as the aggregate decrease in repair costs for units that had lower repair costs in 2017 compared with 2015 divided by aggregate repair costs in 2015. The percent increase in repair needs ("New Problems") is calculated as the aggregate increase in repair costs for units that had higher repair costs in 2017 compared with 2015, including units that had repair needs in 2017 but not 2015, divided by aggregate repair costs in 2015. Survey weights for the 2015 AHS are used for both years. Only units that were occupied in both 2015 and 2017 are included in this analysis.

[14] According to the AHS codebook, respondents are asked to report cracks or holes that are "wider than the edge of a dime."

[15] It is worth noting that the timing of the 2017 AHS interviews overlapped with the landfall of Hurricane Harvey, which resulted in considerable flooding and wind damage to many residential properties in the Houston MSA. However, it does not appear that this damage is captured in the 2017 AHS, as the share of units with repair needs and median repair costs are comparable with, if not slightly lower than, those reported in the 2015 survey.

[16] Using a similar approach to identifying housing problems in the AHS from 1985 to 2009, Eggers and Moumen (2013b) find that between 39 and 44 percent of units that report deficiencies in one year of the survey do not report deficiencies in the next survey.

up from $277 billion in 2010 (JCHS 2019). Although discretionary projects and other activities not captured in our cost-based index (e.g., improvements made to previously vacant properties) likely account for a substantial share of these expenditures, it is clear that the annual investment in improving the national housing stock is considerable.

## CLUSTER ANALYSIS RESULTS

The following sections summarize the typologies of renter and homeowner households with repair needs that emerged from the cluster analyses, including a brief description of the socioeconomic characteristics, unit characteristics, and repair needs associated with each cluster. Summary statistics are presented at the national level.

### Renter-Occupied Unit Typology

For renter households with repair needs, a total of 32 different potential combinations of clustering variables were examined and vetted based on the interpretability and practical value of the resulting cluster solutions. The final combination of clustering variables included the ratio of household income to the federal poverty level, the decade the unit was built, and structure type. A household's poverty status can limit the quality of housing it is able to afford, and the unit's age is directly related to physical deterioration (Kutty 1999). The inclusion of structure type, which was coded as a binary variable indicating whether the unit was a single-family home, was motivated in part by recent interest in the large number of distressed single-family properties converted to renter occupancy following the foreclosure crisis (JCHS 2013, Immergluck 2018, Lambie-Hanson, Li and Slonkosky 2018). See Appendix C for a more detailed discussion of cluster variable selection.

The resulting typology includes four clusters characterizing low-income renter households and four providing a parallel characterization of middle- and upper-income households (Table 3 and Figure 4 for repair costs and Appendix B, Table 1 for household and unit characteristics ). Households in the low-income clusters accounted for a slight majority of renter households with repair needs (51.8 percent) and a disproportionate share of aggregate repair costs (56.7 percent). Median repair costs for each cluster ranged from $1,160 to $2,096.

- **Low-income households in older single-family units:** Units in this cluster had the highest estimated repair costs among renter-occupied units.[17] The households in this cluster were

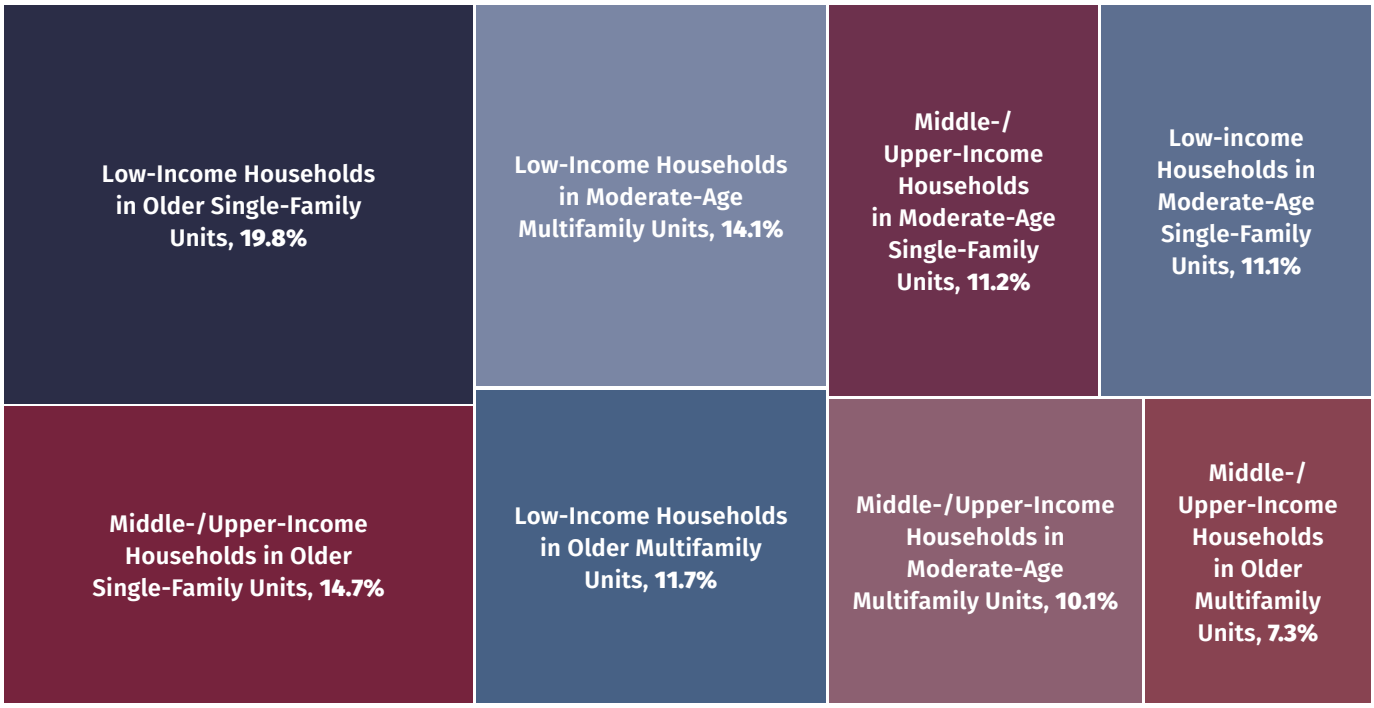
[17] Comparisons of repair costs across clusters are descriptive only and may not indicate statistical significance. See Appendix C for more information.

**TABLE 3. RENTER-OCCUPIED UNIT TYPOLOGY**

| | Low-Income | | | | Middle-/Upper-Income | | | |
|---|---|---|---|---|---|---|---|---|
| Median Costs | $1,449* | | | | $1,350 | | | |
| Average Costs | $2,833* | | | | $2,324* | | | |
| Number of Units (Millions) | 9.0 | | | | 8.4 | | | |
| Aggregate Costs (Billions) | $25.5 | | | | $19.5 | | | |
| | Single-Family | | Multifamily | | Single-Family | | Multifamily | |
| | Older Units | Moderate-Age Units | Older Units | Moderate-Age Units | Older Units | Moderate-Age Units | Older Units | Moderate-Age Units |
| Median Costs | $2,096* | $1,462 | $1,355 | $1,200* | $1,601* | $1,355 | $1,160* | $1,190* |
| First Quartile-Third Quartile | $840–$5,960 | $715–$4,125 | $687–$2,743 | $600–$2,120 | $836–$4,363 | $765–$3,212 | $600–$2,050 | $631–$1,801 |
| Average Costs | $4,162* | $3,447* | $2,202* | $2,094* | $3,248* | $2,884* | $1,749* | $1,670* |
| Number of Units (Millions) | 2.1 | 1.5 | 2.4 | 3.0 | 2.0 | 1.8 | 1.9 | 2.7 |
| Share of Units | 12.3% | 8.4% | 13.7% | 17.4% | 11.7% | 10.1% | 10.8% | 15.6% |
| Aggregate Costs (Billions) | $8.9 | $5.0 | $5.2 | $6.3 | $6.6 | $5.1 | $3.3 | $4.5 |
| Share of Agg. Costs | 19.8% | 11.1% | 11.7% | 14.1% | 14.7% | 11.2% | 7.3% | 10.1% |

Sources: Authors' analysis of 2017 AHS PUF and 2018 RSMeans data from Gordian.
Note: Medians and averages are calculated for units with estimated repair costs > $0.
* Denotes statistically signficant difference from all renter-occupied units with repair needs at p <0.10 level. Only calculated for median repair cost and average repair cost.

FIGURE 4. RENTER-OCCUPIED CLUSTERS BY SHARE OF AGGREGATE REPAIR COSTS




Sources: Authors' analysis of 2017 AHS PUF and 2018 RSMeans data from Gordian.

predominantly headed by single adults, the majority of whom were women. Just over half of the households had children present. Most of these units were located in the South or Midwest.

