



Quantifying Movement Motivations, Demand, and Inflow-Outflow Dynamics in Four Cities (New York, Chicago, Austin, and San Diego) During COVID-19

Preprint

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1 National Renewable Energy Laboratory

2 U-Haul International

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QUANTIFYING MOVEMENT MOTIVATIONS, DEMAND, AND INFLOW- OUTFLOW DYNAMICS IN FOUR CITIES (NEW YORK, CHICAGO, AUSTIN, AND SAN DIEGO) DURING COVID-19

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ABSTRACT

The COVID-19 pandemic has impacted a wide range of human activities, from food delivery habits to major moving and travel decisions. Results indicate multiple pandemic-related factors have influenced millions of relocation decisions by Americans (e.g., health risk, financial pressures, more space, employment), and there are various positive economic and social outcomes of this influence (e.g., remote work and education), enabling more affordable living and opportunity. This paper addresses COVID-19 impacts on mobility, especially involving permanent relocations. Survey design and data analysis with U-Haul targeted customers in Austin, New York, San Diego, and Chicago to understand mobility, new moving dynamics, and motivations.

RESEARCH QUESTIONS AND HYPOTHESIS

Researchers from Yale and Colorado State University explored the extent of social distancing and voluntary responses being followed across the country using mobility patterns and stay-at-home times calculated using mobile phone data and tracing locations (Yan et al., 2021). As parallel interests, this study team conducted a literature review to explore non-temporary mobility patterns and voluntary pandemic responses focused on relocation motivations, related demand, and inflow-outflow dynamics for select cities.

This focus is timely and relevant, as several recent articles have noted significant changes in demand for relocating (Popken, 2020; Patino, Kessler, and Holder, 2021). Using data analytics and visualization methods, our research aims to understand and answer three key questions: (1) What are the primary reasons for moving during the pandemic? (2) Where are people moving to

and from? and (3) What are major trends for top “moving-in” destination areas (e.g., Austin) vs. top metro areas of Americans moving out?

The research team’s null hypothesis is that COVID-19 economic consequences, and health hazard exposure is the primary motivational factor for relocation, and the first objective in the survey is to explore that. To this end, a survey was designed and administered from October through December 2020. The National Renewable Energy Laboratory (NREL) and U-Haul teams analyzed the results of the survey and aggregated spatial mapping data of U-Haul customer transactions to explore the motivational causes and emerging insights of relocation during the pandemic.

METHODS AND DATA

Survey data collection and analyses initially focused on two smaller, yet rapidly growing cities (Austin, Texas, and San Diego, California) and two larger, more populous metropolitan areas of the U.S. (New York, New York, and Chicago, Illinois). For initial analyses, 2,884 customer survey responses and 604,628 customer transactions were analyzed across these four cities.

As context, Austin ranked in the top three U.S. metro areas in percentage population growth from 2010–2019 (U.S. Census Bureau, 2020a), and San Diego in the top eight among major U.S. cities for population growth and in-migration (City News Service, 2019). Overall, these cities were selected to represent diverse demographics and mobility behavior by understanding U-Haul’s customer patterns for people moving in and out of these cities. Survey data consisted of 34 questions—a combination of who, why, how, and when—exploring various aspects of mobility, moving motivations, demand, and evolving spatial migration dynamics.

In order to test our hypothesis, we first established a baseline understanding of primary reasons for moving during COVID-19 using a survey. Next, we analyzed trends and associations between 2019 and 2020 customer transaction data to identify why Austin was different from New York, Chicago, and San Diego. Finally, we mapped and computed inflow-outflow trends and mode choice for access to U-Haul moving services to compare dynamics across the four case study cities.

FINDINGS

As a key finding, NREL and U-Haul discovered that relocation to lower living expenses and for work-related reasons (including remote work) are cited just as frequently, if not more, relative to moving primarily due to COVID-19. At the same time, this may have some correlation with COVID-19, which is a gap for further investigation. Comparisons of the dynamics are shown in preliminary study findings across the four metro regions. Carefully constructed sociodemographic and behavioral analysis could further establish objective associations between COVID-19, living expenses, and the extent of moving, living, and work changes.

