



Technical Appendix: A Repair Cost–Based Index of Housing Quality

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INTRODUCTION

Building on recent efforts to quantify housing quality issues, researchers and data analysts at the Federal Reserve Bank of Philadelphia and PolicyMap have developed a cost-based index of repair needs that combines detailed data on housing conditions from the American Housing Survey (AHS) with estimates of the costs of needed repairs. This technical appendix provides an in-depth overview of the development of this index, detailing the motivation for our approach, the methodology for creating the index, and basic summary statistics. This document is intended for researchers and practitioners seeking to understand or adapt the index and as a reference for point-in-time estimates of repair needs summarized by unit and household characteristics.

BACKGROUND

Housing Quality and Repair Needs

Despite the widespread finding that severe housing problems are on the decline in the U.S. during the past half century, adequate-quality housing is still inequitably distributed across socioeconomic lines (Kutty, 1999; Holupka and Newman, 2011; Mundra and Sharma, 2015; Boehm and Schlottmann, 2008; Jacobs, Wilson, Dixon, Smith, and Evens, 2009). The AHS, administered jointly by the U.S. Department of Housing and Urban Development (HUD) and the U.S. Census Bureau, provides researchers with a powerful tool to track both housing quality trends and socioeconomic disparities in access to quality housing. Since 1985, the AHS has published a composite measure of housing quality referred to by the variable name ZADEQ, which has recently been renamed ADEQUACY.¹ This composite measure classifies housing units as adequate, inadequate, or severely inadequate. Housing units can be flagged as inadequate for having one or more severe problems in the unit's plumbing, electrical, or heating systems, or by having a number of more moderate problems such as water leaks, holes in the floor, or rats.² This measure of housing adequacy is widely cited and included in HUD's biennial *Worst Case Housing Needs* report to Congress (Watson, Steffen, Martin, and Vandenbroucke, 2017). However, recent research suggests that this measure understates the extent of quality issues in the U.S. housing stock (Emrath and Taylor, 2012; Eggers and Moumen, 2013b), given how serious problems must be in order to trigger a classification of inadequate, and some have questioned whether its criteria meaningfully reflect an underlying housing quality construct (Newman and Garboden, 2013; Eggers and Moumen, 2013a).

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¹ Email correspondence with HUD staff confirm that both variable names pertain to the same measure. For details, see the AHS online codebook, available at www.census.gov/data-tools/demo/codebook/ahs/ahsdict.html.

² The specific criteria for determining whether a unit is inadequate or severely inadequate have changed slightly over time. See Appendix E, page 73 of Watson, Steffen, Martin, and Vandenbroucke (2017) for the full, current definition.

Considering these limitations, there have been several recent attempts to create more nuanced and conceptually grounded measures of housing quality. Three recent papers have informed our approach to the cost-based index. Emrath and Taylor (2012) applied a hedonic model to AHS data to create a measure of housing inadequacy based on the degree to which reported problems reduced expected home values and rents. Their approach to identifying deficient units indicated that housing inadequacy was likely more common than the HUD measure suggested, particularly among single-family homes and units where children are present. Eggers and Moumen (2013b) proposed the Poor Quality Index (PQI), which assigned weights based on subjective criteria to unit-level housing problems reported in the AHS. Their results revealed a heavily right-skewed distribution in which the majority of units reported no housing deficiencies, a significant portion was assigned low PQI values, and a small segment was found to have high PQI values indicative of severe disrepair. Last, Newman and Holupka (2017) developed and tested several potential quality indices, finding a strong correlation between Eggers and Moumen’s PQI and more empirically derived weighting schemes.

A separate but highly relevant effort to estimate the costs of addressing substandard housing conditions was undertaken by Listokin and Listokin (2001). To arrive at their estimates, they categorized each housing unit included in the AHS based on the intensity of its rehab needs — none, minor, moderate, or substantial. They then applied flat repair cost estimates provided by housing industry experts to units in each category, aggregating to estimate regional and national summary figures.

The cost-based index outlined in this document adapts Listokin and Listokin’s practical emphasis on estimating repair costs with the recent efforts to develop more meaningful summary measures of housing disrepair. The resulting index provides an intuitive and policy-relevant indicator of repair needs.

Research Advisory Committee³

In June 2017, the Federal Reserve Bank of Philadelphia and PolicyMap convened a group of housing and community development practitioners and researchers to advise the direction of this work. The group discussed several potential strategies for developing a summary measure of housing quality that would enhance the value of the information available in the AHS. The group indicated that in order to address housing quality problems, a better understanding of both the kinds of households most likely to experience housing problems and a clearer idea of the magnitude of those problems were necessary. Further, advisory committee members were interested in understanding the level of investment, in dollars, that might be required to bring the nation’s deficient housing up to an acceptable standard. There was general agreement that a cost-based index could meet both needs.

DATA SOURCES

To develop our cost-based indicator, we combined two data sources: (1) the AHS National Public Use File (PUF), which provides detailed information on housing problems experienced by respondents, and (2) a custom RSMMeans data set from Gordian that estimates the costs of repairs for each type of housing problem reported in the AHS PUF.

American Housing Survey

The AHS has been an invaluable source of information on the housing stock in the United States since its inception in 1973. In its current form, it is conducted every other year through personal interviews either of the householder, or in the case of vacant units, a landlord or other person with detailed knowledge of the property. Results from the AHS are published in an online tool that allows users to create summary statistics and in the National and Metropolitan PUFs, which contain anonymized respondent microdata that can be used to produce custom tabulations. The AHS is designed as a longitudinal survey, enabling researchers to follow the same units over time. A new AHS sample was drawn in 2015 and was accompanied by updates to the survey questionnaire and microdata codebook.⁴

The AHS includes information on a range of housing-related topics, including housing characteristics, housing costs,

³ Members of this advisory committee are acknowledged at the end of this document.

⁴ For additional details, see *Getting Started with the PUF: 2015 and Beyond*, available at www.census.gov/programs-surveys/ahs/tech-documentation/help-guides/puf_start.html.

home improvements, demographics of householders, reasons for recent moves, and housing problems. It is currently the only publicly available, nationally representative source of data with highly detailed information on these characteristics of housing units. Although the Comprehensive Housing Affordability Strategy (CHAS) data, special tabulations of the American Community Survey prepared for HUD, provide information on housing problems at a higher degree of geographic specificity, this data set only includes information on two “housing problems” — lacking a complete kitchen, or lacking complete plumbing. These are insufficient criteria for identifying many housing deficiencies that have tangible impacts on residents’ health and well-being.

The cost-based index outlined in this document was developed based on the 2015 AHS and applied to the subsequently released 2017 AHS PUF,⁵ for which the microdata codebook is identical for the variables included in the index. For the purposes of this analysis, we considered only occupied housing units where an interview was conducted. Out of 66,752 housing units surveyed, 57,984 were occupied housing units⁶ where an interview was conducted (INTSTATUS = 1), 1,054 were interviewed but have their usual residence elsewhere, and 7,714 were vacant housing units.

