Working Paper Proceedings

Engineering Project Organization Conference
Cle Elum, Washington, USA
June 28-30, 2016

Construction Capacity: The Role of Regional Construction Supply Chain Resources in Post-Disaster Rebuilding

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CONSTRUCTION CAPACITY: THE ROLE OF REGIONAL CONSTRUCTION SUPPLY CHAIN RESOURCES IN POST-DISASTER REBUILDING

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ABSTRACT

There is a need to better understand the capacity of the U.S. construction industry to rebuild post-disaster, when there is increased demand for construction resources. The current U.S. residential housing stock is particularly vulnerable to wind damage, with tornado events causing catastrophic damage to homes each year. A method is proposed to analyze *construction capacity*, defined for the first time here as the maximum building volume a regional construction industry can supply with available resources. Building on prior literature from construction supply chain management and supply chain risk management theories, salient regional supply chain elements are proposed (including both material and labor resources) that affect construction capacity. In addition, a method is proposed to analyze this capacity of communities that have been struck by recent tornado events to confirm if the anticipated construction capacity was able to meet the anticipated demand for replacement residential housing units. The corresponding research question addressed by this paper is: *how can pre-disaster construction capacity be measured based on regional construction industry supply chain resources?* Understanding construction capacity will ultimately assist communities in pre-disaster planning and resiliency efforts and may also improve coordination with local construction industry businesses and suppliers. In addition, the research will extend construction supply chain management theory by examining construction supply chains at the regional rather than project level. This research will also add to existing supply chain risk management theory by analyzing pre-disaster regional construction supply chain coordination mechanisms.

KEYWORDS: Construction Capacity, Regional Supply Chains

INTRODUCTION

Over the past decade, the United States has been one of the top five countries in the world most frequently struck by natural disasters, resulting in damaged physical infrastructure and associated financial losses (Guha-Sapir et al. 2015). Aggregate property damages in the U.S. have risen exponentially, alongside increases in the overall population and new residential housing development projects in communities across the country (Kates et al. 2006). In order to facilitate post-disaster reconstruction of physical infrastructure, the U.S. construction industry must have the capacity to respond to sudden increases in demand for construction services by providing an adequate supply of material and labor resources to communities devastated by natural disasters. Here, we introduce and define the term *construction capacity* as the maximum building volume a regional construction industry can supply with available resources. We theorize that construction capacity determines how quickly physical infrastructure can be rebuilt in a post-disaster community. Since disaster recovery is typically implemented and managed at

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both the local and regional levels (Cantrell et al. 2012), it is imperative that we analyze construction capacity at a regional level.

Within the U.S., one type of disaster event, tornadoes, continues to increase in frequency, with 14 additional tornadoes recorded each year (Maynard et al. 2013). Recent unprecedented outbreaks of tornadoes across the U.S. have revealed the existing residential housing stock to be particularly vulnerable to wind damage associated with storms that produce tornadoes. This is particularly troubling since, according to the U.S. Department of Housing and Urban Development, “residential housing is the key component to the long-term growth and survival of American communities” (Cantrell et al. 2012). After catastrophic disasters such as tornadoes, displaced homeowners often spend months living in temporary housing, disrupting community economic and social infrastructures (Soden et al. 2015; U.S. Department of Housing and Urban Development 2012). This leads local residents to feel a sense of urgency to rebuild the residential housing stock (Godschalk 2003; Kates et al. 2006; King 2000).

Although the construction industry plays a critical role in repairing and replacing residential homes destroyed by natural disasters, there remains a lack of pre-disaster planning and coordination between local governments, homeowners, and their local construction industry. One important planning consideration is pre-disaster construction capacity, which is a key determinant of how quickly residential homes can be rebuilt following a disaster such as tornado. However, construction capacity is limited by the availability of regional construction industry resources (U.S. Department of Housing and Urban Development 2012). Supply chains, defined as an integrated series of processes and businesses that work together to provide a forward flow of materials, labor, or services (Chen et al. 2000), facilitate resource sharing within regional construction industries. We propose a method to define and measure pre-disaster construction capacity quantitatively by defining the regional construction supply chain resources, both labor and materials, which drive the U.S. residential construction market. Additionally, we quantify the pre-disaster demand for residential buildings to assess whether the existing construction capacity would be able to meet post-disaster building demands. Through quantitative analysis, we aim to examine how regional construction industries, and their associated supply chain resources, can meet fluctuating post-disaster residential building demands. To this end, we seek to answer the following research question: ***How can pre-disaster construction capacity be measured based on regional construction industry supply chain resources?***