1. Reasons for Moving

Lower living expenses was the predominant motivation factor for moving. This factor represented almost **one-third** (Figure 2) of the survey respondents, followed by “Moved for work” as a next motivating factor. This topic has received significant attention over the years in the domain of social mobility, with a focus on low-income families being able to “move to opportunity” (NBER, 2022). Nearly 9 million Americans live in extreme poverty neighborhoods in which 40% of

residents are poor (average household incomes below \$25,000). With the pandemic, some might think remote work may further enable moving, yet recent U.S. Census surveys have indicated remote work opportunities may be less accessible to lower income groups as opposed to higher income groups (Figure 1). A U-Haul survey is therefore useful, as being a U-Haul customer by default often infers a lower socioeconomic status—those who move themselves are typically not high-income households.

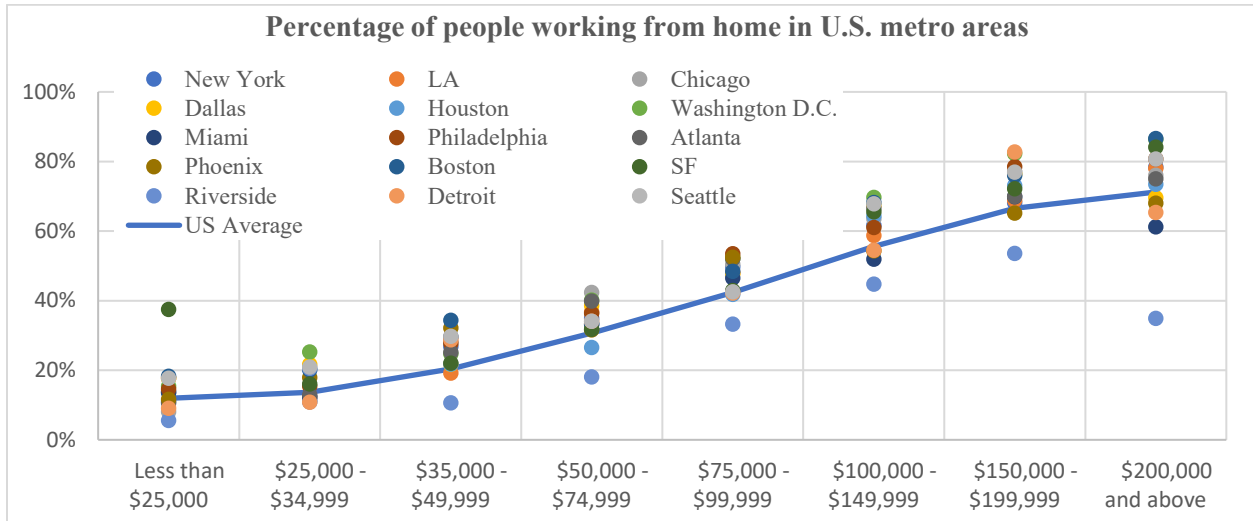


Figure 1. Percent of people in remote work during COVID-19 pandemic by household income brackets (U.S. Census Bureau, 2020b).

The plots for each of the individual cities (Figure 2) gives a more granular view of the reasons across U-Haul moving customers. Moving for work and lower living expenses are balanced for those moving within or away from Austin and San Diego. Customers moving within or away from Chicago and New York show a higher interest in moving for lower living expenses as compared to work.

