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Visualizing the May 22, 2011, Joplin, Missouri, Tornado path using building permits

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Abstract

On May 22, 2011, an EF-5 tornado spanning three-quarters of a mile in width and tracking through nearly the entire west–east extent of Joplin, Missouri, entered the records as one of the deadliest and costliest events in United States history. Building permit data was used from May 23, 2011–December 31, 2020, to examine recovery progress based on roof repair building permits (permit for roof repair only), residential and commercial building permits, and demolition permits. Each of the four permit types was plotted on the four Federal Emergency Management Agency (FEMA) damage zones, catastrophic, extensive, moderate, and limited, by census block to determine what percentage of total permits were issued in each. Further, data on three permit types (commercial excluded) were plotted in the following combinations: (a) roof repair permits with demolition permits and (b) roof repair permits with residential building permits, plotted on the catastrophic and limited zones only. The goal of the second set of plots was to visualize the 2011 damage path using permit data. Mapping data such as these may help recovery planning through a robust understanding of the relationship between damage and permit issuance as a community enters the restoration phase of the Kates recovery model.

Keywords Joplin tornado · Tornadoes · Disaster recovery · Building permit data · GIS · Disasters · Kates recovery model

1 Introduction

An EF-1 tornado entered the community of Joplin, Missouri, from the west at 5:34 pm (CDT) on 22 May 2011 but very rapidly expanded into a massive EF-5, the first in the state since 1957 (Storm Prediction Center [SPC] 2022), with wind speeds estimated at 200 mph

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(320 kph). At its widest point (roughly 0.75 mi., 1.2 km) between 26th and E 28th Streets, the tornado spanned approximately 20 city blocks north-to-south and ultimately extended the entire length of the city. Upon exiting at Joplin's eastern border, the maximum damage within the path was consistent with EF-2–EF-3 speeds, but the tornado continued for several more miles (causing little damage), recording a total of 22.1 miles (35.6 km) of track length (SPC 2022). The event left catastrophic damage[1] in its wake, covering roughly 70% of the path (i.e., 70% of the path by census block contained *at least* one rating of catastrophic damage by FEMA within that block). Approximately, 7500 residential structures were heavily damaged or destroyed, as well as about 300 commercial buildings. Spatially, approximately one-quarter of the city experienced at least some damage (Paul and Stimers 2011).

The use of building permit data appears sparingly in the academic literature and often as a vehicle to accomplish some aspect of a study rather than its focus. Nonetheless, examples are not entirely absent. Shakro (2013) examined how the local government used building permit data to inform land development decisions in Austin, Texas. Permits from 1990–2009 were mapped revealing how growth could be spatially assessed using those data. Arku et al. (2016) interviewed stakeholders to understand what factors affected noncompliance with building permits, uncovering that bureaucracy, inefficiency, burdensome planning regulations, and lack of institutional coordination, among several others, contributed to non-compliance. Bröchner et al. (2021) utilized parallel processing of building plans and permits as one of three prongs in an approach to accelerate urban planning in a Swedish suburban community. Juliafad and Andayono (2021) used building permits as a pretense to understand how building officers in Indonesia understood the building process. Findings indicated that knowledge of permit information was low, affecting officers' capacity to do their job effectively.

Building permit data has been used to understand the process of post-disaster housing recovery, which is the most time-consuming recovery activity at the household level and a costly endeavor (Gunawardena et al. 2014). Following the 1989 Loma Prieta and 1990 Northridge earthquakes, Comerio (2006) and Comerio and Blecher (2010) examined the time between building demolishment and structures either rebuilt or repaired and suitable for occupancy based on building permit issuance and completion data after each quake. Hurricane Katrina, one of the deadliest and most recognizable hurricanes in history, was examined by McCarthy and Hanson (2008) using building permit data to assess the state of repair and recovery progress. Stevenson et al. (2010) utilized a spatial scan statistic in the SaTScan environment to identify statistically significant clusters of rebuilding based on permit data. Also focused on Katrina, Go (2014) called upon permit data to ascertain whether rebuilding took place evenly across socioeconomic groups in the damaged areas. Rathfon et al. (2013) concluded that recovery is not a singular goal but an ongoing process. The authors devised a standard method for measuring and monitoring recovery based on building permit data in post-Katrina New Orleans. Yuepeng et al. (2015) studied the relationship between hurricane landfalls and changes in building permit issuance to assess recovery. The authors claimed that recovery varies by county and that permanent impact pushes losses further into the future. The present study built on the work of analyses focused on building permit data to examine the pace of recovery and the issuance of permits by type and damage zone in post-tornado Joplin.