- **Low-income households in moderate-age single-family units:** Units in this cluster had relatively high estimated repair costs. The households in this cluster were predominantly made up of those with children. More than one-fifth of these units were located in nonmetropolitan areas, and more than half were in the South.
- **Low-income households in older multifamily units:** Units in this cluster had moderate estimated repair costs. The households in this cluster were predominantly headed by single adults, the majority of whom were women. Householders in this cluster were slightly older, and nearly two-thirds were people of color. More than one-third were in the Northeast.
- **Low-income households in moderate-age multifamily units:** Units in this cluster had lower estimated repair costs. The households in this cluster were predominantly headed by single adults, the majority of whom were women. One in six of these households lived in a manufactured home, and nearly half were located in the South.[18]
- **Middle-/upper-income households in older single-family units:** Units in this cluster had relatively high estimated repair costs. The households in this cluster were more likely than renters overall to be headed by a married couple. Nearly two-thirds of householders were non-Hispanic white. These households were not concentrated in any particular region but were somewhat overrepresented in the Midwest.
- **Middle-/upper-income in moderate-age single-family units:** Units in this cluster had more moderate estimated repair costs. Married couples, most of which had children present, represented a slight majority of the households in this cluster. More than six in 10 householders were non-Hispanic white. Households in this cluster were more likely to live in the South or West.
- **Middle-/upper-income households in older multifamily units:** Units in this cluster had relatively low estimated repair costs. Households in this cluster were predominantly headed by single adults and were less likely to have children present. These households were the most likely to

[18] Structure type was used as a binary variable in the cluster analysis to differentiate single-family units from other types of structures. We refer to four clusters as multifamily for the sake of brevity, but they also include renter-occupied manufactured homes.

live in metropolitan areas and in the Northeast.

- **Middle-/upper-income households in moderate-age multifamily units:** Units in this cluster had relatively low estimated repair costs. Households in this cluster were predominantly headed by single adults. Householders were slightly younger and less likely to have children present. Over two-fifths of these units were located in the South.

### *Socioeconomic Characteristics*

The typology reveals considerable socioeconomic variation among renter households with repair needs. The income level of households in the low-income clusters was just at or below the federal poverty line, while households in the middle- and upper-income clusters generally earned more than three times the federal poverty level. Broadly speaking, households in the clusters of low-income renters were disproportionately likely to be families headed by single women and to have children, the latter being especially common among households living in single-family units. Hispanic or Latino and black or African American householders were overrepresented in certain low-income clusters, while non-Hispanic white householders accounted for a near or clear majority of renters in the four middle- and upper-income clusters.

### *Unit Characteristics*

A majority of renter-occupied households with repair needs lived in multifamily structures (52.6 percent), likely a reflection of the predominantly renter-occupied multifamily stock; still, a substantial share rented single-family homes (42.4 percent). Although manufactured homes are typically owner-occupied (Housing Assistance Council 2010), this housing type accounted for a significant portion (17.1 percent) of moderate-age units with repair needs occupied by low-income renters. Across all renter households, those with repair needs were relatively evenly split between smaller (two to nine units) and larger (10 or more units) multifamily structures (26.5 and 26.1 percent, respectively).

Aggregate repair costs were notably concentrated among renters in single-family units.[19] This was particularly acute among low-income renters in older units, who had the highest median estimated repair costs ($2,096) and accounted for nearly one-fifth of the aggregate estimated repair costs among renter households, despite constituting only 12.3 percent of households with repair needs. Single-family units account for a large share of the rental housing stock in rural communities (Housing Assistance Council 2010); accordingly, households in the low-income, single-family home clusters were disproportionately likely to reside in nonmetropolitan areas. By contrast, multifamily units with repair needs, particularly those occupied by more affluent households, were more likely to be located within metropolitan areas.

### *Repair Needs*

Appendix B, Table 1 summarizes the share of aggregate repair costs associated with each category of housing problems. The prevalence of many categories of repair needs was similar across clusters, but there were a few notable differences by structure type. Although leaks and mold were generally common across all eight clusters, these issues accounted for nearly half of aggregate repair costs in clusters of multifamily units. Multifamily units had the highest share of costs attributable to heating-related repair needs. In single-family units, structural issues accounted for a large portion of repair expenses, particularly among older units.

From a public health standpoint, the prevalence of leaks, mold, and heating issues in multifamily units is potentially concerning, as these are some of the housing quality issues most directly linked to adverse effects on residents' health. Damp, cold environments are strongly associated with chronic respiratory issues, in part by creating conditions where asthma and allergy triggers such as mold, mites, and cockroaches can thrive (Krieger and Higgins 2002). Economically vulnerable black and Hispanic children are disproportionately exposed to these respiratory health hazards (Raugh, Landrigan, and Claudio 2008), which is consistent with the socioeconomic profiles of the low-income clusters. Cold home environments have also been associated with anxiety, depression, and increased utilization of health services (Krieger and Higgins 2002, Evans, Wells, and Moch 2003). For many low-income households, heating issues intersect with broader housing affordability challenges, as households in units with inadequate insulation or inefficient heating equipment may not be able to afford to sustain a comfortable home temperature (Krieger and Higgins 2002).

## Owner-Occupied Unit Typology

As with the analysis of renter-occupied units, the development of the typology of owner-occupied units was an iterative process. A total of 25 different combinations of clustering variables were examined (see Appendix C for details). The final clustering solution was again based on the combination of three variables: the ratio of household income to the federal poverty level, the decade the unit was built, and the length of tenure (or the number of years the householder has lived in the unit). The first two variables also define the renter household clusters, reinforcing the importance of the intersection of housing quality with both household socioeconomic status and unit age. The third variable, length of tenure, differs from the renter household clusters. Prior research suggests that home repair and improvement activities may vary across the household life cycle (Baker and Kaul 2002, Gyourko and Tracy 2006, JCHS 2019), indicating that this variation in tenure length is likely to be a meaningful variable for understanding repair needs.

[19] As stated previously, our cost estimation methodology may not capture the full extent of repair needs in multifamily buildings, since many AHS questions pertaining to costly structural repairs are not asked of respondents in these units. As a result, the repair costs for single family or manufactured units may not be directly comparable with those of multifamily units.

## TABLE 4. OWNER-OCCUPIED UNIT TYPOLOGY

| | Low-Income | | | | Middle-/Upper-Income | | |
|---|---|---|---|---|---|---|---|
| Median Costs | $1,776* | | | | $1,449 | | |
| Average Costs | $3,842* | | | | $2,905* | | |
| Number of Units (Millions) | 6.6 | | | | 19.5 | | |
| Aggregate Costs (Billions) | $25.3 | | | | $56.6 | | |
| | Moderate-Age Units | | | Older Units | Newer Units | Moderate-Age Units | Older Units |
| | New Owners | Medium-Term Owners | Long-Term Owners | Medium-Term Owners | Medium-Term Owners | Long-Term Owners | Medium-Term Owners |
| Median Costs | $1,449 | $1,680 | $1,844* | $2,004* | $1,449 | $1,467 | $1,449 |
| First Quartile-Third Quartile | $765–$4,426 | $765–$4,793 | $836–$5,719 | $836–$5,719 | $765–$3,435 | $836–$3,650 | $765–$3,810 |
| Average Costs | $3,112 | $3,783* | $4,187* | $3,917* | $2,770* | $3,009 | $2,997 |
| Number of Units (Millions) | 1.3 | 1.1 | 2.6 | 1.6 | 8.2 | 5.9 | 5.4 |
| Share of Units | 5.0% | 4.1% | 9.9% | 6.3% | 31.4% | 22.6% | 20.7% |
| Aggregate Costs (Billions) | $4.0 | $4.1 | $10.7 | $6.4 | $22.7 | $17.7 | $16.1 |
| Share of Agg. Costs | 4.9% | 5.0% | 13.1% | 7.9% | 27.7% | 21.7% | 19.7% |

Sources: Authors' analysis of 2017 AHS PUF and 2018 RSMeans data from Gordian.
Note: Medians and averages are calculated for units with estimated repair costs > $0.
* Denotes statistically signficant difference from all owner-occupied households with repair needs at p <0.10 level. Only calculated for median repair cost and average repair cost.

Rather than parallel categories for low-income households and middle- and upper-income households, the combinations of clustering variables differ in noteworthy ways across income groups (Table 4 and Figure 5 for repair costs and Appendix B, Table 2 for household and unit characteristics). The only cluster representing recent movers was composed of low-income homeowners, which may reflect their greater likelihood of purchasing homes that are older or in relatively poor condition (Herbert and Belsky 2006, Boehm and Schlottmann 2008a). By contrast, the most affluent cluster was of medium-term homeowners in relatively new units, a somewhat unexpected grouping accounting for almost one-third of owner-occupied units with repair needs.[20] Unlike the renter-occupied typology, in the owner-occupied typology the majority of owner-occupied units with repair needs were in the more affluent clusters. However, as with the renter-occupied unit clusters, units in the low-income clusters accounted for an outsized share of aggregate repair costs (25.3 percent of households with repair needs but 30.9 percent of aggregate repair costs).