Custom RSMeans Database from Gordian

The research team worked with Gordian, a company that provides residential and facilities maintenance, construction, and repair cost data for real estate professionals, to assign specific repairs to each housing problem identified in the AHS and to estimate the costs of reasonable repairs using its RSMeans database.⁷ The majority of these estimates were based on the RSMeans 2018 Contractor’s Pricing Guide database of Residential Repair & Remodeling Costs. A subset of repairs was not available in the Contractor’s Pricing Guide data. These largely pertained to major structural and plumbing repairs and were omitted either because the scale or type of repair required the use of a contractor accustomed to working on larger commercial projects, or because RSMeans could not produce reliable estimates for smaller contractors. For these, RSMeans substituted estimates from the 2018 Facilities Maintenance & Repair Cost database. Estimates based on the Facilities Maintenance & Repair Cost database assume the use of open shop labor, which is associated with lower hourly wages than union labor but still higher than the wage rates used in the Contractor’s Pricing Guide estimates. Both sources of estimates reflect national average costs inclusive of materials, labor, contractor overhead, and contractor profit. For estimates at the metropolitan statistical area (MSA) level, dollar values are adjusted using regional multipliers derived from the RSMeans database (see the Development of National, Regional, and Metropolitan Estimates section for details).

Estimates presented below are expressed in 2018 dollars but predicated on home repair needs reported in the 2017 AHS. Both represent the most current data available at the time of the analysis. Rather than deflating repair costs to 2017, we have chosen to 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.

METHODOLOGY

The following sections provide a detailed description of the process of developing and validating the repair cost index. Initially, the team worked with experts from Gordian to develop a custom data set matching specific repair needs identified in the AHS with the estimated costs of a typical repair. Once costs for specific repairs were established, the research team used the AHS PUF to estimate the cost of repairs for each occupied housing unit in the survey. In most cases, this involved simple crosswalking to map one or more variables to the established repair cost estimate, sometimes scaled to the size of the unit or to an estimate of the area in need of repair. In some housing units, however, one repair might obviate the need for another repair. In these instances, a hierarchy of repairs was established to avoid redundancies. Finally, using survey weights provided in the AHS, unit-level repair estimates were aggregated to produce national-, regional-, and MSA-level estimates of repair costs according to various household and housing unit characteristics.

⁵ Version 3.0 was used in this analysis. For more information, see www2.census.gov/programs-surveys/ahs/2017/AHS%202017%20National%20PUF%20Version%20Control.pdf#.

⁶ Of these, 35 records were dropped from the analysis because the reported unit type was “Boat, RV, van, etc.”

⁷ For more information on the RSMeans database, see www.rsmeans.com/.

Identifying Housing Deficiencies in the AHS

The first step in defining unit-level repair needs entailed reviewing the technical documentation for the AHS to identify variables associated with physical deficiencies in the unit. Variables were primarily drawn from the “Housing Problems” module. Of the 48 variables in this module, 40 variables were determined to be suitable for this analysis; the other eight were excluded because they represented a more generalized version of related variables or were not clearly related to structural deficiencies. Although not listed under the “Housing Problems” module, the variables HEATTYPE and HOTWATER were added to this list, since they captured responses that have historically been considered housing quality issues (e.g., a lack of heating equipment).

To further specify the types of repairs that would be needed in each surveyed housing unit, we reviewed additional AHS variables and identified several that provided useful context for determining the appropriate repair. For example, if a unit needed a heating equipment repair, the type of heating system in that unit would have a major influence on the cost of the repair. The cost of repairing cracks, holes, or leaks in the foundation depend on the kind of foundation as well. Repairing the wall of a full basement is more expensive than repairing a concrete slab. Similarly, problems with plumbing require different corrective measures depending on whether the unit is on sewer or septic and whether it has municipal or well water. Housing units served by a public water supply that have frequent breakdowns in water service may need to have a water main replaced. In contrast, houses on well water may need a very costly well pump replacement. Whether a household incurs the costs of addressing sewer breakdowns may also depend on whether the unit is on a public sewer system or is responsible for maintaining its own septic system.

With the inclusion of all relevant context variables, a total of 99 repair scenarios were specified. The research team dropped those with frequencies below 0.05 percent in the unweighted data, resulting in the 66 combinations of reported problems and repairs presented in [Appendix Table 1](#). As indicated in the “Affected Area or Scaling” column of this table, several repair scenarios involving heating equipment were adjusted for the size and type of the unit or the number of residents.

Assigning Repairs to Housing Problems

For several equipment-related repairs, the frequency or severity of the problem over a specified period of time was used to establish which repair would be most appropriate. If a system broke down one or two times over the specified period, we assumed the system needed repair or servicing. For three or more reported breakdowns, we assumed replacement was needed. For example, in cases where a toilet reportedly broke down once or twice over the previous three months (NOTOILFREQ), it may need a low-cost repair, but if it failed more regularly, the whole toilet may need to be replaced. Similarly, if a house is on a septic system that broke down once or twice over the previous three months (SEWBREAK), a relatively inexpensive unclogging procedure may solve the problem. If it broke down more frequently, a much more expensive replacement of the septic system may be required. When a house on well water had one or two interruptions in water service over the previous three months (NOWATFREQ), the well piping may need to be replaced. When more interruptions occur, a much more expensive well pump replacement may be needed. A unit reporting one or two heating equipment breakdowns over the previous winter (COLDEQFREQ) may need to have its equipment serviced, whereas a greater number of breakdowns may indicate a need for equipment replacement.

Occasionally, repairing a system can be more expensive than simply replacing it. In those cases, we defaulted to the more comprehensive, cheaper cost of replacement. For example, when a housing unit connected to a public water system is without running water once or twice in a three-month period (NOWATFREQ = 1 or 2, WATSOURCE = 1 or 3), a repair to the water main may be needed. However, estimates from the RSMMeans database suggested that repairing a water main in this context may be costlier than replacing one. Accordingly, we assumed that a rational property owner would choose the less costly option of replacement.

Repair Cost Assumptions

For certain housing problems identified in the AHS, developing reasonable repair cost estimates required making assumptions about the dimensions of the housing unit. In the AHS PUF, the variable for unit total square footage is provided as a binned categorical variable (UNITSIZE). To scale repair costs that were provided on a per square foot

basis, we assumed the midpoint of each category.⁸ For units for which the size variable was missing or not reported, we imputed 1,500 square feet based on the overall median unit size reported in the AHS Table Creator.⁹

Dimensional Assumptions

The following list outlines key dimensional assumptions we used to adjust repair cost estimates provided by Gordian to housing unit records in the AHS PUF. More detailed descriptions of repair assumptions, included specific tasks and materials as well as standard assumptions built into the RSMMeans estimates (e.g., typical room size), can be found in [Appendix Table 1](#).