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[1] As defined by the Federal Emergency Management Agency, catastrophic means "extraordinary levels of mass casualties or damage" (Federal Emergency Management Agency [FEMA], 2008, p. 1).

Smith and Sutter (2013) conducted a case study of the response and recovery in Joplin following the 2011 tornado. They noted that volunteers and many private sector organizations were instrumental in the recovery efforts, as government officials took a more hands-off approach. The authors' work underscores the need to study rebuilding following a significant event such as Joplin, and the type of data used in this study is poised to provide a way to assess rapidly where volunteers and organizations may be needed. Smith and Sutter also discussed the quick response of insurance companies following the event. Again, with swiftly deployed data concerning the hardest hit areas and those suffering lesser damage, such assessments might be made more helpful. Aghababaei et al. (2020) completed a longitudinal study using spatial video at 1, 1.5, 2, 3, 4, and 5 years after the May 2011 Joplin tornado event. They found that 64% of the buildings had recovered (fully functional) within 5 years; this aligns with the findings on residential permits herein, 80.8% were issued within 5 years following the event (the values should not be expected to match exactly, as time from issuance to the building phase is needed to complete the repairs or rebuilding). The authors also determined what recovery components might lead to delays in construction—the issuance of building permits emerged. With an enhanced understanding of where and when building permits are issued post-event, as presented in the current research, city planners may be in a better position to streamline such operations to speed recovery. Pilkington et al. (2021) also used spatial video at 0.5-, 2-, and 3-year intervals to monitor rebuilding progress in Joplin following the 2011 tornado. While sociodemographics by census block were considered as factors affecting time to repair (e.g., median age, per capita income, percent household with no vehicle), and correlations were not present, the median age of the structure (older than 40 years) resulted in slower repair time. In the aftermath of a major disaster, Pilkington et al.'s findings informed that the patterns examined in the present research might be somewhat dependent on the age of the structure. Planners with access to rapid assessment data may better understand the spatial patterns in the rush of permit issuance by type and age to gain a fuller picture of the community's needs in the weeks, months, and years after a significant event. As Mayer et al. (2020) studied, the decision-making process on whether to stay or leave the community post-disaster hinged on several factors, including the damage to the structure. Most residents in their study areas (Moore, Oklahoma, and Hattiesburg, Mississippi, both 2013 tornadoes) who experienced total destruction of their home relocated, while lesser damage equated to a tendency to remain in the community. Development of models based on past events and permit issuance may help government officials more accurately determine population change and the needs of those remaining after a devastating event.

The time it takes to return to some sort of normalcy after a disaster is multifaceted, depending on several psychological, socioeconomic, and infrastructure factors (Greer et al. 2020; Lawther 2016; Lee et al. 2017; Masoomi and van de Lindt 2018; Nejat et al. 2018; Santos et al. 2014; Stimers and Paul 2016). The healing process may take considerable time, especially after a significant event. A catastrophe of the magnitude of the Joplin tornado offered a chance to study the spatiotemporal features of recovery in an area where extensive devastation all but eliminated entire neighborhoods. According to Kates (1977; Fig. 1), the emergency phase lasts roughly 1–2 weeks after the event, the restoration phase approximately 1 week to 5 months after the event, the reconstruction phase I lasts about 2 months to 4 years after the event, and the reconstruction phase II lasts some 2–10 years after the event. Alexander (2002) revised the model concerning unit cost and added 10 years to the reconstruction II phase (post-disaster development). Although created and published as a hypothetical model, Kates' model has been used to describe the recovery and reconstruction phases of some of the most well-known disasters in U.S. history, such

