Making Room for Manufacturing:

Understanding Industrial Land Conversion in Cities

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ABSTRACT

Problem: Cities face a dual problem of growing inequality spawned by the loss of middle-income jobs as well as growing demand for urban living which drives up housing costs. As such, planners face a tension in dealing with the stock of urban industrial land. One the one hand, there is an argument for enacting industrial land preservation policies in order to protect the viable manufacturers which provide good jobs. Alternatively, attempts to limit conversion of industrial land may exacerbate the problem of affordable housing and cause cities to forgo growth in other sectors. Planners need better information on the underlying forces that lead to conversion of industrial land and an assessment of the effectiveness of preservation policies.

Research Strategy and Findings: We develop an index of vulnerability of industrial land that is based on location factors, neighborhood dynamics, detailed industrial trends, environmental hazards, and local regulations. We show for the cases of Cook County, IL and Mecklenburg County, NC how these factors can explain the conversion probability and how various industrial preservation polices are effective in limiting conversion. We use a logit model formulation with detailed parcel data and establishment time series data to derive the index of vulnerability.

Takeaway for Practice: This index can be used to strategically plan for which industries to target and which sites to preserve as industrial uses. The statistical models suggest that traditional planning and regulatory tools such as industrial zone designations do reduce conversion risk and factors such as transit accessibility increase the probability of conversion. We argue that local governments should be strategic about which manufacturing industries can be preserved at what locations using these tools. We also develop and demonstrate an open source interactive web-based tool that demonstrates some of the key concepts that can be replicated in other places.

KEYWORDS: Industrial land preservation; manufacturing; land-use policy; economic development.

Introduction

The restructuring of urban economies away from manufacturing and towards services results in highly bifurcated labor markets that generate few moderate income jobs for blue-collar workers. In addition, the growth of high-technology and skilled service sector jobs in cities has generated new demand for urban living, driving up housing prices. Thus, there is pressure to convert scarce urban land from industrial uses for either new housing or commercial uses. In some cities, planners have attempted to slow this transition by promoting "industrial preservation" policies that aim to retain a small, but vital stock of blue-collar jobs in manufacturing. However, industrial preservation generates clear trade-offs for local jurisdictions in the form of potentially forgone taxes and less space for housing. As the dual problems of labor market inequality and rising housing prices grow—especially in strong market cities like San Francisco, Portland, and New York—the question of how much industrial land should be preserved will continue to vex planners. While the zoning tools for industrial preservation have been used since the late 1980s, we still know little about their effectiveness, nor much about the factors that drive conversion of industrial land in the first place. To this end, we developed a model to predict the probability of land use change away from industrial uses. We find that industrial zone designations in plans and regulations do reduce the probability of conversion. We also offer an example of how such a model can be used to develop "smart" industrial preservation policies that target only the land that is most competitive for current industry needs.

Motivation and Research Questions

While the debate over industrial land preservation has waxed and waned over the past thirty years, several recent trends have put the issue back on planners agendas. First,

there is growing discussion nationally of the "return of manufacturing" as higher labor costs abroad, a weak dollar, and strong demand have improved the competitiveness of the U.S. as a production location. Indeed, manufacturing employment has grown by 729,000 jobs since the start of the recovery and exports of manufactured products have increased by 47 percent since 2009.[i] What is also surprising is the geographic imprint of this growth, with former rust-belt states such as Michigan, Illinois and Wisconsin taking part in this recovery along with growing states like North Carolina. While researchers continue to debate the magnitude and potential of the resurgence of U.S. manufacturing (Florida, 2013), some economic development planners are placing renewed emphasis on manufacturing and wondering if urban areas have enough available industrial land to gain from this turnaround (e.g. San Francisco Planning Commission, 2014).

The second trend that makes industrial land preservation a controversial issue is the increased demand for urban living. During the 1990s and 2000s, many large central cities experienced a resurgence of population and jobs based primarily the growth of high-technology and skilled service sector jobs that in turn generate a high number of entertainment and consumption-based jobs in and around industrial neighborhoods (Wyly & Hammel, 1999). The gentrification of urban neighborhoods that began in the 1980s and continued during the 2000s created pressure to convert industrial land to residential or commercial uses (Zukin, 1982).

One example from practice illustrates the tension cities face in attempting to preserve industrial land, while also attempting to encourage expansion of space for growing sectors of the economy such as high-technology office. San Francisco's planning commission is currently debating a proposal to modify the strict zoning requirements for Production, Distribution, and Repair (PDR) activities it set up in the Eastern Neighborhoods Plan in 2008.

Originally, all office and retail developments were banned in core PDR districts in order to protect manufacturing and related enterprises from rapidly rising rents. In March of 2014, the commission considered a proposal to allow vacant and marginally occupied buildings in PDR districts to be redeveloped into properties that contained up to 66 percent non-PDR commercial space. This change would explicitly create an internal cross-subsidy between higher rent office and retail spaces and lower rent PDR space meant to house, existing PDR companies. Specifically, the Planning Staff justify their recommendation of adoption by writing:

> The need for the legislation is based on the strong growth witnessed in the PDR sector over the last few years, and the desire to see this sector continue to expand and thrive. This growth is due, in part, to the demand created by our strong technology and tourism economies, which drive the need for services provided by businesses involved in distribution and repair. This growth is also due to the growth of our local manufacturing sector, which has increased in size over the past two years, after decades of decline. This growth has been spurred by the rise in artisanal manufacturing – a phenomenon being witnessed across the country, and which shows no signs of slowing down. The result of this growth is that PDR space is in high demand, vacancy is exceedingly low, and we are now seeing PDR companies leaving San Francisco because they cannot find space to expand.[ii]

This brief example illustrates the choices that planners must balance when considering policies to protect industrial land. One the one hand, the potential for growth in manufacturing nationally is attractive. However, it is possible that cities may be at a disadvantage in attracting these relatively high-paying jobs since available industrial land has been shrinking in cites.. Despite declines in manufacturing employment in North Carolina, the Charlotte Chamber of Commerce explicitly lists manufacturing as one of its targeted industries along with the new economic engines such as energy and life sciences.[iii] The state of Oregon, explicitly claims vested interest in discouraging conversion of prime industrial land because some of these sites have location characteristics that are not easily replicable.[iv] In this case, planners seeking to make room for manufacturing might seek to enact land-use policies aimed at preserving industrial land and promoting manufacturing.