POINTS OF DEPARTURE

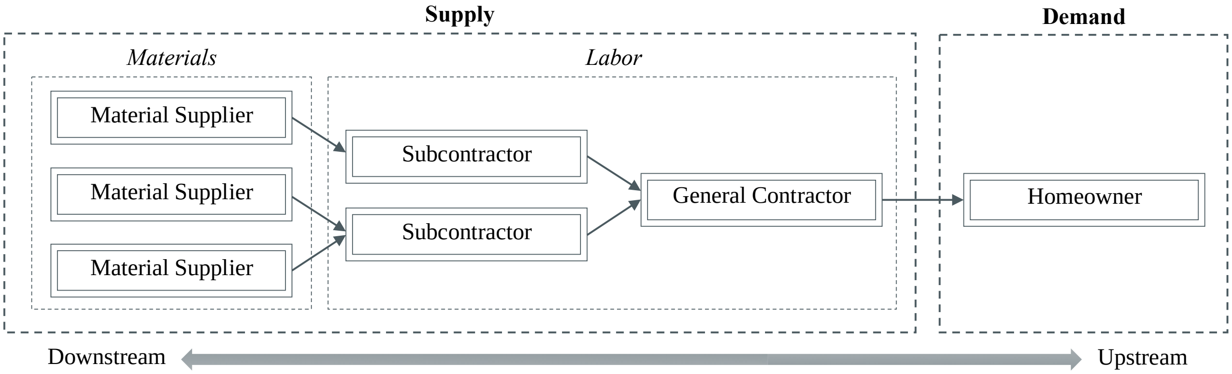
Two theoretical frameworks are developed building on a foundation of industrial and logistics research, namely the concept of construction supply chain management theory and supply chain risk management theory.

Construction Supply Chain Management Theory

Modern supply chain research began during World War II, as the need for efficient military supply chain logistics became a strategic analysis tool (Chen and Paulraj 2007). Since then, it has become increasingly standard practice to address supply chain challenges using an integrated framework of industrial and operational logistics studies; this combined research area is today referred to as ‘supply chain management’ (Chen and Paulraj 2004). Supply chain management has been used to explain how the network of materials, labor, information, and services within a supply chain affect the logistics of supply and demand (Veinott 2013). Traditional supply chain management studies have primarily investigated individual processes within a supply chain, although there has been increasing attention paid to more holistic examinations of the performance of the entire supply chain (Dike and Kapogiannis 2014; Pryke et al. 2014). Such analysis represents a major shift in modern business management strategies by recognizing that the ability of individual firms to supply services is intrinsically tied to a network of larger supply chain resources.

However, the use and implementation of supply chain management concepts remains underdeveloped in many professional fields, including construction. Within the construction industry, the project level has traditionally been the focus point for supply chain management research. Past studies of construction supply chains have examined supply chains almost exclusively from the perspective of an individual construction firm or a single building project (London 2008). A key concept of construction supply chain theory is that project owners and developers are ‘upstream’ in the supply chain, and their demand for construction services must be met by the ‘downstream’ supply of material and labor suppliers. The availability of downstream supply chain resources reflects the overall capacity of the network to provide construction services to others (Croom et al. 2000), as shown in Figure 1.

Figure 1. Project-Level Construction Supply Chain



Recent research into construction supply chains has indicated that the construction industry is influenced by factors beyond the level of an individual firm or single project (Chen and Paulraj 2004, 2007; London 2008). The fragmented nature of the construction industry, composed of numerous interconnected organizations spread across wide geographical areas, suggests that a broader regional perspective provides a more realistic examination of how the construction industry operates (London and Kenley 2001). Clusters of building projects and firms within a local construction industry are intrinsically linked together due to shared competition over limited resources. Regional construction industry supply chains are therefore critical to understanding the ‘real life’ interactions between material suppliers, laborers such as subcontractors and general contractors, and residential homeowners. However, little research exists regarding broader regional level construction supply chains. London (2008) suggests that examinations of regional supply chains have not been adequately studied, and are where the least amount of research has been done regarding supply chain concepts. This lack of regional examinations of construction industry supply chains is, in part, due to the fact that it is difficult to model or show what currently exists above the project level (O’Brien et al. 2004). In fact, London (2008, pg. 29) states, “although attempts have been made to use the industrial clusters of firms and firm networks concept to inform construction industry policy, there has been little formal attempt to examine the potential of a supply chain procurement model as an economic tool or instrument”. Advances in methods of measuring supply chain resources and the use of theoretical models to improve our understanding of relationships within regional supply chains are still needed (Pryke et al. 2014). Measuring pre-disaster supply chain resources and identifying pre-disaster organizational relationships within an existing construction supply chain provides a framework for quantifying regional construction capacity.