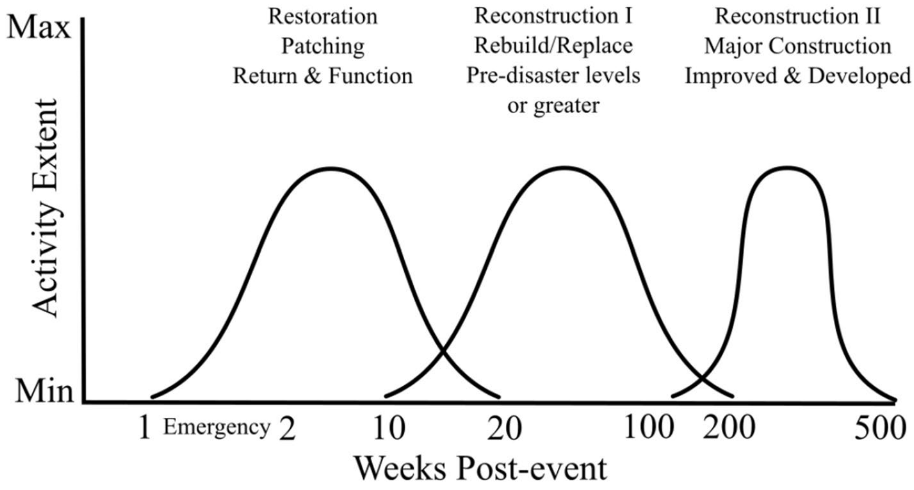

Fig. 1 The Kates Recovery Model

as the 1906 San Francisco, California, and 1964 Anchorage, Alaska, earthquakes (Kates 1977), and more recently 2005's Hurricane Katrina (Kates et al. 2006). However, the model has not been employed to examine the recovery phases of a tornado event; probably because large events like Joplin are incredibly uncommon—88 of 67,758, or 0.13%, of all tornadoes in the United States between 1950–2021 reached F5 or EF-5 strength (SPC 2022).

2 Methods and materials

Building permit data was requested from the City of Joplin in April 2021 for May 23, 2011 (1-day post-event) through December 31, 2020. The data file contained data elements desired for this analysis describing the type of permit, a description of the scope of work, the date of permit issuance, and the street address of each permit issued. A total of 18,750 data rows were included in the initial file. Data rows that contained vague location descriptions (e.g., simply *Rangeline Road* or *20th Avenue*) or no address at all were removed (39). Rows missing a work description or containing a vague description were also eliminated (45). Some rows were labeled *business license*, which is not a building permit, and were removed (192). Errant date information was also cleaned, such as mismatched dates (listed calendar year did not align with yyyy in the dd/mm/yyyy format (12), dates that fell outside of the range requested (4), or rows with no date (25) were all eliminated (317 rows eliminated, 18,433 remained). (Demolition rows that contained a calendar year value but no specific date value defaulted to 15 August of the stated calendar year; 309 rows were altered, none eliminated.) Next, the data was imported into a geographical information system (GIS) and geocoded, which resulted in a match rate of 99.3%, rendering 18,304 rows of useable geodata. Using a 2011 geodata file on damaged structures (Paul and Stimers 2011, 2014) from the City of Joplin's Emergency Management office and 2010 census block files, all remaining permit data points positioned in census blocks that did not

Table 1 All permits issued in damaged areas, 2011–2020 ($n=4925$)