- **Low-income new homeowners in moderate-age units:** Units in this cluster had moderate estimated repair costs. The typical household in this cluster had lived in its unit for fewer than five years, and close to half had children present. Householders were disproportionately likely to identify as Hispanic or Latino. Nearly one-third of units in this cluster were manufactured housing. Over one-quarter of these units were located in nonmetropolitan areas, and more than half were in the South.
- **Low-income medium-term homeowners in moderate-age units:** Units in this cluster had relatively high estimated repair costs. The majority of householders in this cluster were single adults. Householders were disproportionately likely to identify as Hispanic or Latino or black or African American. Nearly one-third of units in this cluster were manufactured housing. Over one-quarter of these units were located in nonmetropolitan areas, and more than half were in the South.
- **Low-income long-term homeowners in moderate-age units:** Units in this cluster had relatively high estimated repair costs. The households in this cluster tended to be headed by single, older adults, particularly older women. The typical householder had lived in their unit for over three decades. Householders were disproportionately likely to identify as black or African American. Over one-quarter of these units were located in nonmetropolitan areas, and over two-fifths were in the South.
- **Low-income medium-term homeowners in older units:** Units in this cluster had relatively high estimated repair costs. Over two-fifths of households in this cluster had children present. Householders were disproportionately likely to identify as Hispanic or Latino or black or African American. These units

[20] It is worth noting that, in 2017, homeowners with similar characteristics (household incomes ≥ 200 percent of the federal poverty level, unit built 1970 or later, length of tenure < 20 years) accounted for 37.5 percent of owner-occupied units overall. (Authors' calculation based on 2017 American Housing Survey PUF.)

were predominantly located in the South and the Midwest.

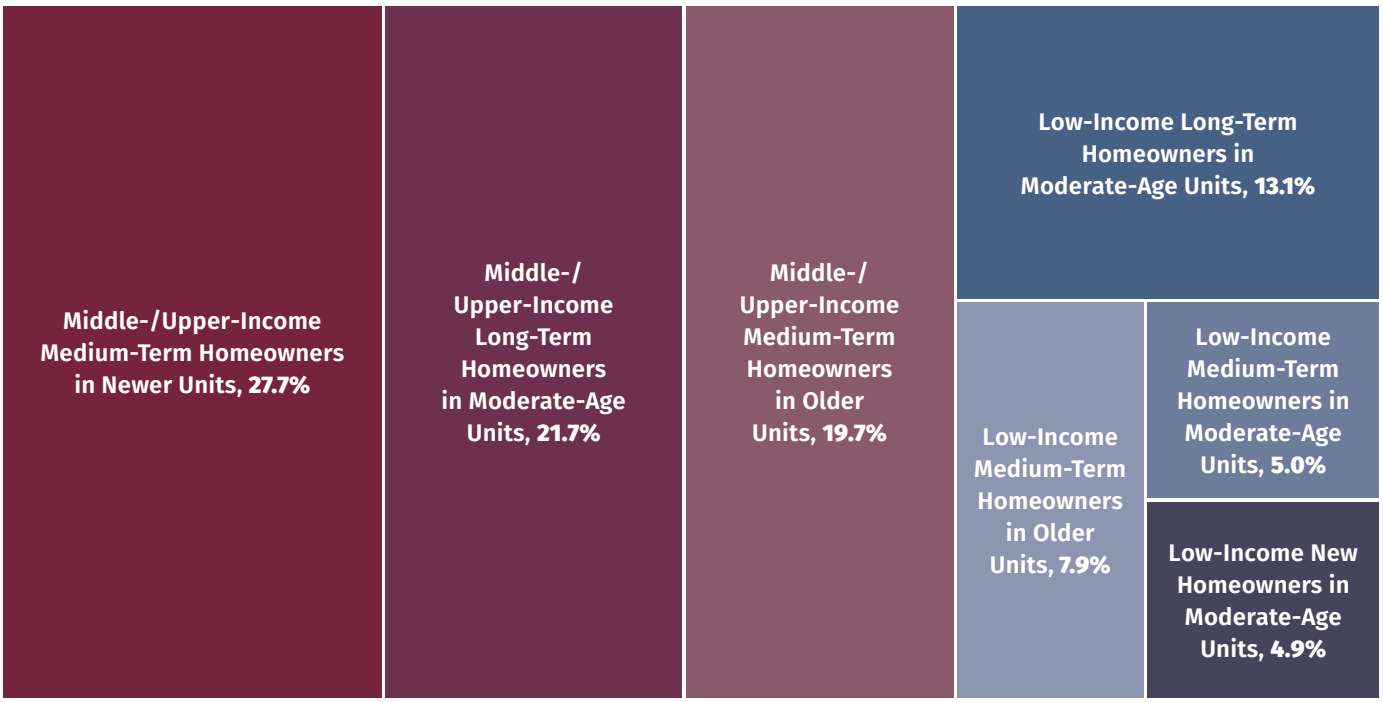
- **Middle-/upper-income medium-term homeowners in newer units:** Units in this cluster had relatively low estimated repair costs, and households in this cluster had the highest incomes. The typical household was headed by a married couple and roughly four in 10 had children present. Close to half of these units were located in the South.
- **Middle-/upper-income long-term homeowners in moderate-age units:** Units in this cluster had more moderate estimated repair costs. Households in this cluster were predominantly headed by older adults in married couples; few had children present. Householders were disproportionately likely to be non-Hispanic white. The typical householder had lived in their unit for almost three decades.
- **Middle-/upper-income medium-term homeowners in older units:** Units in this cluster had more moderate estimated repair costs. The typical householder in this cluster was younger and married, and roughly four in 10 households had children present. The majority of these units were located in the Northeast and Midwest.

### *Socioeconomic Characteristics*

The socioeconomic profiles of owner-occupied units with repair needs confirm that these households were by and large more advantaged than their renter counterparts. Compared with renters with housing repair needs, these households tended to be higher-income, older, and more likely to be headed by a married couple. Nearly three-quarters of homeowners with repair needs and a substantial majority of household heads in each cluster identified as non-Hispanic white, reflecting the considerably higher rate of homeownership among these households compared with black and Hispanic households (JCHS 2018a). Still, it is clear that the low-income clusters identified much more vulnerable subsets of homeowners — their median incomes exceeded the federal poverty level but were still quite low (i.e., all households were below 200 percent of the federal poverty line).

Unsurprisingly, households with longer tenures (30-plus years) in their unit were typically older adults. Low-income, older homeowners had notably acute repair needs, with the highest average repair cost across clusters and the second-highest median repair cost. Even so, the true cost of needed home renovations may be significantly understated for this group, as these homeowners may require additional adaptive modifications in order to create a safe living environment. Senior-headed households that are low-income or headed by a person of color are more likely to include at least one household member with a physical disability (JCHS 2018b, Lipman, Lubell, and Salomon 2012). Furthermore, prior research has found a strong relationship between physical housing deficiencies and unmet modification needs among older homeowners (Newman 2003).

FIGURE 5. OWNER-OCCUPIED CLUSTERS BY SHARE OF AGGREGATE REPAIR COSTS




Sources: Authors' analysis of 2017 AHS PUF and 2018 RSMeans data from Gordian.

### *Unit Characteristics*

The predominant structure type for owner-occupied units with repair needs was a single-family home, reflecting the prevalence of this unit type among owner-occupied units in general. However, roughly one-sixth of low-income homeowners with repair needs lived in manufactured housing, a unit type that accounts for only 6.4 percent of the total owner-occupied stock. Consistent with the profile of these clusters, manufactured housing is predominantly found in rural areas, particularly in the southeastern United States, and is home to a disproportionate share of low-income households (Housing Assistance Council 2010). Contrary to popular perception, the quality of the manufactured housing stock is thought to compare favorably with that of site-built options that are financially attainable to low- and moderate-income households (Boehm 1995, Boehm and Schlottmann 2008b). However, manufactured home owners have historically struggled to access conventional home equity loans (Genz 2001, Goodman and Ganesh 2018), which may make it more difficult to finance needed repairs.

### *Repair Needs*

The distribution of costs in different repair categories was largely consistent across the owner-occupied unit clusters, likely because the vast majority of units were single-family homes (Appendix B, Table 2). Across the board, structural housing problems accounted for the majority of aggregate repair costs, particularly in older units. A slightly smaller share of repair costs in newer units were associated with structural issues, and slightly larger shares were associated with electrical issues and leaks and mold.