- For units that reported no electrical wiring (NOWIRE=3), the costs of installing wiring, outlets, and switches was provided on a per square foot basis. Assuming a typical room size of 12 feet by 12 feet, we multiplied this per square foot cost by 144 and multiplied this per room cost by the number of finished rooms in the unit (TOTROOMS minus UFINROOMS).
- For the sole attic-related repair (COLINSUL), the attic footprint is assumed to be the same as the unit footprint (imputed unit size divided by UNITFLOORS for single-family homes; imputed unit size for all multifamily units). We assumed insulation would be added to 100 percent of the calculated attic footprint.
- In the case of units reporting crumbling foundations (FNDCRUMB), assumptions regarding the affected area of the foundation were provided by Gordian, and calculations were adjusted for each foundation type:
 - Basements (FOUNDTYPE=1, 2): Repairs required an estimate of the surface area of interior walls. To calculate this, the basement length and width were conservatively estimated as the square root of the unit footprint (imputed unit size divided by UNITFLOORS). This value was halved for partial basements (FOUNDTYPE=2). Basement wall heights were assumed to be eight feet. We assumed repairs would apply to 5 percent of the calculated wall area.
 - Crawl Spaces (FOUNDTYPE=3): Repairs required an estimate of the surface area of interior walls. Foundation length and width were calculated using the same method used for basements. Crawl space wall height was assumed to be four feet. We assumed repairs would apply to 5 percent of the calculated wall area.
 - Concrete Slab (FOUNDTYPE=4): We assumed repairs would apply to 25 percent of the calculated unit footprint.
 - Mobile home on masonry foundation (FOUNDTYPE=5): Repairs required an estimate of the surface area of the foundation. Foundation length and width were calculated using the same method used for basements. Foundation wall height was assumed to be three feet. We assumed repairs would apply to 25 percent of the calculated wall area.
 - Mobile home on concrete pad (FOUNDTYPE=6): We assumed repairs would apply to 100 percent of the calculated unit footprint.
 - Mobile home on blocks (FOUNDTYPE=7): We assumed that five blocks would be replaced, irrespective of unit footprint.

⁸ Five hundred square feet was used for units in the “Less than 500 square feet” category and 4,000 square feet was used for units in the “4,000 square feet or more” category.

⁹ See www.census.gov/programs-surveys/ahs/data/interactive/ahstablecreator.html?s_areas=a00000&s_year=n2017&s_table-Name=Table2&s_byGroup1=a1&s_byGroup2=a1&s_filterGroup1=t1&s_filterGroup2=g1&s_show=S (accessed June 2, 2019).

- For roof-related repairs (ROOFSAG, ROOFSHIN, ROOFHOLE, and LEAKOROOF), the total roof area was calculated as the unit size divided by the number of stories (UNITFLOORS)¹⁰ multiplied by 1.25, which assumes a roof pitch of nine feet in 12 feet (approximately 37 degrees). For ROOFHOLE and LEAKOROOF, we assumed repairs would apply to 5 percent of the calculated roof area. For ROOFSAG and ROOFSHIN, we assumed repairs would apply to 100 percent of the calculated roof area.
- Repairs pertaining to exterior walls (WALLSIDE and WALLSLOPE) required an estimate of the exterior wall surface area of the structure. The length and width of the structure were conservatively calculated as the square root of the unit footprint (imputed unit size divided by UNITFLOORS). The typical height of the first floor was estimated at 10 feet and multiplied by the number of stories (UNITFLOORS). We assumed repairs would apply to 5 percent of the calculated wall area.

For replacements of heating systems and water heaters, the number of potential options was limited by the range of equipment sizes available in the RSMMeans data set. Accordingly, for heating equipment replacements, we collapsed the unit size categories into groups depending on the type of system, and those groups were assigned a corresponding equipment size. For respondents in multifamily units with steam or hot water heating systems (HEATTYPE=2), the repair for frequent heating system breakdowns differed from that of single-family or manufactured homes, as these systems are more likely to be centralized in multiunit structures. Instead, for these units, we applied the cost to install baseboard heating equipment in each finished room. For water heater replacement, we used the number of residents reported in the AHS to inform the size of water heater required for each unit. Equipment specifications are detailed [Appendix Table 1](#).

Number of Items in Need of Repair

Several AHS-reported housing problems required us to make assumptions about the number of items in need of repair. For example, the AHS survey asks whether the unit has any windows that are boarded up or broken but does not ask how many. The following list details the assumptions for these types of repairs:

- For units in which one or more rooms lack a working electrical outlet (PLUGS=2), we assumed an average of 1.5 outlets would need to be installed.
- For units with baseboard heating that reported more than two heating equipment breakdowns (COLDEQ-FREQ>2), we assumed that an average of four baseboard units would need to be replaced. For households that reported being uncomfortably cold because of inadequate heating capacity (COLDHTCAP=1) in units with baseboard heating, we assumed an average of two baseboard units needed to be added to the unit.
- For repairs to broken, boarded-up, or leaking windows (WINBROKE=1, WINBOARD=1, or LEAKOWALL=1), we assumed an average of 1.5 windows need to be repaired or recaulked.

Repair Cost Substitutions

Last, for the few repair scenarios lacking a specific RSMMeans cost estimate, we substituted the following costs from similar repairs:

- The AHS contains information on six different rooms that could be affected by mold — bathroom (MOLDBATH=1), kitchen (MOLDKTCH=1), bedroom (MOLDBEDRM=1), living room (MOLDLROOM=1), basement (MOLDBASEM=1), and other (MOLDOOTHER=1). We assumed that the RSMMeans estimate for remediating mold would be similar for each type of room. Accordingly, we applied the remediation cost associated with addressing an affected area of 100 square feet to all room types where mold was reported.
- For heating-related repairs to units with uncommon heat sources (HEATTYPE 6 through 12), we applied the cost of installing a baseboard heater in each finished room. Units that did not have heat (HEATTYPE=13) or reported using a cooking stove for heating (HEATTYPE=14) were also assumed to need the installation of

¹⁰ Although UNITFLOORS is only available for single-family and manufactured units, these are also the only units for which information on roof conditions is collected.

an electric baseboard unit in each finished room (TOTROOMS – UFINROOMS).

- Sewer system–related repairs for standard septic tanks (SEWTYPE=2) were applied to other types of septic tank systems (SEWTYPE 3 through 6).
- For units that experienced disruptions in their water service but did not report the source of their water (WATSOURCE=3), we applied the same repair cost that was used for those connected to a public water system.
- For single-family units where the foundation type was not reported (FOUNDTYPE=8), the repair for a concrete slab basement was assigned, as this was the least expensive basement repair. Similarly, for manufactured housing where the foundation type was not specified (FOUNDTYPE=9), the low-cost repair for concrete block foundations was used.
- Boarded-up windows (WINBOARD=1) were assigned the same window replacement cost as broken windows (WINBROKE=1).
- If the respondent reported not knowing the source of an interior leak (LEAKIDK=1), then we applied the repair cost for a leak from an unspecified source (LEAKOOTH=1).