	Permit Count, Percent of Type Total in That Year, Cumulative Percent of Type Total			
	Residential ($n=1721$, 34.9%)	Commercial ($n=170$, 3.5%)	Roof Repair ($n=1366$, 27.7%)	Demolition ($n=1668$, 33.9%)
2011	370, 21.5, 21.5	36, 21.2, 21.2	1045, 76.5, 76.5	1310, 78.5, 78.5
2012	427, 24.8, 46.3	40, 23.5, 44.7	59, 4.3, 80.8	184, 11.0, 89.6
2013	166, 9.6, 56.0	34, 20.0, 64.7	18, 1.3, 82.1	56, 3.4, 92.9
2014	173, 10.1 66.0	15, 8.8, 73.5	8, 0.6, 82.7	6, 2.8, 95.7
2015	158, 9.2, 75.2	18, 10.6, 84.1	8, 0.6, 83.3	22, 1.3, 97.0
2016	97, 5.6, 80.8	6, 3.5, 87.6	22, 1.6, 84.9	12, 0.7, 97.7
2017	85, 4.9, 85.8	9, 5.3, 92.9	39, 2.9, 87.8	8, 0.5, 98.2
2018	80, 4.6, 90.4	5, 2.9, 95.9	36, 2.6, 90.4	12, 0.7, 98.9
2019	93, 5.4, 95.8	4, 2.4, 98.2	67, 4.9, 95.3	6, 0.4, 99.3
2020	58, 3.4, 99.2	2, 1.2, 99.4	54, 4.0, 99.3	11, 0.7, 99.9

Table 2 Roof repair and demolition permits by permit type and damage classification, 2011–2012 Only ($n=2598$)

Permit Count, % Census Blocks of That Damage Level With At Least one Permit of That Type		
Damage zone	Roof repair ($n=1104$) (%)	Demolition ($n=1494$) (%)
Limited	998, 90.4	663, 44.4
Moderate	938, 85.0	1014, 67.9
Extensive	753, 68.2	1364, 91.3
Catastrophic	598, 54.2	1389, 93.0

Table 3 Residential and commercial permits by permit type and damage classification, 2011–2020 aggregated ($n=1891$)

Permit count, % of total census blocks of that damage level with at least one permit of that type		
Damage zone	Residential ($n=1721$) (%)	Commercial ($n=170$) (%)
Limited	732, 42.5	96, 56.5
Moderate	1,117, 64.9	136, 80.0
Extensive	1,579, 91.7	147, 86.5
Catastrophic	1,557, 90.1	151, 88.8

contain any damaged structures as of May 22, 2011, were removed (9621 rows); the resulting dataset contained 8683 rows of useable permit data ($N = 8683$).

Operations in a GIS were performed to determine the values in Tables 1, 2, and 3. All permit data by type was counted by year to arrive at the raw totals, then percentages were calculated for permit type in each year and the cumulative total of that type. For each of the four permit types, the total number of points that intersected or were contained within each of the four damage categories, including (a) limited (L1), (b)

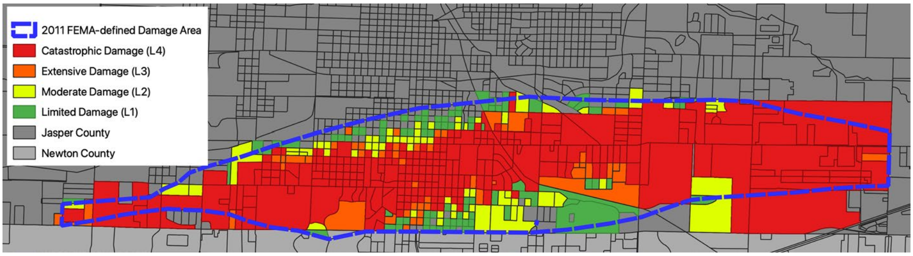

Fig. 2 Four damage zones layered

moderate (L2), (c) extensive (L3), and (d) catastrophic (L4), were found by performing a *select by location* function. It is noted here that the individual values in each damage category, when summed across all four categories, do not equal the *n* value for that permit type; this is due to the extensive overlap between the damage category zones. A census block was classified with that zone's label if it contained at least one point of that damage category from Paul and Stimers' (2011 2014) databases to determine each zone. The overlap did not present an issue in this analysis since the goal was to determine the total number of permits of each type that appeared in a category, not the permit type by unique category with no overlap. As displayed in the Results section, the L4 category (catastrophic damage) covered most of the area, with the L1 category (limited damage) appearing along the periphery—this method allowed for determining which category housed the largest percentages of permits for the four permit types.

The second stage of the analysis consisted of plotting residential, roof repair, and demolition permits (commercial excluded due to far fewer points compared to the other three types) in the following combinations against the backdrop of the catastrophic and limited damage zones: (a) roof repair permits with demolition permits, and (b) roof repair permits with residential building permits and demolition permits. This exercise aimed to visualize the damage path through the centerline and the periphery using only permit data.