Supply Chain Risk Management Theory

The concept of managing risks within a supply chain was first popularized in the U.S. by the insurance industry in an effort to calculate the probability that policies would need to be paid out (Essig et al. 2013). Today, the use of risk management concepts to prevent supply chain disruptions and breakdowns are commonly used in many sectors of the economy. Past research indicates there are two major categories of risk that hinder effective supply chain management: 1) *lack of coordination between supply and demand* (where suppliers are unable to anticipate or meet the demands of the end users), and 2) *disruptions to normal supply chain operations and activities* (such as the upheaval caused by natural disasters) (Kleindorfer and Saad 2005).

Lack of Coordination Between Supply and Demand

Disaster events reduce effective information sharing and coordination efforts (Arneson et al. 2016; Doerfel et al. 2013). However, increased coordination among organizations within a supply chain has been found to reduce both uncertainty and variability throughout the network (Bernstein and Federgruen 2005; Chen and Paulraj 2007). In fact, the sharing of upstream demand information with downstream suppliers, along with coordinated planning efforts across the supply chain, is necessary for regaining control of supply chain efficiency (Lee 2002). Supply chains are more likely to remain functional after a natural disaster when there is an established information sharing and coordination system between upstream and downstream organizations (Frohlich and Westbrook 2001; Tsiakis et al. 2001). Therefore, analysis of pre-disaster supply chain coordination mechanisms is necessary for suppliers to anticipate and meet the needs of customers in a post-disaster setting.

Disruptions to Normal Supply Chain Operations and Activities

The literature on how supply chains react due to fluctuating or uncertain demand conditions is sparse (Bernstein and Federgruen 2005). Sometimes described as a time of ‘punctuated equilibrium’ (Gersick 1991; Lindell and Prater 2003), disasters have the ability to temporarily alter how supply chains function. Such perspectives explain that communities often remain relatively stable (equilibrium) for long periods of time, and then experience rapid and compact (punctuated) moments of upheaval, often triggered by external environmental conditions such as natural disasters (Kendra and Wachtendorf 2003; Lindell and Prater 2003). Although normal supply and demand coordination risks have been studied extensively in the supply chain management literature (Essig et al. 2013; Fisher et al. 1997; Lee 2002; Pang et al. 2014; Saad and Siha 2000), the effect of sudden disruptions, such as those caused by natural disasters, has not been adequately addressed.

PROPOSED RESEARCH METHODS

The purpose of this research was to determine and evaluate elements of regional construction supply chains that influence the ability of local construction industries to replace damaged residential housing stock after natural disasters. This research proposes to study construction capacity in the context of recent natural disasters, specifically tornado events across the Midwest U.S. that have occurred since 2010.

Research Context: Post-Tornado Reconstruction

The U.S. experiences more tornadoes than any other country. Large portions of the U.S. are affected by the severe thunderstorm events that can lead to the formation of tornadoes, especially areas East of the Rocky Mountains (Tippett and Cohen 2016). Over the past decade (2005-2014), U.S. tornadoes have resulted in an average of 110 deaths per year and financial losses ranging from 500 million to 9.6 billion U.S. dollars (NOAA 2015). With increasing urbanization, tornadoes are statistically more likely to hit densely populated areas and destroy large areas of physical infrastructure. This is borne out in the data, as financial losses associated with these storms have risen exponentially in the past decade; it is now commonplace to see over a billion dollars in aggregate economic damage from a single tornado season (Smith and Matthews 2015).