Repair Hierarchy

Some housing units have multiple problems that could be solved by a single repair. To avoid overestimating repair costs with redundant repairs, we developed a set of decision rules to determine which repairs supersede others:

- There are several potentially overlapping repair needs pertaining to roof-related issues (ROOFSAG, ROOFSHIN, ROOFHOLE, and LEAKOROOF). The most intensive repair involves addressing a sagging roof (ROOFSAG=1), which requires costly structural work. As a result, this supersedes all other roof repairs. The next-most intensive repair is replacing missing roofing materials (ROOFSHIN=1). This is followed by repairing a hole in the roof (ROOFHOLE=1). Last, if no other roof-related repair needs are indicated, the repair for a roof leak (LEAKOROOF=1) would be applied to the unit.
- For heating system problems, replacing equipment associated with frequent breakdowns in the heating system (COLDEQFREQ ≥3) supersedes the repairs assigned to inadequate heating capacity (COLDHTCAP=1), which in turn supersedes the repairs associated with less frequent breakdowns (COLDEQFREQ=2). Both frequent heating system breakdowns and inadequate heating capacity would require either replacing or upgrading the heating equipment, which would only need to be performed once for housing units reporting both problems. Similarly, one or two breakdowns of an otherwise functional heating system may only require relatively inexpensive maintenance, but this cost would be redundant if the housing unit also reports a problem that would require heating equipment replacement.¹¹
- For structural repairs, if the exterior walls of a house or building are sloping (WALLSLOPE=1), the structurally deficient portion of those walls would need to be replaced. When exterior walls are reported as sloping and missing materials such as siding or bricks (WALLSIDE=1), the need for a replacement wall supersedes the need for the materials repair. Similarly, for households reporting a leak coming from an unknown outside source (LEAKOOTHER=1) in addition to these exterior wall issues, repairs to the exterior wall are assumed to address the source of the outside leak, superseding the leak repair.
- For leaks from closed doors or windows (LEAKOWALL=1), sealing windows to prevent leaks is superseded by complete window replacement because of broken or boarded-up windows (WINBROKE=1 or WINBOARD=1).
- A leaking water heater (LEAKIWATH=1) is superseded by replacing a broken or missing water heater (HOTWATER=7), since a new water heater would address the leak.

¹¹ It is worth reiterating here that in instances where equipment replacement is less expensive than repair, we assume the property owner would opt to replace.

- In units that lack electrical wiring (NOWIRE=3), the repair assumes the installation of four outlets and one switch in every finished room. This would obviate the need to address the lack of an electrical outlet in each room (PLUGS=2).
- We assumed that leaks originating from a basement (LEAKOBASE=1) were likely to be addressed if the unit already requires repair to a cracked or crumbling foundation (FNDCRUMB=1). Accordingly, the foundation repair supersedes basement leak repairs.

Development of National, Regional, and Metropolitan Estimates

After estimating the total repair cost for each surveyed unit, we used the full sample weighting variable (WEIGHT) to calculate weighted summary statistics and aggregate repair costs tabulated by a number of demographic, geographic, and housing type variables. The National PUF includes variables that specify the census division¹² and, for units in the 15 largest metro areas,¹³ the MSA of each respondent.

All tabulations at the national and census region levels use the weighted national average cost directly from the RSMMeans database. To account for regional variations in construction costs, dollar value estimates for the 15 largest MSAs are adjusted using location factors for the largest principal city. These location factors were drawn from Gordian (2017), which provides cost multipliers at the three-digit zip code level for most major cities.¹⁴

Validation

To assess the internal validity of the repair cost index, we evaluated its relationship to other AHS variables that can be reasonably expected to correlate with housing quality. First, as anticipated, we found that each level of the categorical HUD housing quality indicator (ADEQUACY) was associated with a progressively higher median and average repair cost estimate (Table 1).

Table 1. Comparison of Repair Cost Index to HUD ADEQUACY composite variable.

ADEQUACY Value	Average Repair Cost	Median Repair Cost
Adequate	\$847	\$0
Moderately Inadequate	\$4,361	\$2,440
Severely Inadequate	\$6,487	\$3,346

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

Note: Means and medians include both units with and without repair needs.

Another AHS variable examined for validation purposes was the householder's rating of the unit as a place to live (RATINGSHS). This is an ordinal variable ranging from one (worst) to 10 (best). As expected, the repair cost index had a highly statistically significant ($p < 0.0001$) negative correlation with this measure (-0.21).¹⁵ While this association was moderate in strength, it is worth noting that a large portion of units had an estimated repair cost of \$0. For these units, and those with modest repair needs, resident ratings may have been influenced by other location and neighborhood factors.

Last, operating under the assumption that older units are more likely to experience housing quality issues, we examined the association between the repair cost index and the binned ordinal variable that denotes the decade that

¹² Census divisions are collections of states and the District of Columbia grouped by proximity. Census divisions form the building blocks of census regions. For more information, see www2.census.gov/geo/pdfs/maps-data/maps/reference/us_regdiv.pdf.

¹³ A separate Metropolitan PUF provides microdata for a rotating list of 10 additional MSAs.

¹⁴ These adjustment factors range from a low of 0.79 to a high of 1.40 for this set of principal cities.

¹⁵ The Pearson correlation coefficient is based on weighted data.

the structure was built.¹⁶ Again, we found the expected, highly significant ($p < 0.0001$) negative association (-0.13),¹⁷ indicating that newer units were associated with less costly repair needs. Again, the strength of the association was moderate; however, the level of investment in the maintenance and preservation of older units is likely to vary across different housing market contexts and property owner characteristics.

Limitations

As noted previously, 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 the conservative but reasonable assumptions outlined above and detailed in [Appendix Table 1](#).

There are housing deficiencies that may present threats to the safety and well-being of residents that are simply not reported in the standard AHS modules. These include missing or broken stairs and bannisters, which present major injury risks.¹⁸ Furthermore, we are unable to capture the need for adaptive modifications that may be critical to a resident's ability to safely navigate their unit and perform everyday tasks. Housing deficiencies that are unlikely to be observed in residents' everyday lives, such as lead exposure, water contaminants, and indoor air quality issues, are similarly unavailable in the survey. Additionally, our cost estimates do not include local and national regulatory factors that may significantly affect the cost of repairs, such as lead removal requirements or environmental performance standards, although some of these variations may be reflected in regional cost adjustments. Last, our inability to develop estimates for vacant units means that our estimates pertain to the occupied housing stock only and thus understate the total magnitude of disrepair in the national housing stock (Emrath and Taylor, 2012).

Owing to data constraints, our repair cost index likely understates the magnitude of repair needs for the multifamily housing stock. Many of the cost estimates supplied by Gordian assume the repair applies to a single-family home, unless otherwise specified (e.g., certain manufactured housing-specific repairs). For many interventions, repair 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.

Given these limitations, our cost-based index should be understood as an approximate measure of the costs to mitigate the substandard conditions reported in the AHS.

ESTIMATES OF REPAIR NEEDS

The following sections provide tabulations of our repair cost index by different household socioeconomic and unit physical characteristics. Many of our results align with conclusions that other studies have reached on the characteristics of occupants disproportionately exposed to lower-quality housing (Holupka and Newman, 2011; Mundra and Sharma, 2015; Jacobs, Wilson, Dixon, Smith, and Evens, 2009; Watson, Steffen, Martin, and Vandembroucke, 2017). Our results add nuance by identifying which groups are more likely to need the most expensive repairs. It should be noted that the following results are uncontrolled, weighted tabulations.

Since the demographic, economic, and geographic characteristics explored in this section overlap for an individual household, we create typologies of households with repair needs in a companion report to this technical appendix. These typologies provide a multidimensional view of households experiencing disrepair and are used to summarize the aggregate costs of repairs associated with different segments of this population. These typologies are intended to inform the development and targeting of strategies for improving the quality of the U.S. housing stock. For

¹⁶ The precise year the structure was built is not available in the PUF.

¹⁷ The Pearson correlation coefficient is based on weighted data.