The structural problems reported in the AHS range in severity from peeling paint to sagging walls or roofs (Appendix D). Many of these can present significant health risks to vulnerable residents. For example, holes in walls or floors or broken windows can increase residents' risk of physical injury (Krieger and Higgins 2002). Particularly among units built before 1978, peeling paint and holes in floors or walls may increase residents' risk of lead poisoning (Jacobs, et al. 2009). Visible forms of disrepair are also associated with negative effects on the mental health of adults and children (Evans, Saltzman and Cooperman 2001, Evans, Wells, and Moch 2003). Last, physical housing deterioration has also been linked to higher levels of indoor allergens (Rauh, Chew, and Garfinkel 2002), particularly when these issues coincide with leaks from pipes or windows (Krieger and Higgins 2002), which were also present in many owner-occupied units with repair needs.

## CONCLUSIONS

## Implications for Practice

Consistent with prior research on this topic, we find that the prevalence and severity of home repair needs overlap strongly with broader measures of socioeconomic disadvantage (Krieger and Higgins 2002, Holupka and Newman 2011, Jacobs, et al. 2009, Mundra and Sharma 2015, Raugh, Landrigan, and Claudio 2008). Our results point to more acute housing problems among poor households with children and older adults but also highlight the diverse array of households that experience some degree of repair need. For the most vulnerable residents, such as individuals with disabilities, our cost-based index may understate the degree of home improvement needed to provide a decent standard of living (JCHS 2018b, Brennan 2017). However, households with unmet repair needs are a heterogeneous group, suggesting that the factors influencing their housing conditions are likely to vary as well.

Initially, readers may find it surprising that owner-occupied units with repair needs were by and large occupied by relatively affluent households. However, it is common for homeowners of all income levels to defer noncritical repairs, particularly in response to a downward fluctuation in income or competing budgetary priorities (Gyourko and Tracy 2006). In these instances, the snapshot provided by the AHS is likely to overstate the share of households, both owner- and renter-occupied, with persistent repair needs. Indeed, our brief analysis of the dynamics of home repair needs suggests that most issues are addressed in the intervening years between surveys. Still, it is conceivable that some homeowners in the middle- and upper-income clusters may struggle with costly, unanticipated repairs. For homeowners in these circumstances, conventional financial products such as home equity loans can be important tools for smoothing large expenditures.

On the other hand, low-income homeowners may be less capable of addressing critical repair needs without assistance. These households tend to spend less in absolute terms on home maintenance activities and may be even more likely to defer costly repairs, which can lead to more severe housing problems over time (Herbert and Belsky 2006, Gyourko and Tracy 2006). Although our results suggest that the typical low-income homeowner's repair needs are relatively modest, the associated costs may still exceed what many households are able to pay for out of pocket.

Our cluster analysis segmented low-income homeowners into four groups. Recent homebuyers accounted for roughly one-fifth of low-income homeowners with repair needs. Prior research suggests that unanticipated repair costs are a common financial challenge for these households. A survey of 350 first-time, low-income homeowners found that nearly half encountered unexpected maintenance costs and nearly one-third were unable to afford repairs in their first two years of homeownership (Van Zandt and Rohe 2011). Acquaye (2011) identified a desire among low-income, first-time homebuyers for post-purchase counseling that includes training on home maintenance and minor repairs, which may enable households to affordably address common issues on their own before more costly professional help is required. Considering that children

were present in nearly half of the households in this cluster, targeted outreach around mitigating the risks of childhood lead exposure and asthma triggers may be another effective avenue for engaging these homeowners.

The clusters of medium- and long-term low-income homeowners who reported housing quality issues typically had costlier repair needs than homeowners who bought more recently. However, medium- and long-term homeowners are also more likely to have built significant equity in their homes or to have paid off their primary mortgage in full. This may indicate that these households are better positioned to obtain home equity financing for these repairs; however, lower-income households often struggle to access conventional home improvement loans (Carlin and Divringi 2018, JCHS 2018b) and may be unable to afford additional monthly payment obligations. Furthermore, low-income homeowners who own their homes outright may be reluctant to take on new debt, especially if they plan to pass down the property to family members (Rohe, Cowan, and Quercia 2010). In addition to affordable financing, shared equity products that are due when the property is sold and grants may be more viable alternatives for addressing these households' repair needs.

For the low-income households that occupy the majority of rental units with repair needs, the challenge of addressing substandard conditions is often compounded by multiple forms of housing insecurity (Routhier 2019). Although some may undertake minor repairs in exchange for rent reductions or to make undermaintained units more livable (Desmond 2016), tenants are rarely in a position to address the vast majority of housing problems discussed in this report. These households are also unlikely to find many affordable alternatives: In 2016, there were only 35 affordable and available units for every 100 extremely low-income renter households nationwide (National Low Income Housing Coalition 2018).

*"Our results point to more acute housing problems among poor households with children and older adults but also highlight the diverse array of households that experience some degree of repair need."*

Housing policies intended to improve the quality of the rental housing stock have generally emphasized code enforcement and other regulatory strategies targeting property owners (Krieger and Higgins 2002, De Leon and Schilling 2017, Mallach 2015, Newman 2008). However, there is ongoing debate about whether these practices benefit vulnerable renters or inadvertently exacerbate affordability challenges by increasing the cost of market-rate units (Desmond and Bell 2015), and intensive code enforcement in the absence of strong tenant protections may lead to involuntary displacement (Levy, Comey, and Padilla 2006). Furthermore, our cluster analysis indicates that roughly one-quarter of low-income renter households with repair needs were headed by single women with children, who may face a heightened risk of eviction and discrimination in the private rental market (Desmond 2016). Accordingly, regulatory strategies should be carefully designed to avert or mitigate the potential harms of destabilizing vulnerable tenants.

The vast majority of low-income renter households with repair needs lived in relatively small structures with fewer than 10 units, encompassing all households in the single-family homes clusters and more than half of households in the multifamily homes clusters. A significant portion of these units are likely held by so-called mom-and-pop landlords with small property portfolios.[21] These owners may lack the operating margins and property management expertise to invest in regular maintenance and major repairs, pointing to a potential role for technical assistance and financial incentives to assist well-intentioned property owners (Mallach 2015, Garboden and Newman 2012). However, these strategies must carefully consider the risks of creating perverse incentives for landlords who may improve their units only to raise rents — and price out incumbent tenants — once repairs are completed. Alternatively, expanding access to housing vouchers may enable the lowest-income renter households to secure better-quality units or incentivize landlords to upgrade their properties (De Leon and Schilling 2017, Lindberg, et al. 2010).

While corporate investors are a growing part of the small-scale rental market, they have long dominated the large multifamily landscape, owning over 70 percent of units in buildings with

[21] According to the 2015 Rental Housing Finance Survey (RHFS), 76 percent of units in structures with fewer than five units were owned by individual investors.

25 or more units in 2015.[22] Unlike mom-and-pop investors, these property owners have ample access to capital for making improvements (Reher 2018). However, as more sophisticated investors, their maintenance and improvement considerations are likely to be highly sensitive to the local housing market context. Housing markets with low acquisition costs, low expectations for long-term appreciation, and consistent rental demand may attract investors who maximize short-term cash flow in part by underinvesting in maintenance and repairs (Desmond and Wilmers 2019). A "carrot-and-stick" approach combining penalties and incentives may be required to create a context in which these investors are motivated to act responsibly (Mallach 2010). By contrast, in strengthening housing markets, investors typically remodel to offer upscale units to more affluent tenants or to sell to prospective owner-occupants (Reher 2018, JCHS 2019). This further reinforces the importance of addressing rental housing quality and affordability as interrelated challenges.

Ultimately, much of the available evidence indicates that policies intended to improve housing quality have the strongest positive returns for public health and neighborhood conditions when they target the most vulnerable households (Thomson, et al. 2009, Ellen and Voicu 2006, Woo, Joh and Van Zandt 2016, Lindberg, et al. 2010). In fact, the provision of affordable home improvement loans and grants to lower-income homeowners was identified by the Centers for Disease Control and Prevention as one of six evidence-based, high-impact solutions for addressing the social determinants of health (Centers for Disease Control and Prevention 2016). Using our cluster analysis results to focus on the most economically vulnerable segments of households, our cost-based index indicated a need for roughly $25.3 billion in repair expenditures for low-income owner-occupants and $25.5 billion for low-income renters. Policy and programmatic responses that address the needs of these households are likely to have the highest potential impact on household health and well-being.

## Future Research

Although this report is largely dedicated to estimating the costs of unmet housing repair needs, many reviewers of the housing and health literature have called for additional research on the benefits of housing quality improvements (Thomson, et al. 2009, Jacobs, et al. 2010, Lindberg, et al. 2010, Fenwick, Macdonald, and Thomson 2013). Further examination of large-scale, individual-level data on housing conditions and health outcomes could help identify important thresholds for investment and prioritize policy or programmatic interventions (Thomson, et al. 2009). Additionally, data on longer-term outcomes for households' physical and economic well-being could be used to conduct more comprehensive cost-benefit analyses (Fenwick, Macdonald and Thomson 2013).[23]

Finally, several literature reviews have identified the lack of community-level data as an impediment to developing effective responses to housing quality issues (Krieger and Higgins 2002, O'Dell, Smith, and White 2004, Thomson, et al. 2009, De Leon and Schilling 2017). Given that inadequate housing conditions are strongly associated with unit and household characteristics that tend to be highly clustered within regions, persistent substandard conditions are likely to be geographically concentrated (O'Dell, Smith, and White 2004). At the time of this report's writing, the authors and colleagues at the Federal Reserve Bank of Philadelphia and PolicyMap are developing small area estimates based on the repair cost index presented in this report, with the objective of modeling repair needs at subcounty geographies nationwide.