The nature of tornado storm events is also changing, with more ‘supercell’ events taking place. Supercell thunderstorms develop when separate low-pressure systems collide, creating unstable rotational wind shears, capable of spawning a tornado outbreak (NOAA 2015). A tornado outbreak is broadly defined as a cluster of tornadoes associated with a single large-scale weather system (Fuhrmann et al. 2014). These outbreaks often occur over large geographical regions, resulting in a number of tornadoes destroying infrastructure across a widespread area. Additionally, the number of large thunderstorms capable of producing supercell outbreak events has increased in frequency in the past decade, as have the number of reported tornado occurrences (Fuhrmann et al. 2014). Once considered low-probability events, the incidence of these catastrophic events has progressively increased, resulting in a current average of 1200 tornadoes annually (Maynard et al. 2013).

High winds associated with supercell outbreaks tend to cause severe damage to non-engineered buildings, such as residential homes. Historically, the bulk of wind damage in the U.S. has occurred to wood-framed residential construction, due in large part to less stringent construction codes and minimal structural connection requirements (Marshall 2014). Specifically, the majority of damages occur in buildings made from light-frame timber construction, the most common way American homes have been built since the early 20th century (Liu et al. 1989). In fact, 90% of the residential building stock in the U.S. is comprised of light-frame wood construction (Ellingwood et al. 2004; Standohar-Alfano and van de Lindt 2015), which is extremely vulnerable to wind loads associated with even the weakest of tornadoes. It is therefore imperative that the construction industry be capable of quickly replacing destroyed residential buildings, especially in the aftermath of widespread destruction due to wind damage associated with tornadoes.

Data Collection

The proposed research involved a two-phase, mixed methods approach. First, we reviewed existing literature to determine standard building materials and construction methods currently used in the U.S. residential housing market (Cope 2004; Marshall 2014; Sparks et al. 1994). The American Housing Survey, the most comprehensive housing survey conducted in the U.S., provided additional data regarding the quantity, physical condition, age, and structural framing components of the current U.S. residential housing inventory (U.S. Census Bureau 2015b). Second, quantitative data sets regarding regional construction industry supply chains, including material and labor availability, were collected from publicly available national databases (U.S. Bureau of Economic Analysis 2016; U.S. Bureau of Labor Statistics 2016; U.S. Census Bureau 2012, 2016a; b). These data will be used to identify the capabilities of regional construction supply chains to meet the local demand for new residential housing, known as *construction capacity*.

U.S. Residential Building Stock

Regional construction supply chains that support the U.S. housing industry are comprised of the material suppliers and laborers involved in the building of residential homes. For this research, we first identified the primary building components used in U.S. residential construction industry: structural framing, exterior cladding, and non-structural elements. We specifically examined residential construction standards in the Midwest, the geographic region of the U.S. most vulnerable to tornadoes and associated wind damage.

The main structural framing material used in residential construction is dimensional lumber, used in conjunction with other wood products such as: plywood sheathing, laminated lumber and beams, and oriented strand board (OSB). In fact, 99% of the current Midwest housing stock is comprised of wood framed buildings (Ellingwood et al. 2004; U.S. Census Bureau 2015a). The most common exterior cladding materials found on Midwest homes is broken down as follows: 60% vinyl siding, 14% brick, 12% wood, 9% cement fiber, 3% other (aluminum, concrete block, or stone), and 2% stucco (U.S. Census Bureau 2015a). Other non-structural building components are also used to enclose a residential building and make it habitable, including: concrete, roofing, windows, and doors (Bradtmueller and Foley 2014; U.S. Census Bureau 2015a).

Regional Construction Supply Chain Boundaries

In order to identify the construction capacity within a regional construction supply chain, the geographical areas of the regions must first be established. Although construction supply chain management theory suggests that regional supply chains are the appropriate level to fully understand how the construction industry functions, there is no universal delineation or boundaries to define a ‘region.’ In order to systematically analyze regional construction supply chains in the U.S., this research incorporates economic areas already established by the U.S. government. The U.S. Bureau of Economic Analysis (BEA) has designated 179 regional economic area markets within the United States, based on strong linkages between businesses, transportation routes, social networks, and economic development (Delgado et al. 2016; Porter 2003; U.S. Bureau of Economic Analysis 2016). These regional economic areas each contain a major metropolitan statistical area as defined by the U.S. Office of Management and Budget

(OMB) in February 2004, based on the 2000 census population data. Major metropolitan statistical areas are considered critical hubs of economic activity for multi-county areas within the U.S. Counties surrounding major metropolitan statistical areas, with strong business ties and shared regional markets for labor and materials, are grouped together into regional economic area markets based on statistical analyses conducted by the BEA (Johnson and Kort 2004). For example, Oklahoma City is the largest metropolitan statistical area in the state of Oklahoma, and is the hub of one such regional economic area. The region extends across the western two-thirds of the state and is comprised of 51 counties in Oklahoma, Kansas, and Texas. Counties within this region have a history of inter-county trade and business ties, similar business industries, and similar economic indicators such as employment rates and personal income (Delgado et al. 2016).