3 Results

3.1 Permit issuance by type and damage zone

Each permit type was plotted in a GIS to examine the spatial distribution of the data in the damaged area. The two damage zones used were limited (L1) damage and catastrophic (L4) damage. The middle categories of moderate (L2) and extensive (L3) damage were not mapped here, as the L4 area covered much of the overall damage zone. When overlaid on the other four damage types, L2 and L3 are visible (Fig. 2). However, L1 damage was distinct in appearing on the edges of the most heavily damaged areas (Paul and Stimers 2012). Since those two damage types covered the majority (89.3%) of the damaged area as defined by all census blocks with at least one damage point recorded by FEMA in 2011, and each represented one of the two extremes of

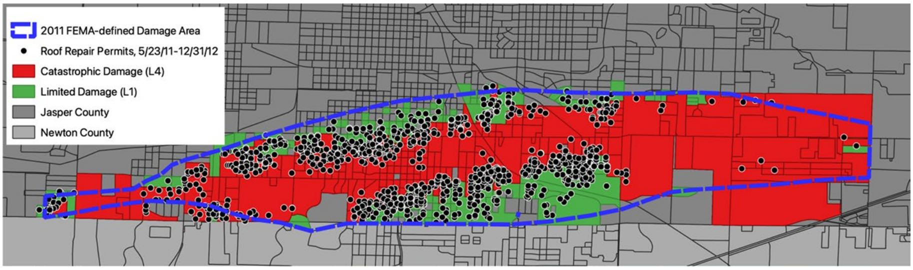

Fig. 3 Roof repair permits, 2011–2012

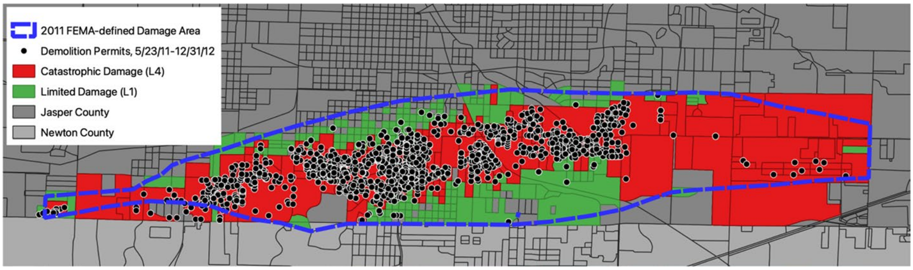

Fig. 4 Demolition permits, 2011–2012

the spectrum of damage, as defined by FEMA, the locations of permits, were examined concerning those areas alone.

3.1.1 Roof repair permits

Permits issued for roof repair or replacement were examined from May 23, 2011–December 31, 2012 (Fig. 3). In this permit category, a large portion of the permits were issued in the approximately 1.5-year period following the event. By the end of 2012, 80.8% of all roof permits for the 2011–2020 study period had been issued (Table 1). However, the value of 80.8% was based on a total count of 1366 permits issued from May 23, 2011–December 31, 2020. Notably, in 2017–2020, the number of roof permits increased considerably from previous years owing to hailstorms that occurred within the area defined by the 2011 tornado. The increase over those years was statistically significant ($p < 0.05$) based on a chi-square analysis of the pre-event data in and out of the damage zone for roof repair compared to the post-event data for the same type and period. Thus, if the period 2017–2020 data is replaced with the mean of the preceding 4 years, then the percentage of permits issued by December 31, 2012, equaled 90.8, within 1.2 percentage points of the demolition issuance percent for the same period. Of all roof permits, 90.4% were issued in a census block with at least one L1 (limited damage) data point in 2011, essentially displaying an inverse relationship to demolition permits. Conversely, 54.2% of all roof repair permits were issued in a census block containing at least one L4 (catastrophic damage) data point; this indicated that