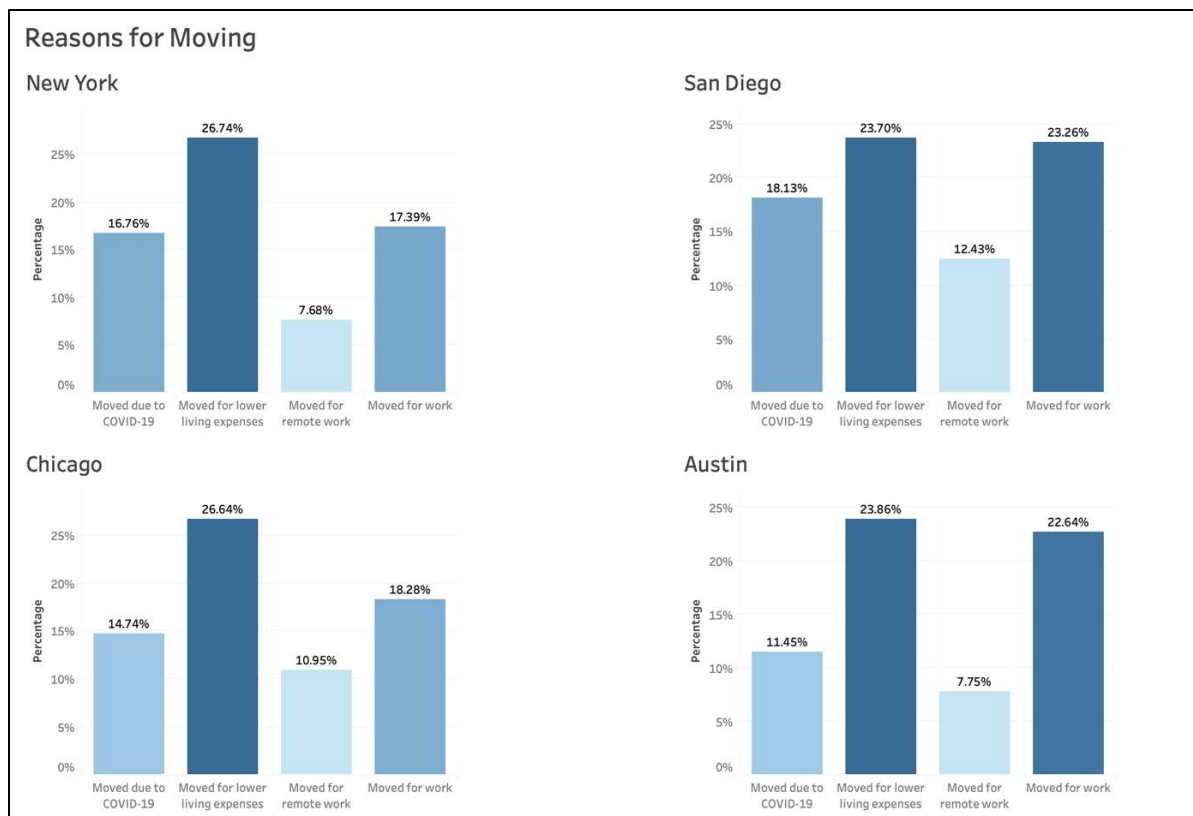


Figure 2. Primary reason stated for moving -- origin cities (n = 2,884 U-Haul customers in 2020).

2. Understanding Moving Trends from Customer Transaction and Survey Data

The team compared the number of U-Haul moves into each of these cities in 2019 versus in 2020. As shown in Table 1, there were fewer moves into New York City, San Diego and Chicago in 2020 relative to 2019 (by 22%, 16% and 11%, respectively), whereas the number of moves into Austin remained relatively flat.

Table 1. Percentage difference of U-Haul moves into Austin, Chicago, New York City (NYC), and San Diego between 2019 and 2020

March, 2019 ~ August, 2020	Austin	Chicago	NYC	San Diego
2019–2020 Difference	0.88%	-11.44%	-22.30%	-16.01%

At the same time, Austin emerged as a top destination for relocating in 2020 because of its lower cost of living while still having a plethora of job opportunities. According to Redfin, Austin, Las Vegas, Phoenix, Sacramento, and Dallas had a large magnitude of positive net inflows (Percentage difference of inflows) of residents than any other major U.S. metros in the fourth quarter of 2020 (Redfin, 2021). In 2020, Austin saw double the number of out-of-town homebuyers relative to 2019 (Anderson, 2020).

Although U-Haul customers may be of different socioeconomic statuses than Redfin homebuying customers, and with mortgage interest rates likely being another factor for home purchases, economists have noted several key factors for moving during the pandemic, including the desire for more space and interest in lifestyle changes (Kwak-Hefferan, 2021).

As one article noted at the end of December 2020, “Buyers are seeking more affordable homes and yard space for their families, home offices for parents, [and] designated areas for remote learning for their children” (Popken, 2020).