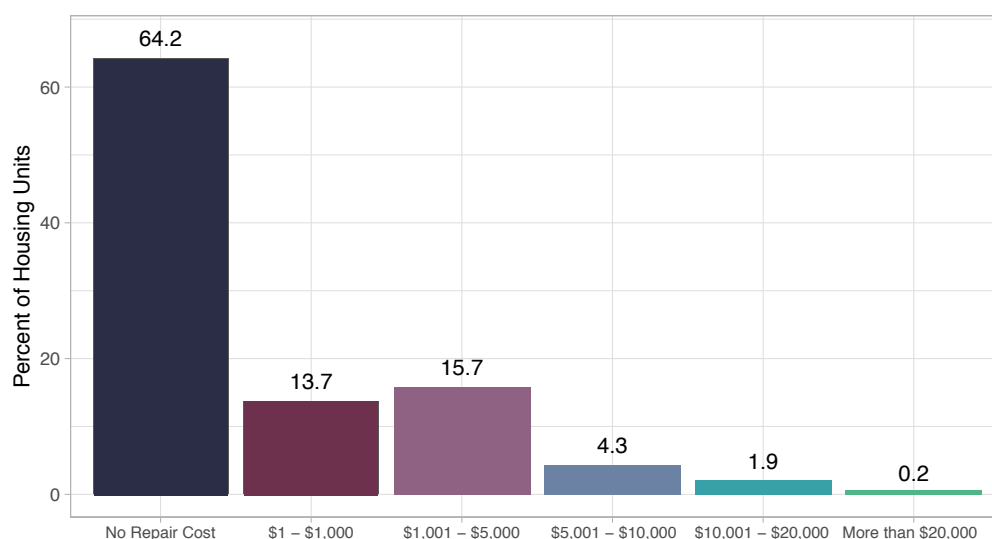
¹⁸ Questions regarding these and other household health and safety issues have been included in supplementary modules in prior surveys but are not part of the standard battery of survey questions.

details, see the companion report to this technical appendix, *Measuring and Understanding Home Repair Costs: A National Typology of Households*.¹⁹

Overall

Based on housing quality problems reported in the 2017 AHS, we estimate that the national cost of addressing home repair needs in the occupied housing stock was \$126.9 billion in 2018 dollars. Despite the decline over the last several decades in inadequate housing, our analysis indicates that approximately 36 percent of housing units needed some degree of repair, although many of these repair needs were modest. By estimating repair costs for each housing problem reported in the AHS, this new analysis allows us to distinguish between units that had relatively minor repair needs and those in need of the greatest rehab investment. Our analysis reveals that the plurality of housing units with repair needs had estimated costs between \$1,000 and \$5,000 (15.7 percent of housing units), and the median cost of repairs was \$1,449. However, the distribution of repair costs is heavily skewed, with a long tail to the right. Only 0.2 percent of housing units were estimated to need repairs totaling more than \$20,000 per unit.

Figure 1. Percent of Housing Units by Repair Cost Category



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

The frequency and cost of repair needs vary greatly by repair category.²⁰ Structural repairs were the second-most common repair need but made up more than half of the national aggregate repair costs. Leaks and mold, in contrast, were the most commonly required repair but constituted just one quarter of aggregate costs. The least costly repair type was pest remediation, which was reportedly needed by nearly 5 percent of housing units but only made up approximately 2 percent of repair costs.

¹⁹ Available at www.policymap.com/issues/housing-quality/ and philadelphiafed.org/-/media/community-development/publications/special-reports/home-repair-costs-national-report.pdf.

²⁰ Categories are based on the AHS codebook. For more information, see www.census.gov/data-tools/demo/codebook/ahs/ahsdict.html.

Table 2. Repair Costs by Category

Repair Category	Number of Units (Millions)	Percent of Units	Aggregate Repair Costs (Billions)	Percent of Aggregate Repair Costs
Electrical	6.7	5.5%	\$8.9	7.0%
Heating	6.1	5.0%	\$5.4	4.3%
Leaks and Mold	20.3	16.7%	\$31.7	25.0%
Pests	6.0	4.9%	\$2.8	2.2%
Plumbing	4.7	3.9%	\$5.9	4.7%
Structural	19.1	15.7%	\$72.1	56.8%

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

Note: Percent of Units column does not sum to 35.8 percent because some units require repairs that fall into more than one category.

Structure Type

Manufactured homes were more likely to need repairs than single-family homes, homes in small multifamily buildings (2–9 units), or homes in larger multifamily buildings (10 or more units).²¹ Slightly more than half (54.5 percent) of manufactured housing occupants did not report any housing problems, compared to 66 percent of households in large multifamily buildings. Furthermore, when manufactured homes needed repairs, those repairs tended to be more expensive than repairs needed by other types of units. The median repair cost for manufactured homes was an estimated \$1,743, higher than that of single-family homes, which was in turn higher than that of multifamily units.

Table 3. Median Repair Costs by Building Type

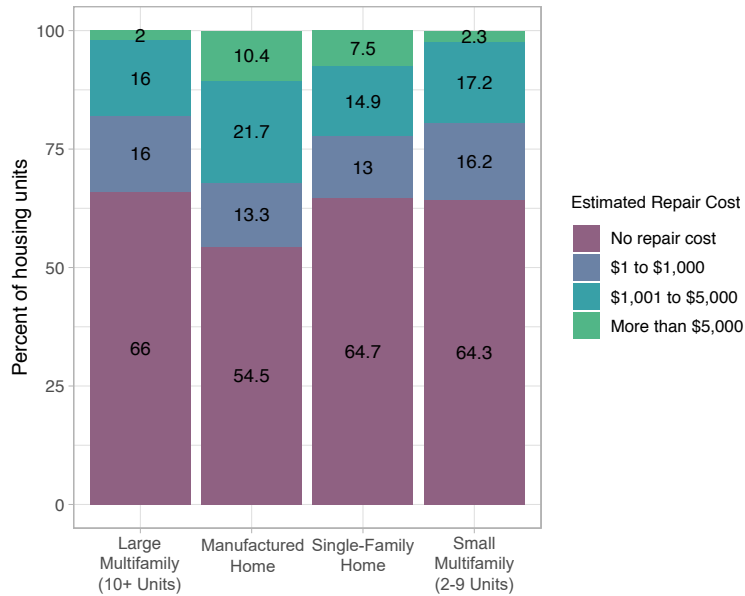
Structure Type	Median Repair Cost
Large Multifamily (10+ Units)	\$1,095
Manufactured Home	\$1,743
Single-Family Home	\$1,502
Small Multifamily (2-9 Units)	\$1,200

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

Note: Medians are calculated for units with estimated repair costs >\$0.

²¹ Differences highlighted in this technical appendix are descriptive only. They were not tested for statistical significance.

Figure 2. Percent of Housing Units by Building Type and Repair Cost Category



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

Year Structure Built

Older housing units were more likely to need repairs than newer buildings, and those repairs were likely to be more expensive. Every repair cost category greater than \$0 increases in frequency as the age of the housing unit increases.