Regional Construction Supply Chains for Residential Construction

Regional material availability is a key component of pre-disaster construction capacity. The number of material manufacturers, suppliers, and retailers within a region dictates how many building units can be constructed. In order to determine which material suppliers are integral to regional construction supply chains, the primary building components used in residential construction must be identified. The location and number of employees for all U.S. construction firms, subcontractor firms, and material suppliers are tracked by a variety of government and private sources (Johnson and Kort 2004; ReferenceUSA 2016; U.S. Bureau of Economic Analysis 2016; U.S. Bureau of Labor Statistics 2016; U.S. Census Bureau 2016b).

Regional labor availability is also an important element of construction capacity. The number of general contractors and subcontractors within a geographic area drives available labor within a regional construction supply chain. For example, when a tornado strikes a residential neighborhood, many homes are destroyed by wind damage and must be replaced. The demand for post-disaster construction services suddenly increases, with multiple building projects occurring simultaneously and competing for locally available labor (U.S. Census Bureau 2016a). For a breakdown of sources used to facilitate data collection regarding regional supply chain materials and labor, see Table 1.

Table 1. Construction Capacity Data Collection

Data Sources	*Data Source Description*
Reference USA	43 million U.S. businesses (by location), including construction industry material & labor suppliers
State Dept. of Transportation	Concrete batch plant database (by location, per state)
2000 U.S. Census	Database of all U.S. construction industry businesses (by location), including self-employed. Includes all businesses which reported taxable earnings since 2000
2013 County Business Patterns	Database of U.S. businesses, including construction industry (by U.S. county location)
U.S. Bureau of Labor Statistics	Construction industry employment numbers (by U.S. county location)
U.S. Bureau of Economic Analysis	Defines 179 regional economic area markets in the U.S., including construction industry specific data

Analysis

Studying pre-disaster construction capacity from a supply chain management viewpoint allows us to analyze the network of existing construction resources. By understanding the baseline pre-disaster construction capacity available before a disaster strikes, communities can determine if their local construction industry has enough resources to quickly rebuild permanent residential housing in a post-disaster setting.

Supply

The regional availability of material and labor resources determines downstream supply within a construction supply chain. The data sources in Table 1 provide the quantity of material manufacturers, suppliers, and distributers (number of firms) and the quantity of general contractor and subcontractor labor (number of employees). For the purpose of this research, only firms providing materials necessary to build and fully enclose a structurally sound residential home in the Midwest region of the U.S. are considered. This includes the number of firms supplying materials such as: roofing shingles, dimensional lumber and pre-fabricated wood trusses, plywood sheathing, vinyl or composite siding, brick veneer, exterior doors and windows, as well as concrete. Labor resources are quantified based on the number of employees, including both self-employed contractors and employees working at a construction firm. This includes the number of employees working as: *general contractors, roofing subcontractors, wood framing subcontractors, glazing and window subcontractors,* and *masonry subcontractors.* These numbers are broken down by U.S. County, and can therefore be used to find the total material and labor employment numbers for any regional economic area. This baseline supply within a regional construction supply chain is calculated for the year 2010, the most recent comprehensive U.S. Census data available.

Demand

In order to quantify both the pre-disaster and post-disaster demand for construction services within an economic region, this research will examine the number of residential permits typically issued and the total number of residential housing units within a given region. The U.S. Census Bureau conducts yearly construction permit surveys, to calculate the total number of residential construction permits issued each year (U.S. Census Bureau 2016a). For example, the number of residential permits issued within an economic region in 2010 represents the total building projects undertaken that year. Therefore, construction capacity can be calculated based on the number of permitted projects the locally available materials and labor were able to supply within the region. This provides a baseline pre-disaster construction capacity calculation that can be conducted for any of the 179 economic regions within the U.S., based on 2010 Census data.