3. Spatial Inflow-Outflow Mapping, Suburban-Urban Migration, and Dynamics of Access to U-Haul Services

Mapping moving patterns (Figure 3) helps us better understand the mobility behavior of each city of interest.

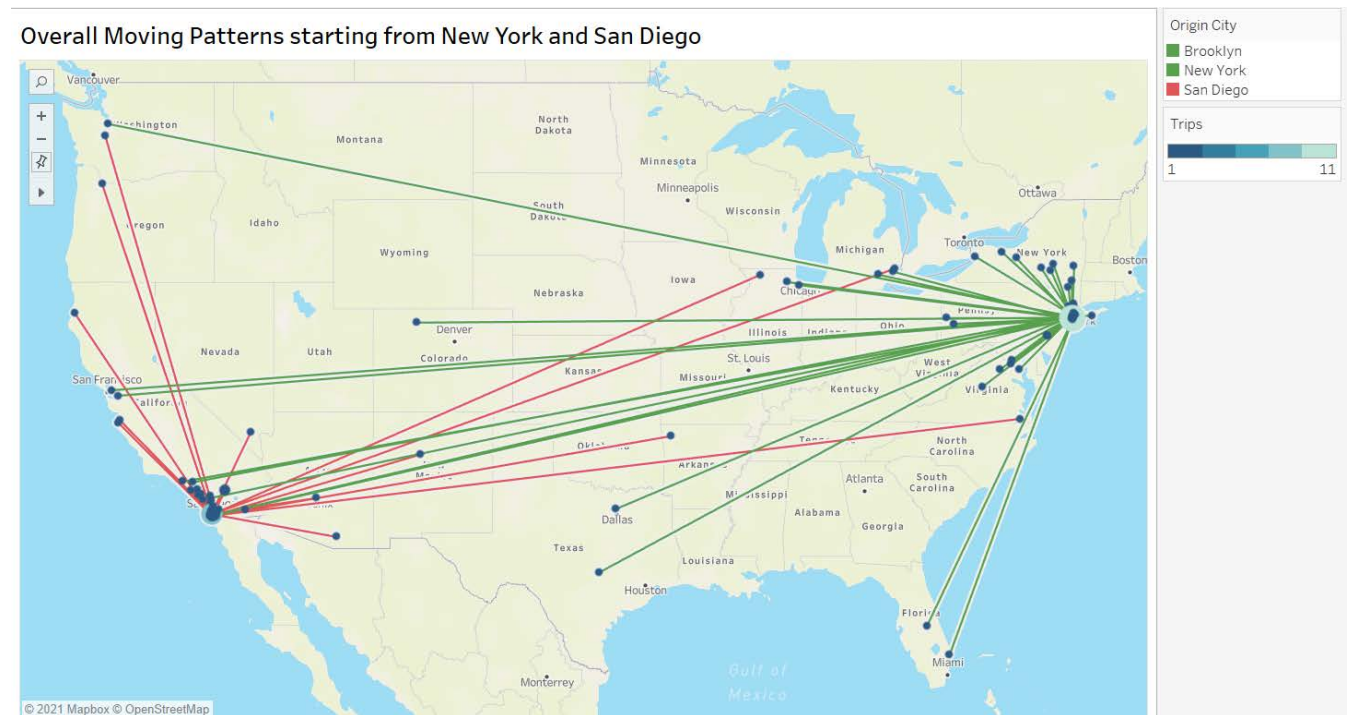


Figure 3. Moving patterns from New York City and San Diego (Note the sample number of respondents by state of residence in the survey: 1,084 for New York, 353 for California, 501 for Illinois, and 490 for Texas).

Approximately 84% of the U-Haul moves out of New York City remain in the state of New York (see Table 2). Of the moves out of New York State, the top destination states are New Jersey, Pennsylvania, and Connecticut. The people leaving New York City for relatively lower living expenses in and around the metro include relocations to cities such as Jersey City, Philadelphia, and Stamford.

The San Diego data similarly shows that the vast majority of U-Haul moves remain within the state of California (91%, see Table 2). Of the small number of moves shown in the data as leaving California, five moved to Arizona, two moved to Virginia, and eight moved to eight other states.