On the other hand, it is important to remember that urban areas have been losing manufacturing jobs for decades and that some land may not be suitable for the specific

industrial sectors that are projected to grow. As Howland (2010)'s careful cost-benefit analysis shows, some cities may already have enough industrial land, and that redevelopment to other uses may be highly beneficial from a fiscal point of view. Before enacting policies that preserve industrial land homogeneously, it is critical that planners better understand the factors that lead to conversion and the effectiveness of policies to preserve industrial land.

Therefore, we address the following two broad research questions. First, what factors drive the conversion of existing industrial land to other uses? Second, are industrial land preservation policies, such as restrictive zoning in industrial corridors effective in limiting conversion? Specifically, we analyse the process of industrial land conversion at the parcel level and develop a method for planners to assess the vulnerability of existing industrial areas. We conduct our analysis on two central urban counties—Mecklenburg County, North Carolina and Cook County, Illinois. Unlike previous studies of industrial displacement, we develop a multifactor model that takes into account each parcel's location characteristics and neighborhood real estate dynamics as well as the regional competitiveness of manufacturing firms located within each parcel. Although our findings differ across the cases, we can conclude that real estate speculation in areas surrounding industrial land increases the risk of conversion and that industrial preservation policies, such as Chicago's Industrial Corridor (IC) program are effective in stemming the loss of industrial land.

Background and Literature Review

The state of urban manufacturing

As planners weigh the potential costs and benefits of preserving industrial land, it is important to understand the current role that the manufacturing sector plays within urban economies. Despite the long-term deindustrialization of urban areas, central cities still

maintain a large number of manufacturing firms and a large inventory of industrial land. Although large-scale, heavy manufacturing declined significantly in the 1980s and 1990s, central cities remain competitive locations for small and mid-sized manufacturing companies. Mistry and Byron (2011) estimate that approximately one third of the nation's small manufacturing establishments (under 20 employees) are located in the ten largest cities. Urban areas remain competitive locations for goods-producing firms for many of the same reasons that first brought industry to the city, including traditional location factors such as access to large markets, key transportation infrastructure, and pools of skilled labor and specialized suppliers (Alonso, 1995; Losch, 1995).

However changes in the nature of competition in goods producing sectors may also favour urban areas which can offer dense networks of competing and complimentary firms. Research on the competitiveness of regional industrial systems (Piore & Sabel, 1984; Scott, 1988) suggests that as transportation costs fell rapidly and global markets opened in the late 20th century, firm competitiveness was increasingly dependent on flexibility. For goods-producing firms, this meant an emphasis on just-in-time (JIT) production methods, which are, in turn, reliant on access to modern transportation nodes. Thus, while globalization and falling transportation costs have freed some large manufacturing plants from central cities, location factors such as the distance to rail, multi-modal depots, highway interchanges and airports and ports—and, more importantly, competitive clusters of complimentary establishments—are still important factors that affect the competitiveness of land for industrial use. In addition, dense networks of small firms are also associated with greater innovation as research indicates that knowledge spillovers play an increasingly important role in regional competitiveness (Cooke & Morgan, 1998; Saxenian, 1994).

Other scholars have emphasized the indirect role of manufacturing firms and the industrial land they occupy in enhancing the health of the overall urban economy. Chapple (forthcoming) analysed employment dynamics and job creation in four bay-area cities and found that the availability of affordable industrial space was essential in business expansions, which were a key component of overall job growth. Scholars have also pointed out that manufacturers and other users of industrial land—broadly defined as Production, Distribution and Repair (PDR)—produce key goods and services that are critical inputs to other sectors of the urban economy, including the construction and commercial sectors (Chapple, forthcoming; Howland, 2010).

Attracting and retaining manufacturing firms in cities is also attractive from the standpoint of job quality and equity. Despite recent accounts of the re-shoring of manufacturing amid significant wage reductions and two-tier union contracting, manufacturing continues to offer average annual wages that are 22.9 percent higher than the average private sector job.[v] Furthermore, jobs in manufacturing typically offer such wages without requiring an advanced degree, making these jobs an attractive match for urban areas with high unemployment among lower-skilled workers. In addition, as Howland (2010) points out, there may be other important reasons for industrial preservation including protecting healthy manufacturing firms from encroachment and preventing housing redevelopment on environmentally degraded land.