[22] Corporate investors are defined as those organized as limited liability partnerships (LLPs) or corporations (LLCs), real estate investment trusts (REITs), or real estate corporations. Authors' calculations are based on the 2015 RHFS, accessed via the RHFS table creator: www.census.gov/data-tools/demo/rhfs/#/.

[23] See Roys, et al. (2016), a cost-benefit analysis of addressing substandard housing conditions in England, for an example of this approach.

# APPENDIX A METROPOLITAN AREA DESCRIPTIVE STATISTICS

## TABLE A1. REPAIR COSTS ESTIMATES BY TENURE, SELECTED METROPOLITAN STATISTICAL AREAS

| | Aggregate Repair Costs (Billions) | All Occupied Housing Units | | | Owner-Occupied Units | | | Renter-Occupied Units | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | % with Repair Needs | Median | Average | % with Repair Needs | Median | Average | % with Repair Needs | Median | Average |
| Atlanta-Sandy Springs-Roswell | $1.9 | 37.2% | $1,275 | $2,483 | 35.2% | $1,275 | $2,513 | 40.6% | $1,192 | $2,440 |
| Boston-Cambridge-Newton | $1.6 | 31.1% | $1,612 | $2,839 | 31.5% | $1,612 | $3,214 | 30.5% | $1,586 | $2,223 |
| Chicago-Naperville-Elgin | $4.1 | 33.5% | $1,707 | $3,459 | 32.4% | $1,826 | $3,803 | 35.6% | $1,512 | $2,880 |
| Dallas-Fort Worth-Arlington | $2.2 | 32.5% | $1,270 | $2,625 | 32.5% | $1,453 | $3,006 | 32.6% | $1,203 | $2,086 |
| Detroit-Warren-Dearborn | $2.0 | 36.5% | $1,496 | $3,228 | 35.6% | $1,605 | $3,265 | 38.7% | $1,478 | $3,152 |
| Houston-The Woodlands-Sugar Land | $2.1 | 38.8% | $1,125 | $2,313 | 36.0% | $1,394 | $2,638 | 43.2% | $1,096 | $1,881 |
| Los Angeles-Long Beach-Anaheim | $4.3 | 36.3% | $1,558 | $2,670 | 32.6% | $1,583 | $2,830 | 39.8% | $1,517 | $2,549 |
| Miami-Fort Lauderdale-West Palm Beach | $1.6 | 36.2% | $1,053 | $2,078 | 33.9% | $1,145 | $2,343 | 39.4% | $819 | $1,748 |
| New York-Newark-Jersey City | $7.7 | 35.4% | $1,666 | $2,928 | 28.3% | $1,848 | $3,369 | 42.7% | $1,623 | $2,623 |
| Philadelphia-Camden-Wilmington | $2.7 | 38.0% | $1,685 | $3,125 | 36.5% | $1,685 | $3,176 | 41.3% | $1,685 | $3,026 |
| Phoenix-Mesa-Scottsdale | $1.3 | 29.9% | $1,261 | $2,597 | 28.8% | $1,412 | $2,943 | 31.9% | $1,179 | $2,023 |
| Riverside-San Bernardino-Ontario | $1.2 | 27.3% | $1,652 | $3,292 | 24.7% | $1,915 | $3,529 | 31.8% | $1,652 | $2,972 |
| San Francisco-Oakland-Hayward | $2.1 | 34.3% | $1,927 | $3,581 | 30.4% | $1,927 | $3,853 | 39.1% | $1,927 | $3,327 |
| Seattle-Tacoma-Bellevue | $1.5 | 33.6% | $1,521 | $2,948 | 33.3% | $1,521 | $3,087 | 34.2% | $1,423 | $2,756 |
| Washington-Arlington-Alexandria | $1.7 | 37.7% | $1,139 | $2,119 | 35.1% | $1,242 | $2,305 | 42.1% | $1,013 | $1,853 |

Sources: Authors' analysis of 2017 AHS PUF and 2018 RSMeans data from Gordian. Cost estimates adjusted for regional variation using zip code–level location factors from Gordian (2017).
Note: Medians and averages are calculated for units with estimated repair costs > $0.

# APPENDIX B TYPOLOGY DESCRIPTIVE STATISTICS

## TABLE B1. DESCRIPTIVE STATISTICS OF RENTER-OCCUPIED UNIT TYPOLOGY

| | All Renter Households | Renter Households with Repair Needs | Low-Income | | | | Middle-/Upper-Income | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Single-Family | | Multifamily | | Single-Family | | Multifamily | |
| | | | Older Units | Moderate-Age Units | Older Units | Moderate-Age Units | Older Units | Moderate-Age Units | Older Units | Moderate-Age Units |
| **Repair Needs** | | | | | | | | | | |
| Aggregate Repair Costs (Billions) | | $45.0 | $8.9 | $5.0 | $5.2 | $6.3 | $6.6 | $5.1 | $3.3 | $4.5 |
| Average Repair Cost | | $2,587 | $4,162 | $3,447 | $2,202 | $2,094 | $3,248 | $2,884 | $1,749 | $1,670 |
| Share of Aggregate Repair Costs by Type of Housing Problem | | | | | | | | | | |
| Electrical | | 8.4% | 6.8% | 5.9% | 10.0% | 10.9% | 6.0% | 7.3% | 12.0% | 11.1% |
| Heating | | 6.0% | 5.2% | 4.7% | 8.7% | 7.1% | 4.4% | 4.2% | 8.8% | 6.8% |
| Plumbing | | 6.6% | 3.8% | 4.2% | 8.1% | 8.9% | 4.1% | 4.3% | 9.4% | 13.6% |
| Pests | | 4.2% | 3.1% | 3.4% | 7.9% | 6.3% | 1.8% | 1.9% | 6.4% | 4.2% |
| Structural | | 41.9% | 60.8% | 59.2% | 15.7% | 25.6% | 60.2% | 55.0% | 14.5% | 17.2% |
| Leaks and Mold | | 33.0% | 20.4% | 22.6% | 49.6% | 41.2% | 23.6% | 27.2% | 48.8% | 47.0% |
| **Household Characteristics** | | | | | | | | | | |
| Median Household Income | $36,240 | $35,000 | $18,600 | $20,000 | $15,000 | $15,450 | $65,000 | $74,000 | $66,000 | $60,000 |
| Median Ratio of Income to Poverty Level (100s) | 210 | 192 | 99 | 105 | 92 | 92 | 355 | 369 | 384 | 357 |
| Median Age of Householder | 42 | 41 | 43 | 41 | 47 | 40 | 44 | 39 | 39 | 36 |
| Median Length of Tenure | 2 | 2 | 3 | 3 | 3 | 2 | 3 | 2 | 3 | 2 |
| Household Type | | | | | | | | | | |
| Married Couple | 28.2% | 29.3% | 25.3% | 31.2% | 20.4% | 22.0% | 39.2% | 50.7% | 25.0% | 29.5% |
| With Children | 15.1% | 17.7% | 19.2% | 23.9% | 12.2% | 16.5% | 21.8% | 29.8% | 9.9% | 13.8% |
| Single Female Householder | 41.9% | 43.0% | 51.6% | 50.6% | 53.2% | 53.7% | 26.9% | 26.3% | 41.8% | 34.9% |
| With Children | 13.4% | 16.7% | 27.1% | 28.6% | 20.5% | 24.3% | 7.2% | 9.2% | 7.8% | 8.4% |
| Single Male Householder | 29.9% | 27.7% | 23.1% | 18.2% | 26.4% | 24.3% | 34.0% | 23.1% | 33.2% | 35.6% |
| With Children | 3.8% | 4.5% | 6.3% | 6.2% | 3.3% | 4.7% | 4.6% | 5.4% | 1.8% | 4.0% |
| Race/Ethnicity | | | | | | | | | | |
| Hispanic or Latino (Any Race) | 19.9% | 21.4% | 21.8% | 21.8% | 29.1% | 24.9% | 15.6% | 14.6% | 21.3% | 19.1% |
| Asian or Pacific Islander* | 5.9% | 5.0% | 2.1% | 3.1% | 4.3% | 5.1% | 3.0% | 4.4% | 8.2% | 8.3% |
| Black or African American* | 20.2% | 21.1% | 26.1% | 24.8% | 25.3% | 24.0% | 14.2% | 16.6% | 17.6% | 18.9% |
| White* | 51.1% | 48.7% | 46.5% | 43.4% | 36.4% | 40.5% | 65.0% | 61.0% | 50.0% | 52.0% |
| Other/Two or More Races* | 2.9% | 3.8% | 3.5% | 6.8% | 4.9% | 5.5% | 2.3% | 3.4% | 2.9% | 1.7% |