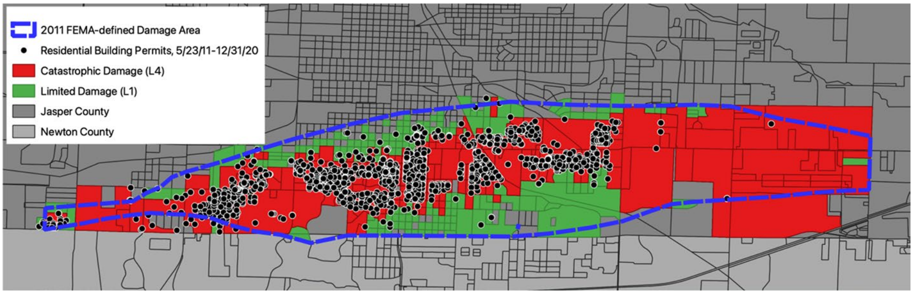

Fig. 5 Residential building permits, 2011–2020

most of the roof repair work occurred along the edges of the tornado path, where damage should be lighter overall than might found along either side of the tornado's centerline (Simmons and Sutter 2012; Turner and Hacker 2011).

3.1.2 Demolition permits

Figure 4 illustrates the count of demolition permits issued over the same post-event period as roof repair permits, May 23, 2011–December 31, 2012; 89.6% of all demolition permits from 2011–2020 were issued over roughly 1.5 years (Table 1). It was assumed that the concentration of permits in the first 2 years of recovery indicated a major rush to tear down buildings and clear lots to remove debris (destroyed structures) or remove structures that could not be salvaged. Appearing mainly in the catastrophic damage area, 93.0% of all demolition permits issued in the specified time frame were in a census block containing at least one catastrophic damage point (Table 2). Moving outward from the centerline, far fewer permits were issued in areas described as limited in damage, with no catastrophic overlap. Removing the catastrophic layer to expose all census blocks with at least one data point marked as limited damage, just 44.4% of demolition permits were issued over those census blocks, indicating that the path of most significant destruction can tacitly be observed through plotting the demolition permits in the 17 months immediately following the event.

3.1.3 Residential permits

The issuance of residential building permits (Fig. 5) follows a pattern that is predictably close to that of the demolition permits. From May 23, 2011–December 31, 2021, 1721 residential building permits were issued, with 75.2% of those issued by December 31, 2015 (Table 1). Unlike roof repair, housing reconstruction and recovery should proceed slower due to the increased workload of building an entire structure as opposed to repairing or replacing just one component (the roof) of an existing structure. Roof repair aligned with the second Kates (1977), a model under which roof repair aligned with the second phase termed *restoration*, and lasting approximately 20 weeks post-event, through the third phase called *reconstruction* I, lasting up to about 4 years post-event (Fig. 5). Kates described the *reconstruction* I phase as rebuilding or replacing to pre-disaster levels or greater; repairing a roof falls under those descriptions. However, housing stock recovery aligned with the

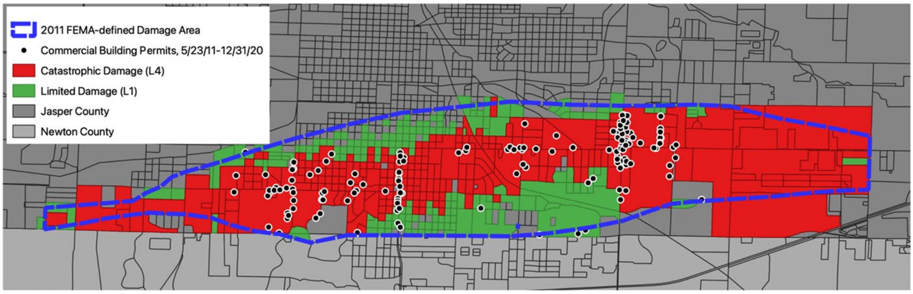

Fig. 6 Commercial building permits, 2011–2020

third and fourth phases (*reconstruction* I and *reconstruction* II) described by by Kates as major reconstruction, improvement, and development. Those descriptors also appeared to fit the Joplin housing recovery process. During the roughly 10-year period following the event, 90.1% of all residential construction permits were issued in a catastrophic damage zone compared to 42.5% in a limited damage zone (Table 3). While not exact, these residential building permit values are effectively reversed compared to demolition permit issuance when examined based on damage zones L1 and L4 (limited and catastrophic; Tables 2 and 3).