Industrial land conversion

Despite the factors that make urban areas attractive locations for manufacturing and planning efforts to preserve industrial land, the amount of land zoned for industrial uses continues to shrink. For example, industrial land shrank in San Francisco from 14 percent of total land area in 1948 to 4.5 percent in 2012 (Chapple, forthcoming). While much of this decline is understandable, given the long-term sectoral decline of manufacturing, even viable

industrial firms are sometimes threatened by displacement due to real estate pressures. The literature on industrial displacement dates back to the late 1980s and finds strong links between the conversion of industrial land—especially older multi-story loft buildings—and residential gentrification. Gilloth and Betancur (1988) document the displacement of viable manufacturing firms in the River North area in Chicago, which was immediately adjacent to the central business district and high-end residential communities. They highlight the role of selective rezoning of individual properties by local alderman. Curran (2007) documents a similar process of industrial displacement caused by residential gentrification in the Williamsburg area of Brooklyn. Also, Lester and Hartley (2014) conduct a quantitative analysis of 20 large cities and find that residential gentrification plays a catalytic role in speeding up the loss of manufacturing jobs relative to non-gentrifying areas. As such, we expect that land price appreciation in the neighborhoods surrounding industrial parcels, as well as the distance of each parcel from the central business district (CBD), will be key drivers of conversion (Dingle & O'Hanlon, 2009).

Planning responses and industrial preservation policy

The issue of industrial displacement spawned a variety of planning responses to preserve industrial land. Debate over the extent to which land-use policies can alter the economic structure of a given place has waxed and waned over the past several decades. Rast (1999) makes perhaps the strongest causal argument in his analysis of the anti-industry biases contained in Mayor Richard J. Daley's Central Area Plan of 1955, which he argues led to the displacement of thousands viable jobs in light manufacturing in and around the Loop. Paralleling this research was a policy agenda that began in the 1980s to "save" healthy manufacturing firms from displacement by real-estate speculation and conversion to residential or commercial uses. The Center for Community Innovation at UC Berkeley catalogued over 30 cities and states that have conducted industrial land use studies in recent

years suggesting that matching the supply and the demand for industrial land uses is a concern in practice.[vi] Some cities such as Chicago developed Planned Manufacturing Districts (passed in 1988), which entirely outlawed residential conversions and sought to buffer heavier manufacturing uses from residential with large-scale commercial development (Fitzgerald & Leigh, 2002; Leigh & Hoelzel, 2012). Chicago also created a set of designated Industrial Corridors in 1992 that covered a larger portion of the city. Industrial Corridor designation requires that a developer seeking a zoning variance for a non-industrial use must secure approval from the Plan Commission instead of simple aldermanic support. This is quite similar to 'Industrial Sanctuaries' policy adopted by the City of Portland. The Bloomberg administration in New York created Industrial Business Zones (IBZs) where residential uses are prohibited and relocation incentives for manufacturing firms are given. Hillsborough, OR uses lot size minimums to protect large industrial sites while creating flex zones that allow for 'non-industrial' uses such as call centers in industrial zones.

However, not all efforts by cities are conducive for preservation of manufacturing in the city. Some of the dominant paradigms of regenerative city building such as attracting the creative class or Smart Growth see little use for industrial uses within cities (e.g. Bronstein, 2009; Florida, 2013). It is also unclear if these industrial preservation policies and regulations within cities are entirely beneficial and efficacious. Howland (2010) found that there is a regulatory oversupply of parcels zoned for industrial in Prince George's County in Maryland and in many cases the demand does not spatially match the supply. Howland argues for a more surgical approach to identifying and targeting areas that merit preservation and ones that should be left to undergo their natural transformations. In some cases, these preservation policies are met with scepticism by local stakeholders aiming to reshape the waterfronts and downtowns into commercial, residential and recreational hubs (e.g. CBRE Consulting 2007).

Research Strategy, Methods and Data

Based on the above review of the literature on urban manufacturing, industrial displacement and land-use policies, we develop the following conceptual framework to guide our empirical analysis of industrial land conversion. This framework includes five factors (parcel location, neighborhood real estate dynamics, industry trends, location specific protection policies and environmental hazards) that are either theoretically or empirically linked in the literature on industrial land conversion.

- *Location characteristics* includes a set of variables that capture the accessibility and/or spatial competitiveness of each parcel, such as the distance to various transportation infrastructure including airports, highway ramps, rail and multi-modal transfer sites (Miron, 2010). We also include a measure of the distance of each parcel from the CBD to capture a parcel's centrality vis-à-vis the region, and also because so much of the literature links industrial displacement with the expansion of downtowns for residential and commercial uses. We expect that industrial parcels with good accessibility to transportation nodes will be less likely to convert, while parcels located near the CBD are more likely. We also include the distance to nearest transit station, whose siting have accelerated the industrial displacement in the cities in favour of mixed use commercial and residential developments nearby.
- *Neighborhood real-estate dynamics* refers to the degree of land value increases in the areas surrounding each parcel as well as subdivision activity. We expect that higher neighboring price increases, especially of residential parcels, will exacerbate the risk of conversion (Curran, 2007; Walks, 2001).
- *Establishment and Industry dynamics* captures a set of variables that measure the economic competitiveness of the companies located within industrial parcels. We expect that parcels that are home to firms that operate in relatively high-growth industries

nationally would be able to withstand industrial displacement. Also, manufacturing firms that are expanding and adding employment are more likely to be profitable and are likely to keep the properties in industrial use (Koritz, 1991; Troske, 1996)

- *Industrial Protection Policies* is an indicator of local land use policies that have been enacted to encourage industrial development in certain areas, or slow the pace of industrial land conversion with special zoning requirements. Thus, if a parcel falls within a designated industrial zone, such as Chicago's industrial corridor or Mecklenburg's designation as future industrial zone, we expect that that the parcel is likely to stay on as a industrial parcel (Leigh & Hoelzel, 2012).
- *Environmental hazards*. Lastly, we expect that the presence of nearby brownfield sites or abandoned environmentally compromised parcels will dampen the risk of conversion to residential uses (Howland, 2004; McGrath, 2000).