* Non-Hispanic or Latino

*(Continued on page 20)*

# APPENDIX B TYPOLOGY DESCRIPTIVE STATISTICS *(continued)*

## TABLE B1. DESCRIPTIVE STATISTICS OF RENTER-OCCUPIED UNIT TYPOLOGY

| | All Renter Households | Renter Households with Repair Needs | Low-Income | | | | Middle-/Upper-Income | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Single-Family | | Multifamily | | Single-Family | | Multifamily | |
| | | | Older Units | Moderate-Age Units | Older Units | Moderate-Age Units | Older Units | Moderate-Age Units | Older Units | Moderate-Age Units |
| **Unit Characteristics** | | | | | | | | | | |
| Year Built | | | | | | | | | | |
| 1990 or Later | 27.7% | 21.6% | 0.0% | 38.5% | 0.0% | 38.9% | 0.0% | 44.6% | 0.0% | 45.4% |
| 1970–1989 | 29.4% | 29.9% | 0.0% | 61.5% | 0.0% | 61.1% | 0.0% | 55.4% | 0.0% | 54.6% |
| 1950–1969 | 20.2% | 22.3% | 46.4% | 0.0% | 43.5% | 0.0% | 49.2% | 0.0% | 44.6% | 0.0% |
| 1949 or Earlier | 22.7% | 26.3% | 53.6% | 0.0% | 56.5% | 0.0% | 50.8% | 0.0% | 55.4% | 0.0% |
| Structure Type | | | | | | | | | | |
| Manufactured Home | 4.0% | 4.9% | 0.0% | 0.0% | 2.9% | 17.1% | 0.0% | 0.0% | 0.8% | 9.5% |
| Single Family Home | 37.9% | 42.4% | 100.0% | 100.0% | 0.0% | 0.0% | 100.0% | 100.0% | 0.0% | 0.0% |
| 2–9 Units | 28.4% | 26.5% | 0.0% | 0.0% | 52.4% | 42.9% | 0.0% | 0.0% | 52.7% | 39.2% |
| 10 or More Units | 29.7% | 26.1% | 0.0% | 0.0% | 44.7% | 40.0% | 0.0% | 0.0% | 46.5% | 51.3% |
| **Geographic Characteristics** | | | | | | | | | | |
| In Metropolitan Area | 87.9% | 87.2% | 81.2% | 78.6% | 89.6% | 85.8% | 83.7% | 87.2% | 95.5% | 92.7% |
| Census Regions | | | | | | | | | | |
| Northeast | 19.0% | 18.6% | 15.7% | 8.3% | 37.5% | 10.3% | 15.6% | 6.4% | 43.0% | 12.3% |
| Midwest | 19.5% | 18.6% | 24.4% | 15.0% | 19.8% | 16.8% | 26.5% | 15.5% | 15.7% | 14.8% |
| South | 36.5% | 37.9% | 42.8% | 52.5% | 23.5% | 46.7% | 30.0% | 45.0% | 17.1% | 45.0% |
| West | 25.0% | 24.9% | 17.2% | 24.2% | 19.1% | 26.1% | 27.9% | 33.0% | 24.1% | 27.9% |

Sources: Authors' analysis of 2017 AHS PUF and 2018 RSMeans data from Gordian.

## TABLE B2. DESCRIPTIVE STATISTICS OF OWNER-OCCUPIED UNIT TYPOLOGY

| | All Owner Households | Owner Households with Repair Needs | Low-Income | | | | Middle-/Upper-Income | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Moderate-Age Units | | | Older Units | Newer Units | Moderate-Age Units | Older Units |
| | | | New Owners | Medium-Term Owners | Long-Term Owners | Medium-Term Owners | Medium-Term Owners | Long-Term Owners | Medium-Term Owners |
| **Repair Needs** | | | | | | | | | |
| Aggregate Repair Costs (Billions) | | $81.8 | $4.0 | $4.1 | $10.7 | $6.4 | $22.7 | $17.7 | $16.1 |
| Average Repair Cost | | $3,142 | $3,112 | $3,783 | $4,187 | $3,917 | $2,770 | $3,009 | $2,997 |
| Share of Aggregate Repair Costs by Type of Housing Problem | | | | | | | | | |
| Electrical | | 6.2% | 9.7% | 7.9% | 6.6% | 4.0% | 7.3% | 5.3% | 4.9% |
| Heating | | 3.3% | 4.4% | 3.8% | 3.9% | 3.9% | 3.2% | 2.8% | 2.9% |
| Plumbing | | 3.7% | 6.0% | 4.3% | 3.9% | 2.3% | 3.9% | 3.6% | 2.9% |
| Pests | | 1.2% | 1.9% | 1.4% | 1.5% | 1.5% | 0.9% | 1.0% | 1.2% |
| Structural | | 65.0% | 56.8% | 59.4% | 66.1% | 71.3% | 61.6% | 66.6% | 68.3% |
| Leaks and Mold | | 20.7% | 21.3% | 23.1% | 18.0% | 16.9% | 22.9% | 20.7% | 19.9% |
| **Household Characteristics** | | | | | | | | | |
| Median Household Income | $70,000 | $65,000 | $20,040 | $18,000 | $17,100 | $20,400 | $95,010 | $72,000 | $88,000 |
| Median Ratio of Income to Poverty Level (100s) | 389 | 358 | 114 | 110 | 119 | 119 | 480 | 434 | 459 |
| Median Age of Householder | 56 | 55 | 50 | 57 | 68 | 52 | 49 | 64 | 47 |
| Median Length of Tenure | 13 | 13 | 4 | 15 | 32 | 7 | 8 | 29 | 7 |
| Household Type | | | | | | | | | |
| Married Couple | 60.2% | 56.4% | 45.0% | 42.0% | 32.1% | 38.5% | 68.1% | 59.7% | 57.6% |
| With Children | 22.8% | 23.4% | 27.9% | 19.6% | 6.7% | 22.1% | 34.7% | 7.3% | 31.7% |
| Single Female Householder | 23.5% | 26.2% | 35.2% | 39.7% | 44.5% | 39.9% | 17.8% | 25.5% | 22.1% |
| With Children | 4.4% | 5.5% | 12.7% | 9.9% | 5.4% | 14.7% | 4.5% | 1.8% | 5.6% |
| Single Male Householder | 16.4% | 17.4% | 19.8% | 18.2% | 23.4% | 21.6% | 14.1% | 14.8% | 20.3% |
| With Children | 2.1% | 2.5% | 4.8% | 2.9% | 1.6% | 6.3% | 2.3% | 1.0% | 2.9% |
| Race/Ethnicity | | | | | | | | | |
| Hispanic or Latino (Any Race) | 10.0% | 11.0% | 19.9% | 20.9% | 10.4% | 19.5% | 10.2% | 6.9% | 10.2% |
| Asian or Pacific Islander* | 4.6% | 4.0% | 4.9% | 3.2% | 2.2% | 2.6% | 5.7% | 3.4% | 3.4% |
| Black or African American* | 8.9% | 9.9% | 8.9% | 13.3% | 19.5% | 13.8% | 7.7% | 9.1% | 7.9% |
| White* | 74.9% | 72.9% | 61.6% | 59.7% | 64.9% | 62.2% | 74.1% | 78.8% | 77.3% |
| Other/Two or More Races* | 1.7% | 2.2% | 4.7% | 3.0% | 3.1% | 1.9% | 2.3% | 1.9% | 1.2% |