Additionally, the total number of residential housing units per city, county, and state is also collected by the U.S. Census (U.S. Census Bureau 2016a). This data can be used to provide communities with predictive models regarding regional construction capacity. For example, if an economic region has a total of 50,000 residential housing units, we can calculate how many homes would be damaged or destroyed if a tornado event wiped out 1%, 3%, or 5% of the regional housing stock. If 3% of the homes in the region are destroyed by a tornado (1,500 houses), but the region only issues 800 residential permits in a typical year, then the community can anticipate a gap between the pre-disaster regional construction capacity and the post-disaster rebuilding needs.

Validity

In order to confirm if pre-disaster regional construction capacity, as determined using proposed methods outlined in this paper, accurately reflects actual post-disaster conditions on the ground following a tornado event, this research proposes examining case study communities in a number of economic regional areas in the U.S.

Case Study Communities

As part of this study, the research team is currently tracking 3 communities in Nebraska and Oklahoma, all of which were devastated by tornadoes in the past 4 years, and are currently involved in the process of rebuilding residential housing that was destroyed by tornado related wind damage. Each community is located in a different regional economic area as defined by the BEA and has varying population size. However, all communities were struck by an EF-4 tornado (with wind speeds of 166 – 200 mph) or EF-5 tornado (with wind speeds of over 200 mph). Residential homes taking a direct hit by this strength of tornado experience catastrophic damage, lose structural integrity, and must be completely rebuilt (Marshall 2014). For a breakdown of the case study communities, see Table 2.

Table 2. Case Study Communities

Location	*Population*	*Tornado Event*
Pilger, Nebraska	~ 350	2 separate EF-4 tornadoes in June 2014
Wayne, Nebraska	~ 5000	EF-4 tornado in October 2013
Moore, Oklahoma	~59,000	EF-5 tornado in May 2013

Case Study Analysis

According to the U.S. Bureau of Economic Analysis (Delgado et al. 2016; U.S. Bureau of Economic Analysis 2016), Pilger, Nebraska and Wayne, Nebraska are located within the 'Sioux City regional economic area market.' This region contains 23 counties in Nebraska, South Dakota, and Iowa, as shown in Figure 2. Sioux City, Iowa is the largest metropolitan area within the region, and is a hub for transportation routes, material suppliers, and construction workers. The city of Moore, Oklahoma is located within the 'Oklahoma City regional economic area market,' as shown in Figure 3. The Oklahoma City economic region is quite large geographically, comprised of 51 U.S. counties in the states of Oklahoma, Kansas, and Texas. As the biggest metropolitan area within Oklahoma, in terms of population, Oklahoma City is a huge driver of economic growth throughout the entire region.

Identification of the pre-disaster construction capacity for each of these regions can be measured and quantified using publicly available data sets. The case study regions can then be used to examine the actual pre-disaster regional construction supply chain and the post-disaster housing needs recorded after a tornado event. The anticipated construction capacity can then be validated through comparison with the case study regions.

Figure 2. Sioux City Economic Region

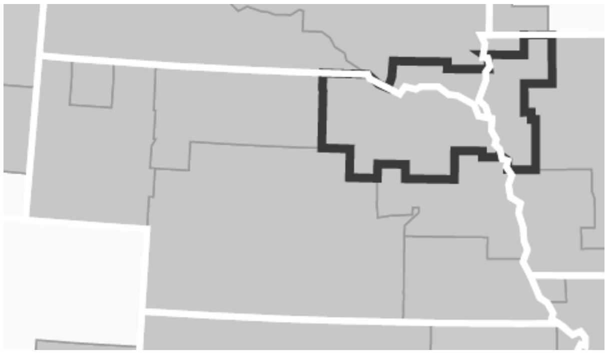
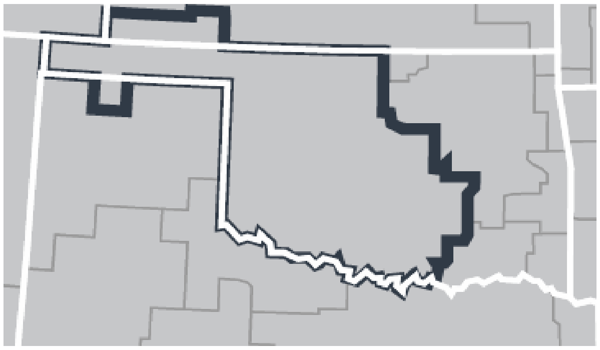


Figure 3. Oklahoma City Economic Region



In order to determine the pre-disaster construction capacity, the regional construction supply chain resources were identified. For example, according to the 2010 U.S. Census data, the total population for the Oklahoma City region is 2,060,174 people (U.S. Census Bureau 2012). The economic region has a strong construction industry, with 5.08% construction industry growth rate and 197 total businesses providing subcontractor and general contractor services in the area. Table 3 indicates the pre-disaster construction capacity elements (in terms of material and labor resources) that existed within the Oklahoma City economic region in 2010.