While, all these factors have been identified separately in the literature, to our knowledge, no other study has used them together empirically at a parcel level.

Explaining Industrial Land Conversions: Empirical Analysis

In selecting our proposed cases, we took into account two distinct factors. First, we wanted to vary our cases based on their relationship to the traditional U.S. manufacturing 'Rust Belt.' We argue that having one case within this traditional core, and one case in a 'newly' industrializing region in the U.S. South would ensure that our method was valid across multiple contexts. Second, we wanted to choose regions that were large enough and diverse enough that our proposed datasets would offer sufficient sample sizes. Ultimately, we chose Mecklenburg County, North Carolina-which is home to Charlotte—and Cook County, Illinois, which contains the City of Chicago. Both counties are at the center of their respective metropolitan regions and are home to the majority of regional manufacturing jobs.

The primary task in both counties was to identify parcels that had been converted from industrial uses. We defined a converted parcel as one which had formerly had an industrial business, and for which current land use was not industrial. We modelled the risk of conversion as a logit model at the parcel level. The explanatory variables include locational factors that are specific to the parcel such as distances to multimodal facilities and ports, real estate dynamics factors that include neighbourhood changes in prices for the parcel, variables that provide indicators of the health of the firm and the industry in the region. To model the effect of public policies, we include an indicator variable that specifies whether or not a parcel is in a designated industrial corridor or empowerment zone. For a more detailed discussion of individual explanatory variables, data sources and construction steps see Appendix A.

The extent and geography of conversion

The resulting datasets used for the analysis contained 6,702 and 2,698 industrial or formerly industrial parcels with fully available values for all the independent variables that we use to predict conversion, for Cook and Mecklenburg Counties respectively. In Appendix A we provide a detailed description of all the variables in the dataset and visually describe their distribution for converted and non-converted parcels separately. Correlations between independent variables are practically non-existent in the case of Cook County and pose some concerns in the case of Mecklenburg County. We also discuss the caveats to interpretations in the Appendix.

Before turning to our main results, it is important to describe the context and extent of industrial land conversion in each case. In Mecklenburg County, approximately 3,650 acres of industrial land were converted into non-industrial uses since 1990. Of this area, about 30 percent of the land area converted to residential uses; however, more than 54% of the converted parcels converted to residential (see Figure 1). In Mecklenburg County, 45% of the

parcels that housed apparel manufacturing firms experienced conversion. Between 1990 and 2010, the number of jobs in this sector fell by over half. Similarly, computer and electronic equipment manufacturing also decreased by over half, and one third of the parcels that housed firms in that industry converted to other uses. While chemical manufacturing increased between 1990 and 2000, the industry suffered a dramatic decline between 2000 and 2010. Nevertheless, only 24 percent of the parcels with those firms experienced conversion, suggesting that clean-up costs associated with these industries have an impact on conversion rates.

[FIGURE 1 ABOUT HERE]

In Cook County, the extent of industrial conversion was much greater, given the relative size of the county. Approximately 4,750 acres of land that is previously industrial is no longer in such use. This represents 11.4% of the total stock of industrial land in Cook County in 2011 (~ 41,000 acres). A large number of these conversions were for residential use (46.2%) and accounted for 53.6% of the area. Parcels with firms in printing and fabricated metal products were more likely to convert into non-industrial uses. These industries are consistently declining both regionally and nationally and the statistics are consistent with the literature on industrial displacement (Giloth and Betancur, 1988).

Along with the extent of conversion, what is also striking is the geography of conversion. In Cook, most of the conversion is centred around areas that is just north of the loop and following big transportation corridors such as I-94 and east of the I-294, i.e. in areas that are relatively affluent and in more central locations. On the other hand, conversion in Mecklenburg County is seen inside the business district (bounded by I-277) as well as in areas that are relatively far from the center. While, the conversion to residential is more

geographically even, construction of the new light rail line LYNX is likely to contribute to the significant conversions into office and commercial uses along the South Blvd. corridor.

Substantive Findings

Factors affecting the probability of industrial conversion

We examined the impact of two land-use/economic development policies on the probability of industrial land conversion (see the full set of results in Appendix Table B1). For Cook County, parcels located within a designated Industrial Corridor[vii] were significantly less likely to convert. In fact, this variable was the single most important factor in our model of conversion risk. This is a strong indicator that such industrial preservation policies are in fact effective land use tools. Since the program was enacted in 1992, we are confident in concluding that the policy is effective as our window of conversions begins at approximately the same time (1990-2010). There were 12,368 parcels located within Chicago's industrial districts, of which only 79 were converted over the sample period (0.6 percent). Location inside a Federal Empowerment Zone was also negatively associated with industrial conversion. This makes sense as empowerment zone incentives consist mainly of employment tax credits to business owners, rather than redevelopment subsidies to developers. The Chicago Empowerment Zone is located in two non-adjacent areas on the South and West sides that have not generally participated in the residential gentrification processes that are prevalent in the north and northwest sides of the City.

In Mecklenburg, the Centers and Corridors framework was introduced in 1994 and refined and adopted in 2010 to guide the development in the region[viii]. We used the 'Industrial Centers' from this framework as a proxy for where the county is targeting industrial activity. While this policy is not as strong as Chicago's Industrial Corridor program, it is significantly associated with a reduction in conversion risk. This framework is

responsible for aligning the sub area plans and zoning designation and changes including Urban Industrial designation in the Zoning code. This suggests that careful land-use planning can impact the probability of industrial land conversion. In Mecklenburg, of the 253 parcels in the Industrial Center designation, only 13 converted into non-industrial uses, whereas over three thousand parcels are not under this designation suggesting much larger scale of potential conversions.