* Non-Hispanic or Latino

*(Continued on page 22)*

## TABLE B2. DESCRIPTIVE STATISTICS OF OWNER-OCCUPIED UNIT TYPOLOGY

| | All Owner Households | Owner Households with Repair Needs | Low-Income | | | | Middle-/Upper-Income | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Moderate-Age Units | | | Older Units | Newer Units | Moderate-Age Units | Older Units |
| | | | New Owners | Medium-Term Owners | Long-Term Owners | Medium-Term Owners | Medium-Term Owners | Long-Term Owners | Medium-Term Owners |
| **Unit Characteristics** | | | | | | | | | |
| Year Built | | | | | | | | | |
| 1990 or Later | 34.6% | 27.7% | 52.3% | 52.7% | 10.3% | 0.0% | 60.7% | 12.4% | 0.0% |
| 1970–1989 | 28.0% | 27.7% | 47.7% | 47.3% | 31.5% | 0.0% | 39.3% | 35.1% | 0.0% |
| 1950–1969 | 21.4% | 23.5% | 0.0% | 0.0% | 29.4% | 51.6% | 0.0% | 27.3% | 54.1% |
| 1949 or Earlier | 16.0% | 21.1% | 0.0% | 0.0% | 28.8% | 48.4% | 0.0% | 25.2% | 45.9% |
| Structure Type | | | | | | | | | |
| Manufactured Home | 6.4% | 8.4% | 30.2% | 31.9% | 10.5% | 6.1% | 9.4% | 4.8% | 0.7% |
| Single Family Home | 89.2% | 88.0% | 65.0% | 64.8% | 87.3% | 90.4% | 86.4% | 92.4% | 95.3% |
| 2–9 Units | 2.1% | 1.7% | 0.8% | 1.3% | 1.2% | 1.9% | 2.0% | 1.5% | 1.8% |
| 10 or More Units | 2.3% | 1.9% | 4.0% | 2.0% | 1.0% | 1.6% | 2.2% | 1.3% | 2.2% |
| **Geographic Characteristics** | | | | | | | | | |
| In Metropolitan Area | 82.8% | 81.5% | 71.1% | 72.0% | 73.9% | 76.6% | 85.1% | 82.7% | 84.1% |
| Census Regions | | | | | | | | | |
| Northeast | 17.4% | 17.3% | 7.5% | 8.6% | 16.9% | 18.7% | 10.3% | 21.8% | 26.6% |
| Midwest | 23.9% | 23.8% | 17.0% | 14.2% | 22.5% | 32.2% | 19.1% | 25.8% | 30.2% |
| South | 37.9% | 38.3% | 52.0% | 56.7% | 44.3% | 33.6% | 45.5% | 33.3% | 24.7% |
| West | 20.9% | 20.6% | 23.5% | 20.4% | 16.3% | 15.6% | 25.1% | 19.1% | 18.4% |

Sources: Authors' analysis of 2017 AHS PUF and 2018 RSMeans data from Gordian.

# APPENDIX C DETAILED CLUSTER METHODOLOGY

## Cluster Analysis Methodology

The literature on clustering methodology is not prescriptive; rather, because it is an exploratory technique, analytical choices are driven by the user's objectives and pragmatic considerations (Everitt, et al. 2011, Punj and Stewart 1983). The cluster analyses presented in this report employed a hierarchical agglomerative clustering algorithm to group households with repair needs into typologies of owner- and renter-occupied units. The objective of these analyses was to develop practically useful, data-based classifications of households with repair needs, rather than identifying underlying structures or relationships within the data. We developed separate clusters for owner- and renter-occupied units to allow for the development of targeted policies and programmatic interventions to address housing repair needs, as the responses to disrepair among vulnerable homeowners and renters are likely to differ considerably.

In the first step of the hierarchical clustering algorithm, each observation is considered to be in a single-member cluster. In a series of successive steps, the most similar pairing of clusters is merged, and the distances between the resulting merged cluster and all other clusters in the analysis are recalculated. This process continues until all observations are combined into a single cluster. Hierarchical methods do not impose a predefined number of clusters; rather, they allow the user to identify a meaningful level of agglomeration based on quantitative and practical criteria.

### *Cluster Variable Selection*

The first step in the analysis was to develop a list of candidate clustering variables. The identification and selection of clustering variables were driven by a review of the existing literature on housing quality and an exploratory analysis examining the association of unit and household characteristics with the cost-based index for units with repair needs. Table C1 summarizes the variables considered in this stage of the analysis. Characteristics were only included in this list if the association with the cost-based index was statistically significant (based on Pearson's correlation coefficients).

Several of the variables listed in Table C1 were removed from consideration for the cluster analysis for practical reasons. The binary overcrowding variable was excluded because only a small share of units fell into this category (<6 percent), and it was therefore unlikely to be useful for defining broad typologies. The variable for total monthly housing costs was also excluded, in part because these costs are expected to vary widely across housing markets and are less meaningful for national comparison. Furthermore, this variable was highly collinear

**TABLE C1. VARIABLES CONSIDERED FOR INCLUSION IN THE CLUSTER ANALYSES**

| Variable | Rationale |
|---|---|
| **Unit Characteristics** | |
| Single-family home (renter-occupied units only) | Physical inadequacy in single-family homes may be more widespread than commonly thought (Emrath and Taylor 2012, Kutty 1999). Many distressed single-family properties have been converted to rental occupancy in recent years (JCHS 2013). |
| Year built | Older units are more likely to be classified as inadequate (Kutty 1999, Emrath and Taylor 2012). |
| Unit size (owner-occupied units only) | Larger units may be more costly to maintain (Kutty 1999). |
| Number of bedrooms (renter-occupied units only) | Larger units may be more costly to maintain (Kutty 1999). |
| Metropolitan status | Rural and/or nonmetropolitan areas appear to have higher rates of housing disrepair (Emrath and Taylor 2012, Housing Assistance Council 2010, Holupka and Newman 2011). |
| Total monthly housing costs | Lower-quality housing is associated with lower rents and home values (Holupka and Newman 2011, Emrath and Taylor 2012). |
| **Household Characteristics** | |
| Poverty status | Low-income households are more likely to be exposed to substandard housing conditions (Holupka and Newman 2011, Herbert and Belsky 2006, Krieger and Higgins 2002, Boehm and Schlottmann 2008a). |
| Single female–headed household | Single-parent households (which are disproportionately headed by women) are among the most housing-disadvantaged household types (Holupka and Newman 2011). |
| Children present (renter-occupied units only) | Children are thought to be particularly vulnerable to substandard housing conditions (Evans, Saltzman and Cooperman 2001, Krieger and Higgins 2002, Raugh, Landrigan and Claudio 2008, Holupka and Newman 2011). |
| Length of tenure in unit | Longer tenures are associated with worse housing conditions for lower-income households (Shuey, Leventhal and Coley 2016, Mundra and Sharma 2015); investments in home improvement may vary throughout the household life cycle (Baker and Kaul 2002, Gyourko and Tracy 2006, JCHS 2019). |
| Overcrowding | Overcrowding is associated with broader housing disadvantage and insecurity (Holupka and Newman 2011, Routhier 2019, Koebel 1997). |

with the poverty variable, which is included in each iteration of the cluster analysis for both owners and renters (see the Cluster Analysis section).

### *Data Preparation*

Data preparation was an iterative process, with adjustments based on the interpretability of cluster solutions. Continuous variables, as well as ordinal variables that had many potential values, were initially too noisy for the analysis, yielding clusters that were undifferentiated or of little practical value. To improve the quality of cluster solutions, these variables were binned into ordinal variables with no more than four levels. Categories were determined based on practical cutoffs (e.g., poverty levels) or to create comparably sized groups:

- Length of tenure: (1) less than 10 years; (2) 10–19 years; (3) 20+ years
- Ratio of income to the federal poverty level: (1) less than 100 percent; (2) 100–199 percent, (3) 200+ percent
- Age of unit by decade built: (1) 1990s and later; (2) 1970s and 1980s; (3) 1950s and 1960s; (4) 1940s and earlier
- Number of bedrooms: (1) 0–2; (2) 3; (3) 4+
- Unit size: (1) up to 1,499 square feet; (2) 1,500–1,999 square feet; (3) 2,000–2,499 square feet; (4) 2,500+ square feet

In any cluster analysis where the input variables have different ranges or are a mix of variable types,[24] clustering variables must be standardized to avoid biasing the cluster results. Additionally, for many hierarchical methods, standardized variables must be converted to a symmetrical dissimilarity matrix, where the distance between each possible pairing of observations is computed for the entire data set (Gordon 1987). Guidance on cluster analysis suggests that the method of calculating the dissimilarity index has minimal impacts on the resulting cluster solutions (Punj and Stewart 1983), although Gower's dissimilarity measure, used here, is recommended for models with mixed variable types (Everitt, et al. 2011). Using PROC DISTANCE in the SAS software,[25] a symmetric dissimilarity matrix was produced for each potential combination of standardized clustering variables. These output matrices were then used as the inputs for the clustering algorithm.

### *Cluster Analysis*

Both typologies presented in this report were developed by systematically testing and evaluating the outputs of multiple permutations of potential clustering variables using PROC CLUSTER in the SAS software. This procedure enables the user to specify the hierarchical clustering method, which determines how the distances between clusters are computed. The average linkage method was selected for this analysis because linkage methods appear to be best suited for dissimilarity matrix data (Gordon 1987, Everitt, et al. 2011), and this method provides additional statistics for evaluating cluster solutions that are not available in other options in PROC CLUSTER.

The ratio of household income to the federal poverty level was included in each iteration of cluster variables examined, owing to the high practical significance of this variable and its clear theoretical relationship with a household's likelihood of experiencing poor housing conditions (Holupka and Newman 2011, Routhier 2019, Herbert and Belsky 2006). With consistent inclusion of the poverty ratio variable, each potential combination of three to five clustering variables was examined for each tenure data set, although clustering variables with substantial collinearity were not considered simultaneously.[26] A total of 25 clustering variable combinations for owner-occupied units and 32 combinations for renter-occupied units were examined.