3.1.4 Commercial permits

Lastly, commercial building permits (Fig. 6) were examined for the period May 23, 2011–December 31, 2020. Reaching roughly three-quarters (73.5%) of the 170 total permits issued by 2014, commercial building was mainly undertaken over the same period as was residential building. Commercial permits were concentrated along pre-existing business corridors in the damaged area's west, west-central, and eastern portions. By damage level, 88.8% of all commercial permits were issued in a census block with at least one L4 (catastrophic) damage point in 2011. For census blocks that recorded at least one L1 (limited) damage data point, just 56.5% of commercial rebuilding permits were issued in those areas.

4 Discussion

The second stage of this analysis focused on mapping the permit types of roof repair, demolition, and residential to determine if the main path (L4, catastrophic damage) and the peripheral path (L1, limited damage) could be observed using only permit data (commercial permits were excluded as the small number of points was not enough to represent the path). Two maps are presented, first, roof repair permits along with demolition permits, and residential building permits mapped adjacent to demolition permits (with roof repairs for reference).

Fig. 7 Roof repair and demolition permits, 2011–2012

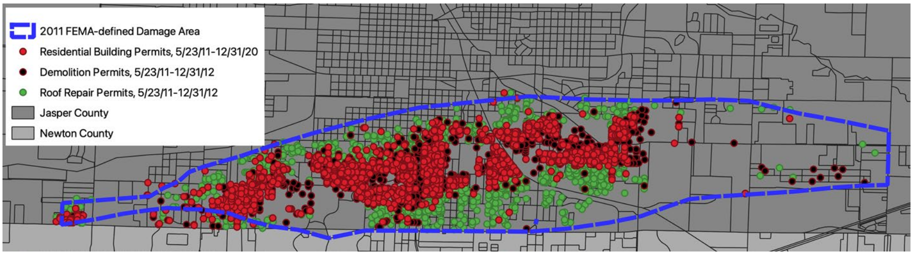

Fig. 8 Residential rebuilding 2011–2020, roof repair and demolition permits, 2011–2012

4.1 Roof repair permits and demolition permits as path descriptors

First, roof repair and demolition permits were plotted (Fig. 7). Demolition permits (May 23, 2011–December 31, 2012) ran along the path's centerline, describing the area of heaviest damage. Roof repair permits (matching period) skirted the catastrophic damage zone and mainly occupied the periphery as established by the demolition permits. The emergent pattern indicated that sufficient data on demolition permits in the wake of a significant tornado may act as a proxy for the zone of heaviest destruction, while roof repair permit data can be utilized to delimit the areas least affected by the event.

4.2 Residential building permits, roof repair permits, and demolition permits as path descriptors

Next, demolition and roof permits (again, from May 23, 2011–December 31, 2012; Fig. 8) were displayed alongside residential building permits (May 23, 2011–December 31, 2020). In a similar configuration, residential building permits gathered primarily in the center of the tornado's path and aligned well with the demolition data except for two noticeable pockets, one in the west-central and one in the east-central portion of the path—still-empty lots on which no rebuilding had occurred as of December 31, 2020 (verified by ground truthing, June 17–18, 2021). Roof repair data over the same period as above was again used here to display the peripheral areas where limited damage occurred.

Meyer and Hendricks (2018) examined data and photographs in a GIS from a fertilizer plant explosion in West Texas and arrived at conclusions similar to those here. As the extent of damage lessened beyond the hardest hit areas, they found that homes that were repaired 1 year later were the lesser-damaged structures, while those receiving more damage were the hardest hit by the incident. Nejat et al. (2020) built a model of post-disaster housing recovery in Staten Island, New York, in the wake of Hurricane Sandy. The authors intended to build a predictive model of post-disaster housing recovery decisions. Data such as the type produced by the present research could be used to calibrate such a model for local rebuilding knowledge. Combined with an understanding of spatiotemporal processes concerning the type of building more likely to take place in the short term, the Nejat et al. model could be applied to post-tornado disaster areas. The practical implications include adding these findings to on-ground assessments in disaster areas to better understand the future rebuilding needs following a tornado. Further, using these data with a space–time clustering model (Stevenson et al. 2010) could provide a wealth of information concerning the pace of rebuilding and guidance on where resources are likely to be needed should these data be applied in a predictive manner.