In Cook County the location factors generally behave as theory predicts. Parcels that are farther away from the CBD are less likely to convert as they become unattractive to other kinds of redevelopment. The farther the parcel is from rail depots, the more likely it is going to convert. A similar relationship is observed for distance to freeway ramps, although the coefficient is not significant for Mecklenburg. For Mecklenburg, the proximity to airport has no effect on conversion even when it is likely that it is supposed to increase the likelihood of commercial conversion and decrease that of residential conversion. This is partly offset by the protection of industrial land close to the airport. While in Chicago, proximity to airport seems to weakly (yet significantly) induce conversion of industrial parcels. In Chicago, access to multimodal transfer points are predicted to be critical for manufacturing firms and we find that parcels closer to them are less likely to convert .

While the location factors generally behave as predicted by theory, two factors which we expected to be critical were not significant in Mecklenburg. Interestingly, we find no statistically significant relationship between the relative performance of a parcel occupant's industry sector nationally (i.e. the industry mix). Likewise, neighborhood real estate values largely have no effect. It is possible that real estate dynamics may simply be different in Charlotte, which does not have a long legacy of gentrification of areas nearby the CBD. While distance to transit station is an important predictor of conversion in Cook County, it is

not in Mecklenburg. This is despite the cluster of conversion activity near the newly developed LYNX line.

The results for Cook County are similar in some ways to those of Mecklenburg, yet differ in key ways as well. In general, all of the five factors that we use in our conceptual model of industrial conversion risk are significant and all but one have the impact we expected. There are several potential reasons why the models estimated for Cook County are more robust. First, since Cook County is much larger and contains a larger number of conversions, there is simply more statistical power. Second, Cook County—and the City of Chicago in particular—is in many ways an archetypical case of industrial restructuring. The parcels which are closer to key logistical access points, such as rail depots, highway interchanges and multimodal transfer points seem to be competitive in terms of remaining industrial, while parcels closer to airports (O'Hare and Midway) are more likely to convert. Consistent with the literature and with anecdotal evidence, we find a statistically significant negative effect for the distance to the CBD, indicating that parcels located closer to downtown are more likely to convert.

In Cook County our measures of industry and firm competitiveness are negative and significant. We find a negative and significant relationship between the net change in employment at the establishment-level and conversion risk. This indicates that relatively healthy manufacturing companies which are adding jobs are able to meet potentially rising rents and withstand pressure to convert. Similarly, the impact of the industry mix is negative and significant indicating that conversion is more common among parcels that are home to establishments in declining industries. Although the estimates were insignificant for Mecklenburg, we interpret these findings as providing support for the argument that industrial trends are an important factor in the conversion risk calculus.

Unlike the findings for Mecklenburg, we find that neighborhood real estate dynamics do play a role in the conversion of industrial land. Specifically, we find a positive and significant effect of nearby home price appreciation on conversion risk. This indicates that parcels which are located in tracts that experience a greater change in average sales price are more likely to convert. This is consistent with the scenario described in the literature on industrial displacement whereby land owners seek zoning variances to redevelop their industrial properties as condominiums or loft properties to take advantage of rising residential land prices.

Interestingly, our findings on the impact of environmental hazards are the opposite of what theory predicts. Specifically, we found that parcels closer to brownfield sites were more likely to convert. Rather than evidence of residential developers seeking out contaminated properties, we interpret this finding as indicative of the relative concentration of conversions near the CBD which is also home to more of the older industrial properties that may contain more environmental hazards. It may very well be that this finding is driven by inadequate capture of environmental hazard by brownfield location in the EPA databases (which is an indication of existing redevelopment interest). There are better and more localised sources of environmental hazards, but are difficult to obtain and cannot really be generalised to a method that can be replicated at a national scale. Other reasons for brownfield development or lack thereof, such as inadequate infrastructure are detailed in the literature and the readers are referred to Howland (2004) and De Sousa (2008).

Visualizing Industrial Land Conversion Risk

As discussed in the introduction, one of the key outputs of this analysis is the development of an index of industrial land vulnerability. We use the predicted values that result from the regression analysis as the index since they represent the estimated probability of conversion based on the independent variables included in the regression. In Figures 2-3

below, we present the spatially aggregated index of industrial vulnerability, even though the index is calculated at a parcel level. We use area weighted index for block group for display purposes.

[FIGURE 2 & 3 ABOUT HERE]

Areas closer to the higher income neighbourhoods in Charlotte have high risk of conversion (darker colors). In general, while the probability of conversion is low for parcels in the outskirts of the county, they appear as higher risk areas because of the small number problem and larger block group size (i.e. artefact of choropleth maps). The geography of conversion and risk in Cook County is broadly consistent with the results of the regression analysis (Figure 3). Industrial conversions are concentrated on the north side of the City of Chicago and in the suburban areas just north of the city. A significant number of conversions have taken place in the areas immediately surrounding the Loop area and that there are some individual parcels that remain and are under a high risk of conversion. Throughout the county, there are concentrations of higher risk parcels around both O'Hare and Midway airports.