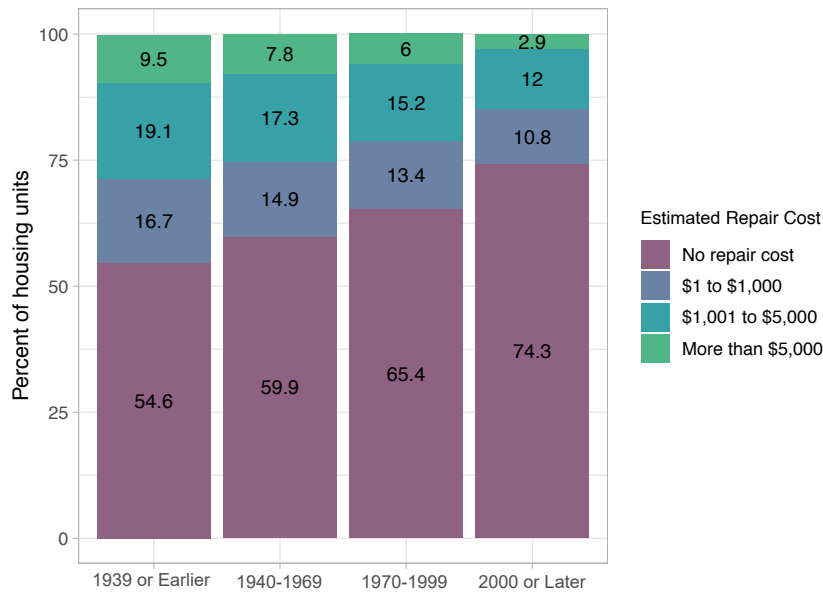
Table 4. Median Repair Cost by Year Built

Year Structure Built	Median Repair Cost
1939 or Earlier	\$1,556
1940–1969	\$1,449
1970–1999	\$1,449
2000 or Later	\$1,333

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

Note: Medians are calculated for units with estimated repair costs >\$0.

Figure 3. Percent of Housing Units by Year Built and Repair Cost Category



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

Metropolitan Area Status

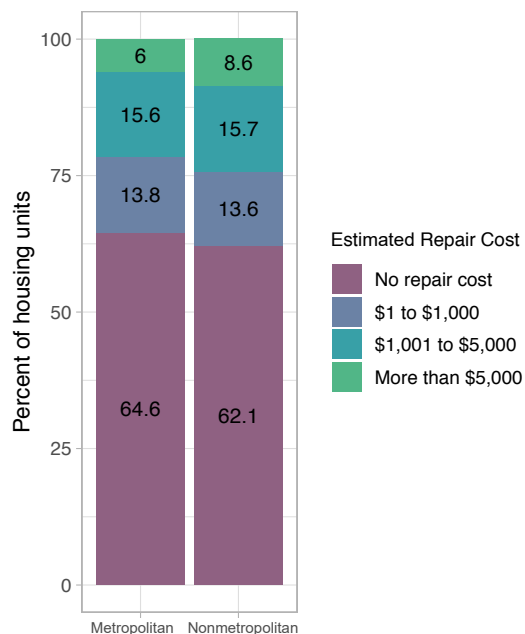
Units located in metropolitan areas were less likely to need repairs than units located in nonmetropolitan areas. Among units in need of repair, those in nonmetropolitan areas had slightly higher costs. The median repair cost for nonmetropolitan housing units was \$1,502, compared with \$1,449 for metropolitan housing units. These findings are consistent with those of Lee, Parrott, and Ahn (2012), who found that those living in urban areas are more likely to live in adequate housing than those living elsewhere.

Table 5. Median Repair Cost by Metropolitan Area Status

Metropolitan Area Status	Median Repair Cost
Metropolitan	\$1,449
Nonmetropolitan	\$1,502

Sources: Authors’ analysis of 2017 AHS PUF and 2018 RSMeans data from Gordian.
 Note: Medians are calculated for units with estimated repair costs >\$0.

Figure 4. Percent of Housing Units by Metropolitan Area Status and Repair Cost Category



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

Largest Metropolitan Areas

The 2017 AHS PUF provided MSA identifiers for units in the largest 15 metropolitan areas. To compare repair costs across MSAs, we applied regional cost adjustments based on published zip code-level adjustment factors from Gordian (2017). Our comparison revealed that both rates of repair needs and the cost of repairs varied regionally. Some of the most expensive housing markets — San Francisco, New York, and Boston — also have relatively high median repair costs.

Table 6. Percent of Housing Units Needing Repairs and Geographically Adjusted Median Repair Cost for the 15 Largest Metropolitan Statistical Areas

MSA	Percent with Repair Needs	Median Repair Cost
Atlanta	37%	\$1,275
Boston	31%	\$1,612
Chicago	34%	\$1,707
Dallas	33%	\$1,270
Detroit	37%	\$1,496
Houston	39%	\$1,125
Los Angeles	36%	\$1,558
Miami	36%	\$1,053
New York	35%	\$1,666
Philadelphia	38%	\$1,685
Phoenix	30%	\$1,261
Riverside	27%	\$1,652
San Francisco	34%	\$1,927

Seattle	34%	\$1,521
Washington, DC	38%	\$1,139

Sources: Authors' analysis of 2017 AHS PUF and 2018 RSMMeans data from Gordian.
 Note: Medians are calculated for units with estimated repair costs >\$0.

Tenure

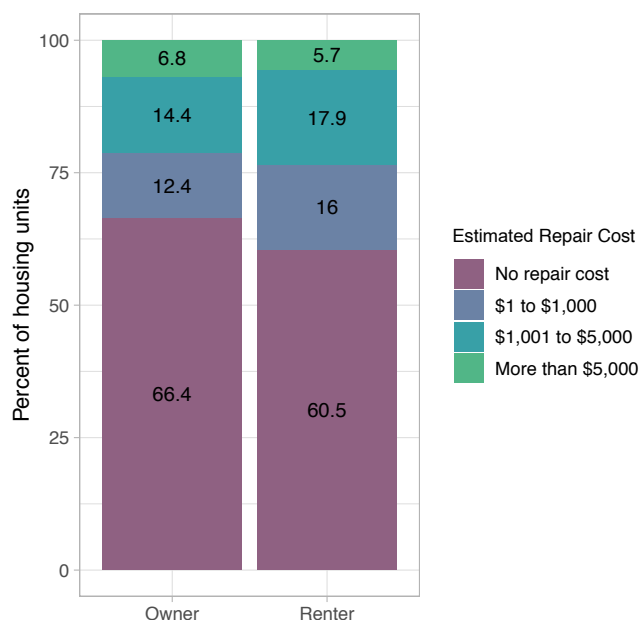
Owner-occupied housing units were less likely to need repairs than renter-occupied units (60.5 percent of renters have no repair needs, compared with 66.4 percent of owners). However, among households with repair needs, median repair costs were higher for owner-occupied units.

Table 7. Median Repair Cost by Tenure

Tenure	Median Repair Cost
Owner-Occupied	\$1,449
Renter-Occupied	\$1,355

Sources: Authors' analysis of 2017 AHS PUF and 2018 RSMMeans data from Gordian.
 Note: Medians are calculated for units with estimated repair costs >\$0.

Figure 5. Percent of Housing Units by Tenure and Repair Cost Category



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

Poverty

Consistent with the findings of prior research, we find that households with lower incomes are more likely to live in housing that needs repair than households with higher incomes (Lee, Parrott, and Ahn, 2012; Holupka and Newman, 2011; Mundra and Sharma, 2015; Boehm and Schlottmann, 2008; Watson, Steffen, Martin, and Vandembroucke, 2017). The AHS reports the ratio of a respondent's household income to the federal poverty level (FPL), which is our preferred income metric among those available in the AHS PUF, since it is adjusted for household size. We grouped households into three categories: those with income below the FPL, those making 100 percent to 199 percent of the FPL, and those making 200 percent or more of the FPL.