### *Cluster Evaluation*

For each potential combination of clustering variables, the agglomeration schedule output by PROC CLUSTER was used to determine the number of clusters in a potential solution. Focusing on solutions that contained four to 12 clusters, we looked for local peaks in the Pseudo F statistic, per guidance from methodological references (Everitt, et al. 2011). To narrow the large pool of potential cluster solutions, a short table of descriptive statistics was used to assess interpretability. The set of solutions that provided well-differentiated clusters was further narrowed based on the utility of the classifications for understanding repair needs.

Visualizations of cluster results called "dendrograms" were also examined to assess whether the selected solution provided the greatest explanatory power with the fewest possible clusters. Dendrograms illustrate the agglomeration sequence produced by the clustering algorithm. A given cluster solution can be visualized by drawing a vertical line through the diagram, with the number of intersections reflecting the resulting number of clusters. The x-axis reflects the change in R-squared, representing the share of overall variation explained at the corresponding level of agglomeration. Since the motivation for this cluster analysis

[24] Although continuous variables were converted to ordinal categorical variables, these are still treated as different from binary categorical variables in distance calculations.

[25] SAS software version 9.4 for Windows.

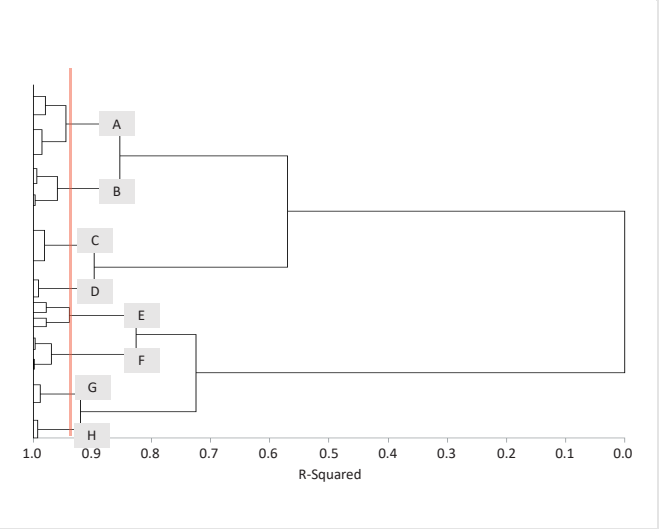
[26] These variable pairings were (1) the number of bedrooms and child present, and (2) the number of bedrooms and single-family home.

is classification, the R-squared statistic provides a reasonable indicator of cluster quality (SAS Institute Inc. 2008). As one would expect, moving from right to left — from fewer to more clusters — increases the percent of variation explained by the cluster solution. As identified and defined in Figure C1, an eight-cluster solution with an R-squared value of 0.94 was selected for the renter household typology. The selected cluster solution (Figure C2) for owner-occupied households yields seven clusters, with an R-squared value of 0.86.

To confirm that the resulting typologies reflected meaningful variation in repair needs, an analysis of variance (ANOVA) was performed for both sets of clusters with the natural logarithm of the cost-based index as the target variable. For both sets of clusters, the result was highly significant ($p < 0.001$), suggesting that the cluster repair cost means were not equivalent across groups. To further assess the differentiation in repair costs between clusters, pairwise Tukey-Kramer tests were used to compare the log-transformed index means for each potential pairing of clusters within each set. Results indicated that 9 of the 21 possible homeowner cluster pairings and 19 out of the 28 possible renter cluster pairings had significantly different log mean repair costs ($p < 0.01$).[27] Although this implies that the magnitude of repair needs is similar across certain clusters, these clusters were still differentiated by other socioeconomic and unit characteristics.

[27] ANOVA and Tukey-Kramer tests were conducted on unweighted observations. Full results are available upon request.

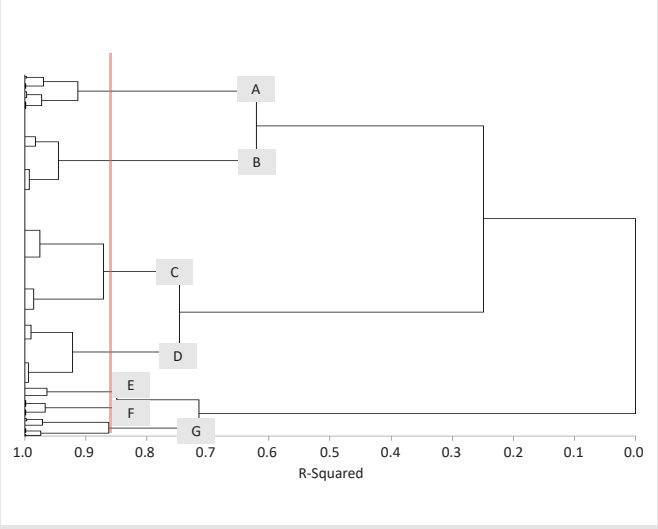
## FIGURE C1: RENTER-OCCUPIED TYPOLOGY DENDROGRAM




Cluster key: (A) Low-income renters in moderate-age multifamily units; (B) low-income renters in older multifamily units; (C) middle-/upper-income renters in moderate-age multifamily units; (D) middle-/upper-income renters in older multifamily units; (E) low-income renters in moderate-age single-family units; (F) low-income renters in older single-family units; (G) middle-/upper-income renters in moderate-age single-family units; (H) middle-/upper-income renters in older single-family units.

Sources: Authors' analysis of 2017 AHS PUF and 2018 RSMeans data from Gordian.

## FIGURE C2: OWNER-OCCUPIED TYPOLOGY DENDROGRAM




Cluster key: (A) Low-income medium-term homeowners in older units; (B) middle-/upper-income medium-term homeowners in older units; (C) middle-/upper-income medium-term homeowners in newer units; (D) middle-/upper-income long-term homeowners in moderate-age units; (E) low-income new homeowners in moderate-age units; (F) low-income medium-term homeowners in moderate-age units; (G) low-income long-term homeowners in moderate-age units.

Sources: Authors' analysis of 2017 AHS PUF and 2018 RSMeans data from Gordian.

# APPENDIX D REPAIR CATEGORIES

For a full list of housing problem scenarios and corresponding repairs, see the Technical Appendix to this report, available at www.philadelphiafed.org/-/media/community-development/publications/special-reports/home-repair-costs-technical-appendix.pdf.

| Category | Housing Problem |
|---|---|
| **Electrical Problems** | • No electrical wiring<br>• Wiring not concealed by walls<br>• Number of times fuses blown or circuit breakers tripped in last three months<br>• Not every room has working electrical outlet |
| **Heating Problems** | • Unit uncomfortably cold for 24 hours or more last winter for one of the following reasons:<br>  ° Main heating equipment broke down<br>  ° Inadequate heating capacity<br>  ° Inadequate insulation<br>• No heating equipment* |
| **Leaks and Mold** | • Outside water leak from roof in last 12 months<br>• Outside water leak from basement in last 12 months<br>• Outside water leak from walls or around closed windows or closed doors in last 12 months<br>• Outside water leak from other or unknown source in last 12 months<br>• Inside water leak from own plumbing fixtures backing up or overflowing in last 12 months<br>• Inside water leak from pipes leaking in last 12 months<br>• Inside water leak from broken water heater in last 12 months<br>• Inside water leak from other or unknown source in last 12 months<br>• Mold present in kitchen in last 12 months<br>• Mold present in bathroom in last 12 months<br>• Mold present in bedroom in last 12 months<br>• Mold present in living room in last 12 months<br>• Mold present in basement in last 12 months<br>• Mold present elsewhere in last 12 months |
| **Pests** | • Number of times there were signs of rodents in last 12 months<br>• Number of times there were signs of live or dead cockroaches in last 12 months |
| **Plumbing Problems** | • Number of toilet breakdowns lasting six hours or more in last three months<br>• Number of times unit was completely without running water in last three months<br>• Number of sewer breakdowns lasting six hours or more in last three months (for units with septic tanks or cesspools)<br>• No hot and cold running water* |
| **Structural Problems** | • Foundation has holes, cracks, or crumbling†<br>• Roof has holes†<br>• Roof has missing shingles or other roofing materials†<br>• Roof surface sags or is uneven†<br>• Outside walls missing siding, bricks, or other wall materials†<br>• Outside walls slope, lean, buckle, or slant†<br>• Windows boarded up or broken†<br>• Floor has holes large enough to catch foot on<br>• Inside walls or ceiling have open holes or cracks<br>• Peeling paint larger than 8 inches by 11 inches |

Source: American Housing Survey Online Codebook (accessed February 20, 2019).
*Derived from variables outside the Housing Problems module
†Denotes questions that are not asked of respondents in multifamily units

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