To demonstrate the use of this index of vulnerability we created a prototype of an interactive web-based tool (available http://www.makingroomformanufacturing.org) that can help planners identify vulnerable parcels. Using open source software, the website displays parcels that are converted between 1990 and 2010 along with the vulnerability index of the current industrial parcels. The user also has the ability to display information about specific parcel and neighborhood characteristics, including the distribution of the vulnerability index, the number of people in different occupations within a five mile radius and the proportion of population in different racial categories. These characteristics are chosen only for demonstration purposes

We argue that planning tools such as the prototype demonstrated here can be a crucial tool for planners who are attempting to craft a "smart" industrial preservation policy that accounts for broader industrial trends as well as neighborhood and location characteristics. For example, an economic development planner can select all the parcels of a target sector and examine the conversion probability, while examining the national and regional trends in the industry. A land use planner can examine the clusters of high conversion probability parcels in a neighbourhood and can propose to enact preservation policies or think proactively about alternative uses in relation to other infrastructure investments and regulatory changes. A real estate developer might use the vulnerability assessment to identify parcel assemblage possibilities for different kinds of redevelopment activities. A community group might use the tool to understand the potential changes in their neighbourhood based on broad economic trends as well as identify environmental justice implications of vulnerable parcels. Because the index accounts for multiple factors, different groups can use it for different purposes in their own planning.

Conclusion

Economic developers and political leaders are excited by the potential for a manufacturing renaissance in the United States. After facing decades of declining industrial jobs and large inventories of industrial land, many cities are now at a critical juncture point. One the one hand, vacant industrial properties are an economic drag in that they are not revenue generating and they may limit the potential for the type of high-density residential and commercial development that creates vibrant urban places. One the other hand, if cities do not maintain their industrial lands they may be overlooked by manufacturing companies seeking to (re)locate to the United States. In addition, if cities do not maintain viable clusters

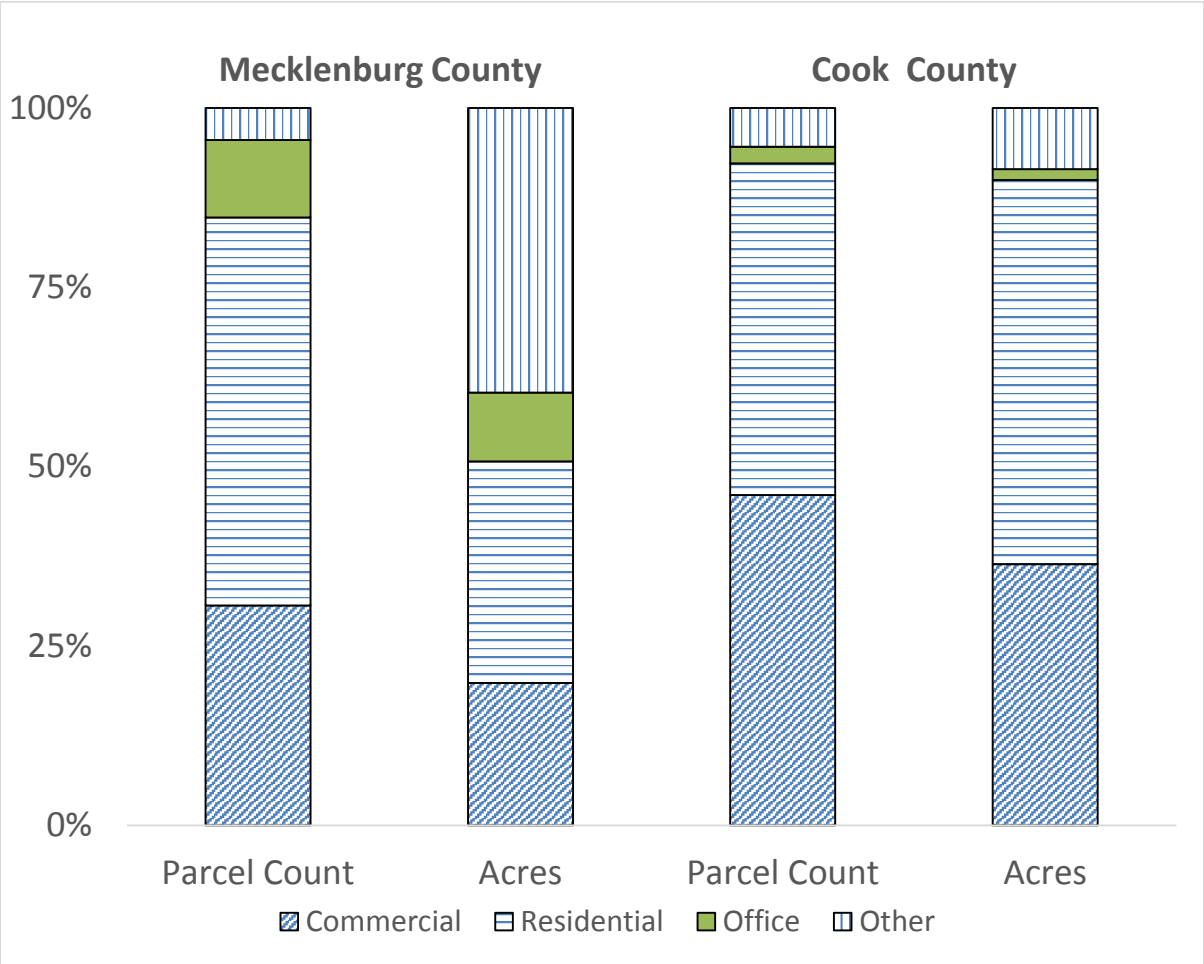
of manufacturing firms and related industrial businesses, critical agglomerative forces may be eroded, further undermining the chances of manufacturing's return.