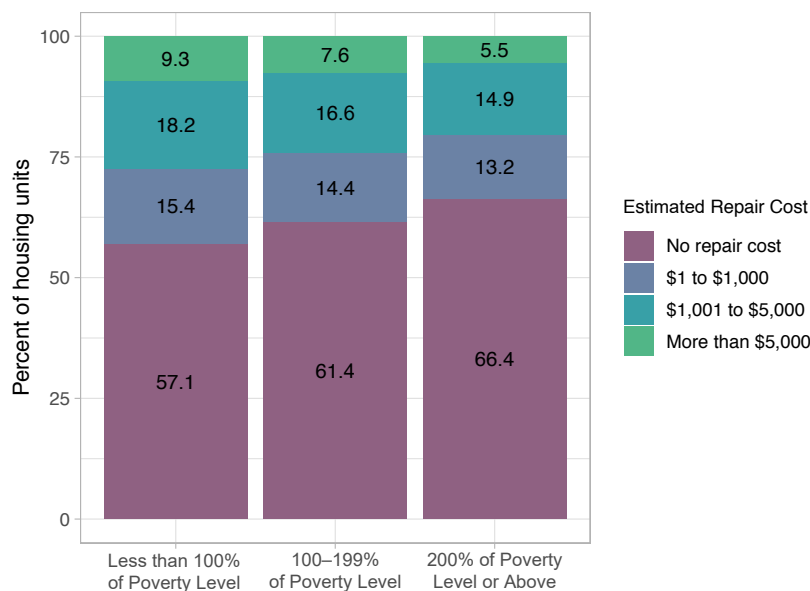
Only 57.1 percent of households earning below the FPL did not need housing repairs. That number increased to 61.4 percent for households at 100 to 199 percent of the FPL and to 66.4 percent for households earning at least twice the FPL. Typical repair costs were also highest for households below the FPL, followed by households between 100 and 199 percent of the FPL.

Table 8. Median Repair Cost by Ratio of Income to Federal Poverty Level

Income Level	Median Repair Cost
Less than 100%	\$1,556
100-199%	\$1,449
200% or Above	\$1,426

Sources: Authors’ analysis of 2017 AHS PUF and 2018 RSMMeans data from Gordian.
 Note: Medians are calculated for units with estimated repair costs >\$0.

Figure 6. Percent of Housing Units by Income Level and Repair Cost Category



Sources: Authors’ analysis of 2017 AHS PUF and 2018 RSMMeans data from Gordian.

Rental Subsidy

The AHS records self-reported responses on whether rental units are subsidized, and if so, by what means. This includes respondents from the survey’s intentional oversample of HUD-assisted units, those who receive state or local subsidies, and those who receive informal rent reductions as part of an arrangement with an employer or family member. The most common rental subsidy among respondents was public housing or other site-based subsidies. Fewer respondents used housing vouchers and fewer still lived in informally subsidized units.²²

According to our estimates, site-based subsidized housing units²³ were slightly more likely to need repairs than unassisted units, but the two groups had similar median repair costs. Housing units with informal rent reductions and households subsidized by a portable voucher were more likely to need repairs. Households with informal rent reductions also had relatively high median repair costs.

²² The unweighted sample size for these rental subsidy types ranged from roughly 1,200 to 4,900.

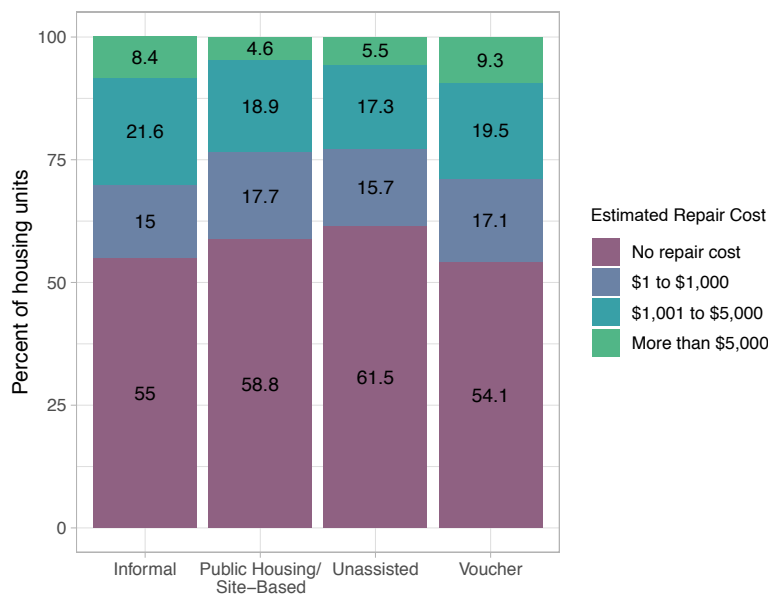
²³ Includes households for whom the following values of RENTSUB were assigned: 1: Public housing; 3: Nonportable voucher; 4: Other government subsidy; and 5: Rent reduction requiring annual recertification not reported elsewhere. See AHS code book for details.

Table 9. Median Repair Cost by Renter Subsidy Type

Rental Subsidy Type	Median Repair Cost
Informal	\$1,680
Public Housing/Site-Based	\$1,350
Unassisted	\$1,355
Voucher	\$1,449

Sources: Authors’ analysis of 2017 AHS PUF and 2018 RSMeans data from Gordian.
 Note: Medians are calculated for units with estimated repair costs >\$0.

Figure 7. Percent of Housing Units by Renter Subsidy Type and Repair Cost Category



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

Reason for Recent Move

Respondents who moved to their current home within the last two years could report 10 possible reasons for moving. We analyzed repair needs for households citing three of these reasons: to lower their housing costs, to live in a better home, or because they were forced to move by their landlord, the bank, the government, or a disaster.²⁴

Median repair costs were lower for households moving in order to live in a better home and those moving in order to lower costs. Households that reported being forced to move had typical repair costs equivalent to the overall median (\$1,449). Those that moved for a better home and those that moved for lower housing costs had similar repair cost distributions, which is at least partly due to the overlap between these two categories. Those that were forced to move, however, were much more likely to be in a unit that needed repairs.

²⁴ Sample sizes for each reason range from roughly 860 to 4,750. These categories were not mutually exclusive — nearly 1,100 respondents moved in order to both lower costs and to find a better home.