Table 2. Frequent destination states and percentage of trips for NYC and San Diego

Origin City	Destination State	Frequency	Percentage of trips
NYC	New York	498	83.98%
	New Jersey	26	4.38%
	Pennsylvania	13	2.19%
	Connecticut	11	1.85%
	other	45	7.60%
San Diego	California	160	91.43%
	Arizona	5	2.86%
	Virginia	2	1.14%
	other	8	4.57%

As shown in Figure 4 and Table 3, similar to the New York City and San Diego scenarios, the majority of the movement (approximately 85%) from Austin and Chicago remains within their respective states. The remaining movement is dispersed, with the top states being Florida, Colorado and Virginia for Austin, and Texas, Indiana, Michigan and Wisconsin for Chicago.



Figure 4. Moving patterns from Austin and Chicago.

Table 3. Top destination states and percentage of trips for Austin and Chicago.

Origin City	Destination State	Frequency	Percentage of trips
Austin	Texas	203	86.02%
	Florida	5	2.12%
	Colorado	4	1.69%
	Virginia	3	1.27%
	other	21	8.90%
Chicago	Illinois	312	84.78%
	Texas	6	1.63%
	Indiana	6	1.63%
	Michigan	5	1.36%
	Wisconsin	5	1.36%
	other	34	9.24%

4. What About the Pandemic?

Figure 5 shows the mobility pattern of respondents who indicated that their primary factor for moving was the COVID-19 pandemic specifically, whereas previous results were for overall moving patterns from respective cities. For these respondents, the San Diego respondents mostly moved within their state, whereas the other respondents moved to different cities across the U.S.

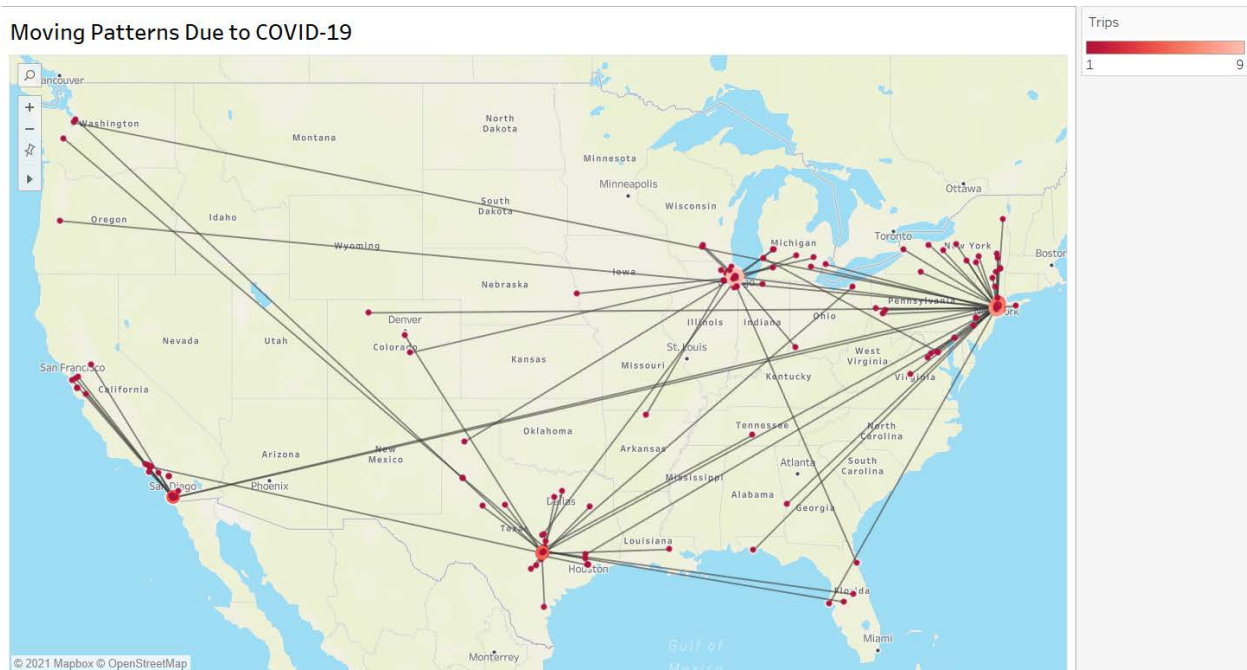


Figure 5. Origin-destination diagram of respondents who moved due to COVID-19.