Recognizing this tension, this paper has produced the first multifactor analysis of industrial land conversion. The purpose of this analysis is to provide a tool that can help planners better understand the trends which influence the conversion of industrial land within their jurisdictions. While many of our findings are consistent across our two illustrative cases—including the importance of freight accessibility, parcel size, and proximity to the CBD—the differences between the cases suggests that the dynamics of industrial land conversion are also driven by factors that are unique to each area. For example, we found that industrial conversion in Cook County was much more sensitive to neighboring residential real estate appreciation, compared to Mecklenburg. This could indicate a fundamental difference in the nature of residential real estate markets, whereby Charlotte does not face the same pressure to gentrify inner-city neighborhoods as Chicago. In addition, we found that national industry trends seemed to matter more for Cook compared to Charlotte. This is likely due to the fact that the overall industrial structure is different across the cases. Ultimately, this finding suggests that differential industrial trends and the historical competitive advantages of each city's industrial legacy are important for planners to consider.

Ultimately, this analysis suggests that planners need a more nuanced approach to industrial land preservation. Cities need to be strategic about their industrial land inventory and match the supply of industrial land to the strategic economic goals of the region. To do so, plans and planners have to identify strategic industries for the region, and craft land-use policies that take into account the needs of each industry and look for ways to meld alternative uses together with industrial ones. Furthermore, any provisioning of public

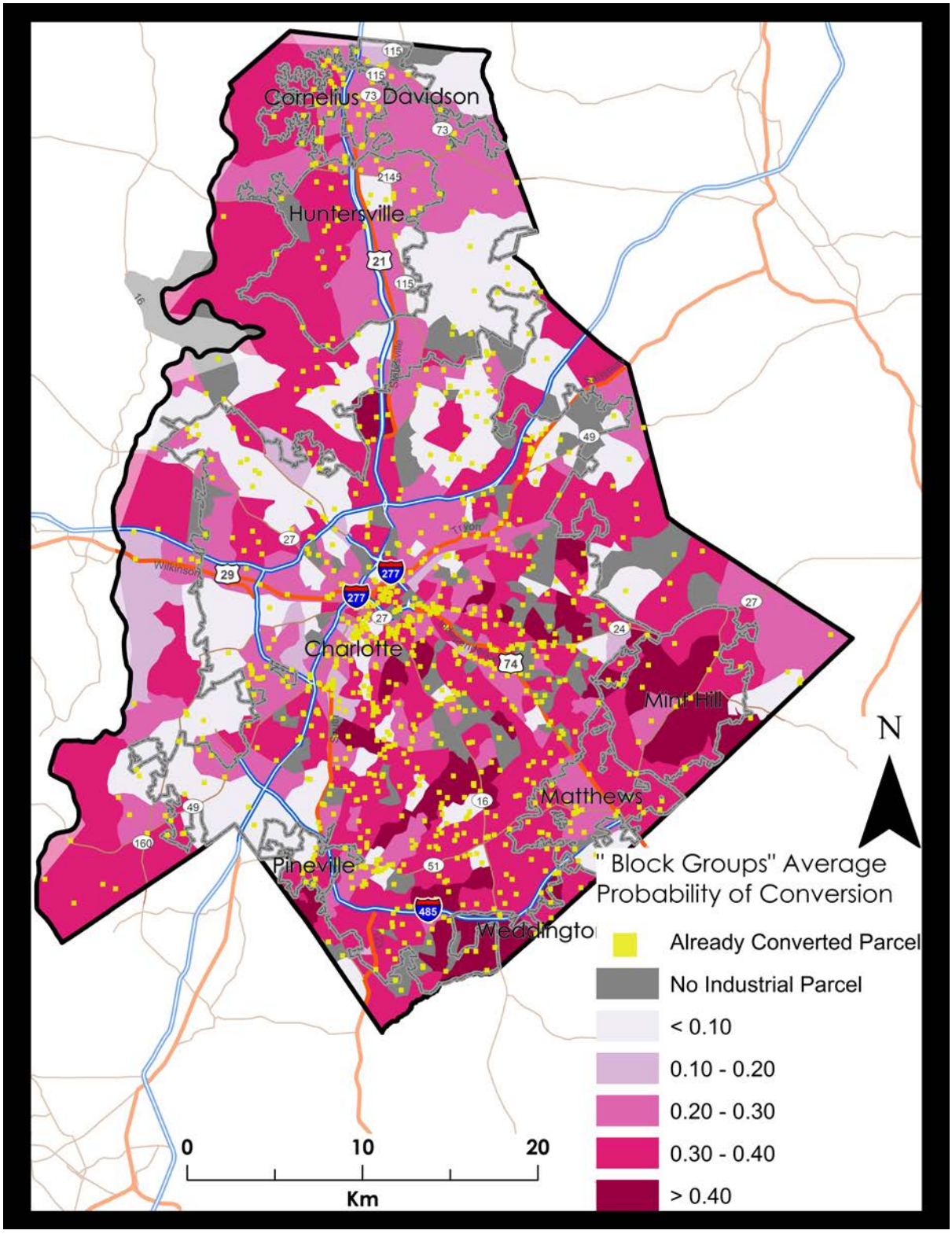
infrastructure such as multimodal facilities and transportation investments should be strategically coordinated with industry locations. One of the tools, they could use in this analysis, is our index of conversion probability. This tool helps identify which parcels are likely to convert based on multiple factors. However, in the end planners need to use this tool to strategically assess whether such conversions are in the best interest of the region and craft housing, commercial and industrial land policies and plans.

Figure 1. Proportion of current uses of converted Industrial Parcels, by parcel count and acreage in Mecklenburg County, NC and Cook County, IL.