5 Limitations

While the Joplin event was massive and produced a large dataset of damage points and building permits following the event, limitations exist in this research. First, the Joplin datasets (Paul and Stimers 2011 2014 and present research) were the only ones used; thus, comparisons between this event and others are not yet possible. As such, the visual patterns found here may not be transferable to other locations. Tornadoes are unique, as is every community struck by one (Stimers and Paul 2016). For that reason, only a generalized understanding of these data emerged from this work. Further, as discussed in Methods and Materials, some data limitations arose during the cleaning phase. Due to the nature of the data rows removed (e.g., vague locations that could not be reconciled, data with a calendar year but no specific date, 0.7% of the data points that failed to geocode), this dataset does not represent 100% of all building permits issued during the study period. However, after the initial cleaning, of the 18,750 data points, just 446 were eliminated (2.4%) due to data quality issues.

6 Conclusions

The spatial and tabular data presented here showed that the commonly seen rebuilding activities of roof repair, demolition, residential rebuilding, and commercial rebuilding occurred at different phases of the recovery process, which encompassed both the extent of activity and the timeframe. In the aftermath of a major tornado that struck Joplin, Missouri, on May 22, 2011, roof repair permits concentrated mainly on the periphery of the catastrophic damage zones and occurred primarily within the 1.5-years following the event; this stands to reason as the peripheral areas typically witness far less damage than areas along the centerline of a tornado's path. Although pockets of extensive and even catastrophic damage occurred in Joplin along the periphery, such occurrences are owed to the wind speed vector addition phenomenon of vortices along the central vortex (Stimers 2021), which can result in small areas of massive damage nestled in far less-damaged sections. Also, the damage differential across space can vary widely based on the construction quality of the structures in the area (Burgess et al. 2014) and the building codes within that municipality (Ripberger et al. 2018).

In a near-dipolar relationship, the issuance of demolition permits occurred mostly within the zones categorized as catastrophic. Here again, most such permits were issued within 1.5 years immediately following the event. After the removal of debris and destroyed or unsalvageable structures, residential building permits stood as an extension of demolition permits, delimiting the most heavily damaged areas. On a much smaller scale, commercial rebuilding followed a similar pattern as residential rebuilding regarding its relationship to the catastrophically damaged areas. In using roof repair permits plotted along with demolition permits and again with residential rebuilding permits, the areas of most and least destruction became readily visible, supporting the assumption that permits whose scope of work is based on lesser damage can be used to visualize the spatial construct of the areas that received the least damage. In contrast, the removal and rebuilding of structures aligned with the areas upon which the most catastrophic damage was leveled.

These methods could be applied to other major tornado events to determine if these patterns manifest similarly (e.g., Hallam, Nebraska, 2004; Greensburg, Kanas, 2007; Parkersburg, Iowa, 2008; Tuscaloosa, Alabama, 2011; Moore, Oklahoma, 2013, the most recent EF-5 as of September 2022; SPC 2022). The data required for such an analysis, at least in part, is public record (permit data), although damage-related data may be more challenging to obtain. Hurricanes, floods, wildfires, and earthquakes are other disaster types that typically cover large areas. As such, it could be subjected to analyses as those presented herein to observe the rebuilding process and delimit components of that process using building permit data as proxies for damaged areas. Examining the rebuilding progress after significant disaster events is essential to understanding how a community responds to and recovers from a tragedy such as the May 22, 2011, Joplin tornado. Knowledge gleaned from such analyses can be used to understand better the needs of other communities beset with destructive occurrences stemming from the intersection of humans and the environment.

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Code availability Not applicable.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval Not applicable.

Additional declarations for articles in life science journals that report the results of studies involving humans and/or animal Not applicable.

Consent to participate Not applicable.

Consent for publication Consent is provided.

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