Out of those who cited COVID-19 or lower living expenses as the primary motivation for moving, the largest percentage moved from one urban area to another, which is consistent with the overall

city type movement among all respondents. Movement from an urban to a suburban area, or from one suburban area to another were the second and third most common move types among these respondent subgroups (Figure 6).

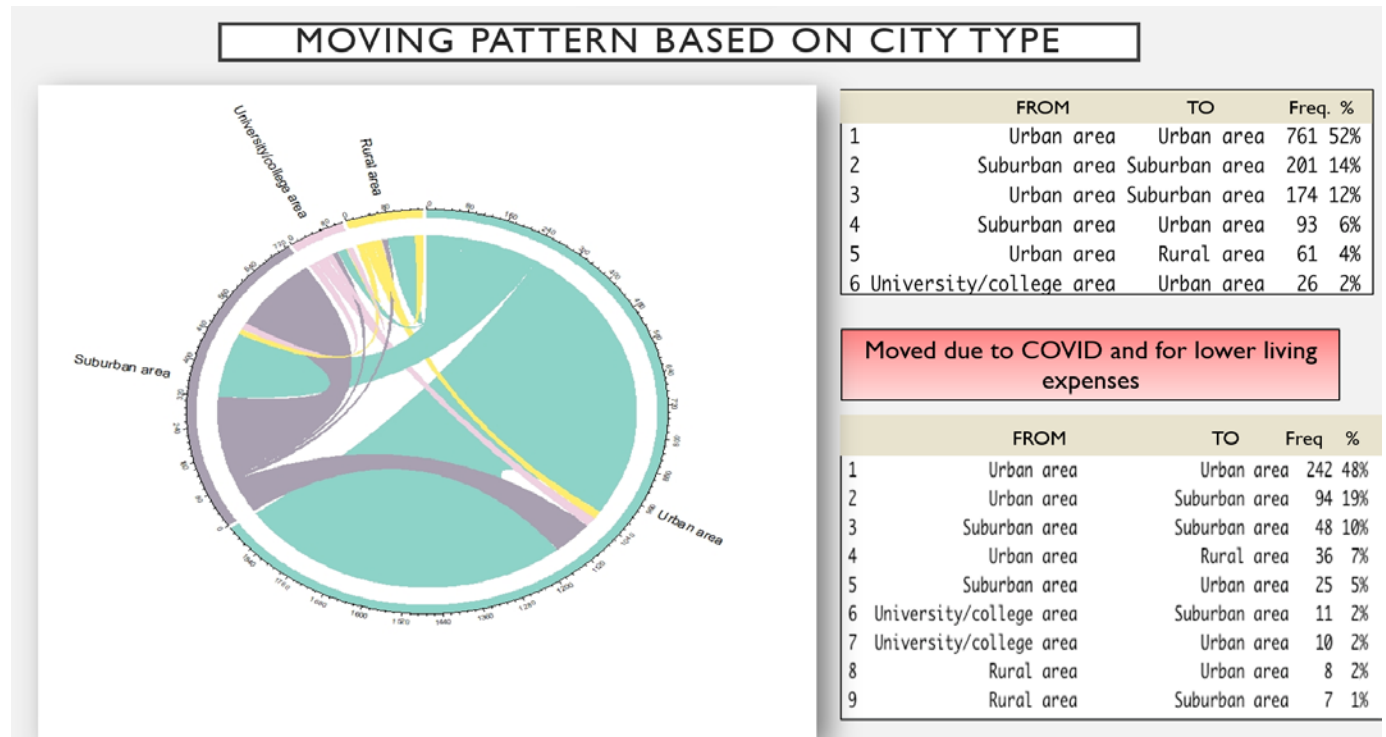


Figure 6. Moving patterns based on city type.

As demonstrated in Table 4, a majority of respondents use car-pooling as their main mode of transportation to get to U-Haul. New York and Chicago respondents use public transport the most, which is reflective of the subway and loop systems, respectively.