Table 3. OKC Regional Construction Supply Chain

Materials	*Number of Firms*
Roofing Shingles	124
Dimensional Lumber & Trusses	298
Plywood Sheathing	124
Siding	10
Brick Veneer	107
Exterior Windows & Doors	4
Concrete	5
Labor	*Number of Employees*
General Contractors	3704
Roofing Subcontractors	2152
Framing Subcontractors	355
Glazing and Window Subcontractors	522
Masonry Subcontractors	1019

These regional construction industry resources represent the maximum available downstream supply capable of meeting the upstream demand for construction services, otherwise known as construction capacity. The material suppliers, general contractors, and specialty subcontractors were able to supply a large number of residential housing units in the region in 2010 (the latest Census data year). Specifically, in 2010 there were 6,866 residential construction permits issued for the counties located within the Oklahoma City economic region (U.S. Census Bureau 2016a). These permits represent the pre-disaster regional demand, and provide a baseline number for the amount of residential construction taking place in the region at that time.

In contrast, there were 10,892 residential permits issued in the Oklahoma City economic region in 2013, following a devastating EF-5 tornado supercell event. This 59% increase in residential housing demand produced competition for locally available materials and labor. According to damage surveys conducted in the months following the Moore, Oklahoma tornado, approximately 12,000 residential homes were damaged or destroyed due to the high wind speeds and wind-borne debris associated with the tornado (Marshall 2014). The Oklahoma City economic region contained a total of 900,886 residential housing units in 2010 according to the U.S. Census (U.S. Census Bureau 2012). Thus, the May 2013 supercell storm spawned a single tornado that destroyed over 1% of the Oklahoma City economic region's total residential housing stock in a matter of minutes, doubling the demand for construction services in the area.

The collection and analysis of pre-disaster residential housing supply and demand, in case study regions such as the Oklahoma City economic area, allowed us to begin to quantify the pre-disaster regional construction capacity. Regional construction supply chains determine regional construction capacity, support the residential construction industry, and are comprised of critical material suppliers and construction workers. The standard building methods and materials used on residential construction projects determine which material and labor resources are integral to regional construction supply chains. Comparison of pre-disaster regional construction capacity and post-disaster demand for construction services determines if the regional construction supply chain is capable of quickly rebuilding the residential building stock.

CONCLUSIONS AND RELEVANCE

The need for regional-level disaster preparedness planning, to address the challenges faced in quickly replacing physical infrastructure after a disaster, must become a priority for communities and the regional construction industries that serve them. Supercell thunderstorm events continue to increase in frequency across the Midwest U.S., spawning tornado outbreaks and causing severe financial losses. The majority of U.S. homes are made of structural wood framing elements that are particularly vulnerable to wind damage, and high wind speeds associated with tornadoes pose a threat to the U.S. residential housing stock. Pre-disaster regional construction supply chain resources either facilitate or hinder post-disaster rebuilding efforts. To further understand the role of construction supply chains in disaster recovery, we ask the research question: how can pre-disaster construction capacity be measured based on regional construction industry supply chain resources?

We propose a method to measure pre-disaster *construction capacity*, based on regional construction industry supply chain resources. Construction capacity is defined here for the first time as the maximum building volume a regional construction industry can supply with available resources. This study intends to provide a framework for analyzing and understanding how regional construction supply chain resources, including labor and materials, impact construction capacity and thus the ability of communities to quickly rebuild damaged residential construction in tornado prone regions of the U.S. This research will add to the limited existing literature regarding construction supply chain management theory, by identifying construction capacity as a key component of effective post-disaster regional supply chains. It will also add to supply chain risk management theory by analyzing how sudden unexpected increases in construction demand, due to a natural disaster, can disrupt the regional supply chain. In terms of practical implications, this study is intended to provide a framework for communities to assess their ability to rebuild residential construction after a tornado event. More importantly, the research should serve as a tool to begin a dialogue between local communities and the regional construction industries that provide needed building services.

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