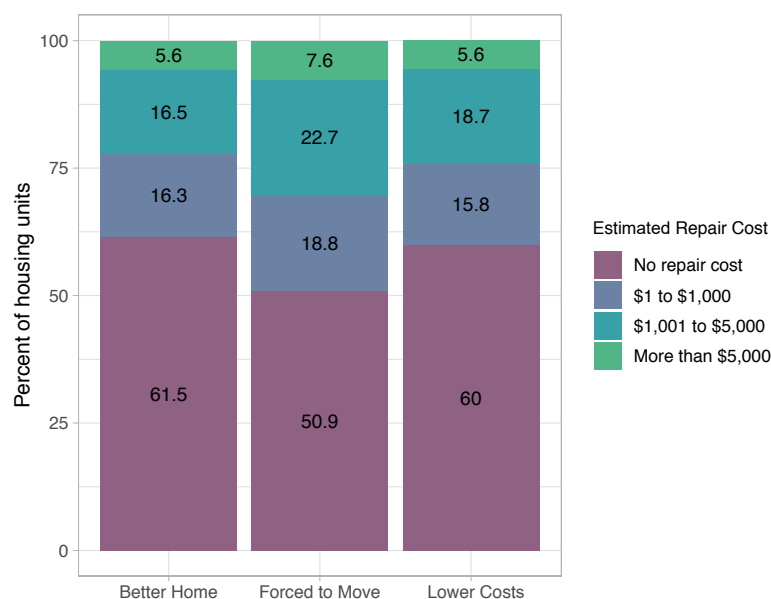
Table 10. Median Repair Cost by Reason for Recent Move

Reason for Recent Move	Median Repair Cost
Better Home	\$1,301
Forced to Move	\$1,449
Lower Costs	\$1,355

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

Note: Medians are calculated for units with estimated repair costs >\$0.

Figure 8. Percent of Housing Units by Reason for Recent Move and Repair Cost Category



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

Race and Ethnicity

We assigned each household to a category based on the race and ethnicity of the householder who completed the survey questionnaire. For ease of comparison, we examined mutually exclusive categories, meaning that all racial categories exclude those who also identified as Hispanic or Latino, and those who identified as Hispanic or Latino can be of any race.

Asian householders were the least likely to report any housing problems, and, among units with repair needs, their costs tended to be lower. White householders were slightly more likely than Asian householders to report needed repairs but were still below the overall rate. All other groups were more likely than average to have some level of repair needs.

While the sample size is small (n=192), it is notable that nearly half of surveyed households with Native American householders needed repairs and that the median repair cost for those housing units was \$2,570, over \$1,000 more than that of housing units headed by householders of any other racial or ethnic group.

Table 11. Median Repair Cost by Race or Ethnicity of Householder

Race or Ethnicity of Householder	Median Repair Cost
Asian or Pacific Islander	\$1,219
Black or African American	\$1,502
Hispanic or Latino (Any Race)	\$1,449
Native American or Alaska Native	\$2,570
Other/Two or More Races	\$1,430
White	\$1,449

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

Note: Medians are calculated for units with estimated repair costs >\$0.

Figure 9. Percent of Housing Units by Race or Ethnicity of Householder and Repair Cost Category



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

Disability

Households with one or more disabled members were more likely to live in a housing unit in need of repair than households with no disabled members. Among those with repair needs, median repair costs were also higher in households where at least one member had a disability. As noted previously, for household members with disabilities, even this elevated figure may underestimate the amount of investment needed to make a housing unit accessible.

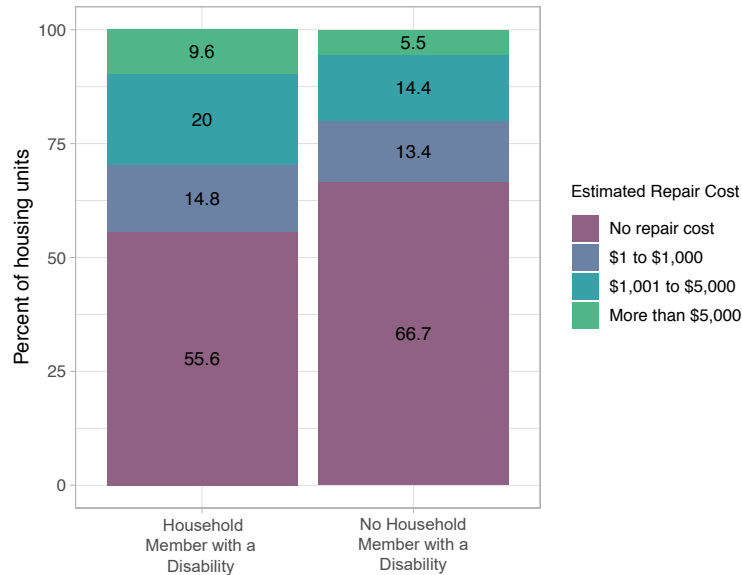
Table 12. Median Repair Cost by Disability Status of Household Members

Disability Status	Median Repair Cost
Household Member with a Disability	\$1,680
No Household Member with a Disability	\$1,355

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

Note: Medians are calculated for units with estimated repair costs >\$0.

Figure 10. Percent of Housing Units by Disability Status of Household Members and Repair Cost Categories



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

Household Type

We examined six household types in this analysis. In addition to looking at households headed by married couples, we also grouped households with single householders according to the reported gender of the householder. This gave us three main household types — married couple, single female householder, and single male householder. For each of these household types, we produced overall estimates as well as estimates for the subset of households that included children.

Our analysis shows that housing units where children live were more likely to need repairs than similar housing units without children. Among households with children, married couples were the least likely to live in housing that needs repairs, while female householders with children were the most likely. Repairs needed by female householders with children were also likely to be more expensive than repairs for any of the other five groups, for which typical costs mirrored the overall median.

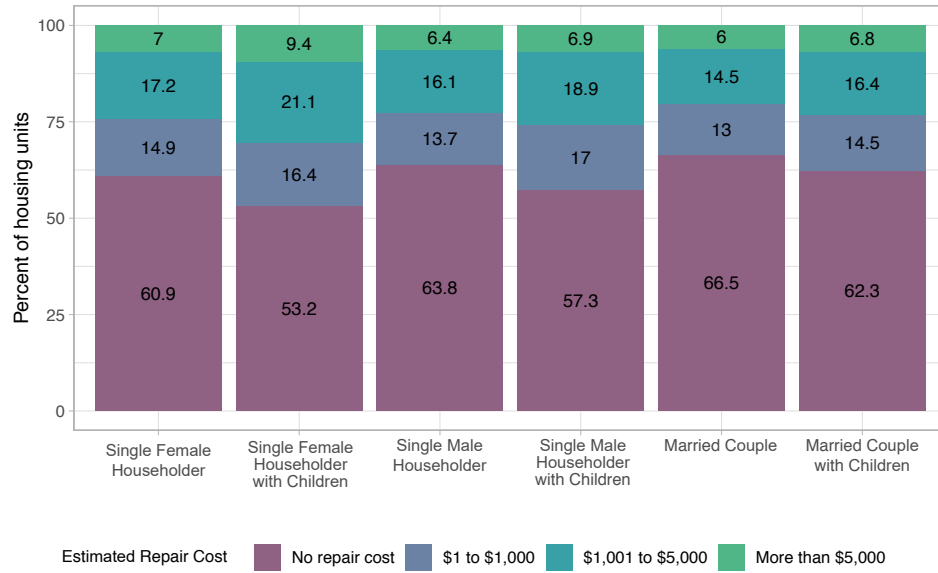
Table 13. Median Repair Cost by Household Type

Household Type	Median Repair Cost
Single Female Householder	\$1,449
With Children	\$1,599
Single Male Householder	\$1,449
With Children	\$1,449
Married Couple	\$1,449
With Children	\$1,449

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

Note: Medians are calculated for units with estimated repair costs >\$0.

Figure 11. Percent of Housing Units by Household Type and Repair Cost Category



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

HOUSING QUALITY RESEARCH ADVISORY COMMITTEE

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