Table 4. Modes of transportation used to get to U-Haul services and their percentages by city.

MODE	CITY			
	Austin	Chicago	New York	San Diego
Car_traveling_alone	38%	27%	20%	29%
Car_traveling_withotherpeople	57%	50%	33%	63%
Ridehailing_service	5%	11%	16%	5%
Taxi	0%	1%	9%	1%
Motorcycle_OR_Scooter	0%	0%	1%	1%
Bus	0%	7%	7%	3%
Train	0%	4%	14%	0%

CONCLUSION

Regardless of the pandemic, people are moving, though overall relocation through U-Haul was reduced in 2020 when compared to 2019. While there were a reasonable percentage of respondents who moved due to COVID-19, the most prominent factors behind moving from one city to another remain moving for lower living expenses followed by work related moves. Next steps might be design of new surveys for further review and analysis of more disaggregated sociodemographic and behavioral data to establish objective associations on the extent of COVID-19 impacts on mobility and moving; sustained changes to moving, living, and work; and whether there are measurable improvements in social equity to lower-cost living in urban demographic trends and outcomes.

REFERENCES

- Johnathon P. Ehsani, Jeffrey P. Michael, Keshia M. Pollack Porter, Michelle L. Duren, Yeeli Mui (Jun 6, 2021)
Mobility Patterns Before, During, and Anticipated After the COVID-19 Pandemic: An Opportunity to Nurture Bicycling
Luis Melgar, Yan Wu (May 11, 2021)
Americans Up and Moved During the Pandemic. Here's Where They Went
Monik Gupta, Nishant Mukund Pawar, Nagendra R. Velaga (Mar 19, 2021)
Impact of lockdown and change in mobility patterns on road fatalities during COVID-19 pandemic
Song Gaom Jimeng Rao, Yuhao Kang, Yunlei Liang and Jake Kruse (May 16, 2020)
Mapping county-level mobility pattern changes in the United States in response to COVID-19
Anderson, D. (2020). "Austin Is Attracting Twice As Many Out-of-Town Homebuyers As Last Year." *Redfin News*. <https://www.redfin.com/news/october-november-2020-housing-migration-trends/>.
- City News Service. (2019). "San Diego Ranks Eighth In Population Growth Among Major US Cities." *kpbs.org*. <https://www.kpbs.org/news/2019/may/23/san-diego-ranks-eighth-population-growth-among-maj/>.
- Kwak-Hefferan, E. (2021). "COVID-19 Created the Hottest Real Estate Market Denver Has Ever Seen." *5280*. <https://www.5280.com/2021/05/covid-19-created-the-hottest-real-estate-market-denver-has-ever-seen/>.
- National Bureau of Economic Research (NBER). (2022). "Moving To Opportunity." Accessed February 3, 2022. <https://www.nber.org/programs-projects/projects-and-centers/moving-opportunity?page=1&perPage=50>.
- Patino, M., Kessler, A., and Holder, S. (2021). "More Americans Are Leaving Cities, But Don't Call It an Urban Exodus." *Bloomberg CityLab*. <https://www.bloomberg.com/graphics/2021-citylab-how-americans-moved/>.
- Popken, B. (2020). "Millions of Americans moved during the pandemic—and most aren't looking back." *NBCnews.com*. <https://www.nbcnews.com/business/business-news/millions-americans-moved-during-pandemic-most-aren-t-looking-back-n1252633>.
- Redfin. (2021). "Austin Was the Most Popular Destination for Redfin.com Users Looking to Move to a Different Metro in the Fourth Quarter." News Release. <https://press.redfin.com/news-releases/news-release-details/austin-was-most-popular-destination-redfincom-users-looking-move>.

U.S. Census Bureau. (2020). “Most of the Counties with the Largest Population Gains Since 2010 are in Texas.” Press Release No. CB20-53.

<https://www.census.gov/newsroom/press-releases/2020/pop-estimates-county-metro.html>.

Yan, Y., Malik, A. A., Bayham, J., Fenichel, E. P., Couzens, C., and Omer, S. B. (2021).

“Measuring voluntary and policy-induced social distancing behavior during the COVID-19 pandemic.” *PNAS*, 118(16), e2008814118.

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