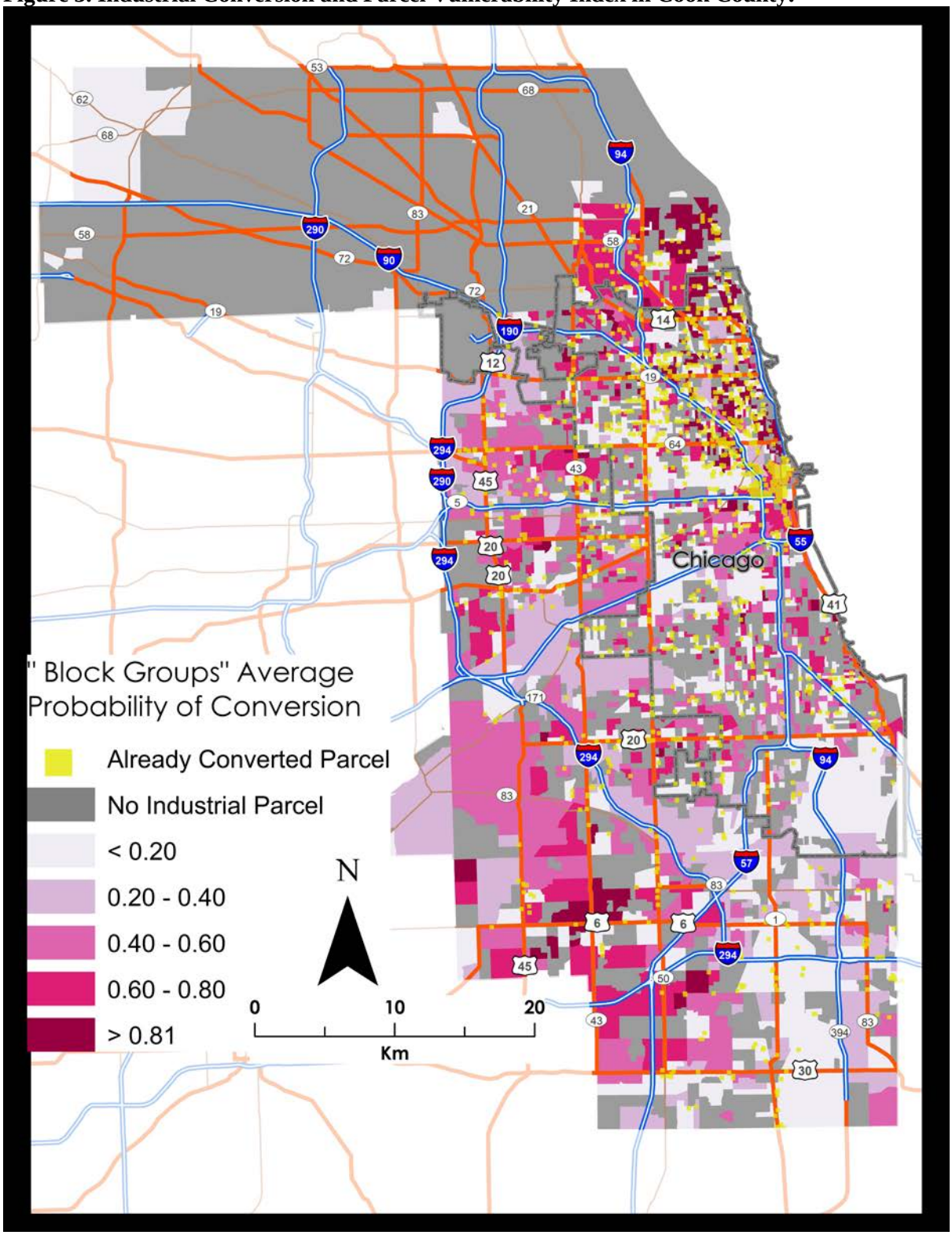
Source: Authors' analysis of Mecklenburg County parcel data and National Establishment Time Series (NETS).

Figure 2. Industrial Conversion and Parcel Vulnerability Index in Mecklenburg County.



Note: Although the vulnerability index is calculated at the parcel level, we display only the area weighted average of the index for each census block group for visual clarity.

Figure 3. Industrial Conversion and Parcel Vulnerability Index in Cook County.



Note: Although the vulnerability index is calculated at the parcel level, we display only the area weighted average of the index for each census block group for visual clarity.

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Appendix A

In this appendix, we give more details about the data preparation and the full set of statistical results. For more information, readers are referred to www.makingroomformanufacturing.org

Measuring Conversion

To define the dependent variable in our analysis (i.e. industrial conversion at the parcel level), we combined two distinct data sources using ESRI ArcGIS software. First, we gathered parcel boundaries from the County Tax Assessor's offices in Mecklenburg and Cook county; approximately 1.44 million records for Cook County and 0.37 million records for Mecklenburg County for years 2000, 2005 and 2010. Second, we used establishment level data from the National Establishment Time Series (NETS), which provided information about the location and annual employment for all former and current manufacturing business establishments. The NETS database is a privately produced establishment-level longitudinal database (1990-2010) built from the Dun and Bradstreet (D&B) business credit rating service. The database is a near universe of private-sector businesses in the United States and one of its chief benefits for economic development researchers is the ability to track establishment-level births, deaths and relocations over time at a detailed geographic scale. The NETS datasets included 35,557 and 6,339 records for Cook and Mecklenburg Counties, respectively. The universe of records include any establishment that was located within the county—alive or dead—between 1990 and 2010 and had a primary NAICS classification within the 31-33 NAICS super sector.

For each county, we geocoded all NETS records that ever had a NAICS classification with manufacturing (31-33) using the latitude and longitude listed by year from 1990 – 2010. The NETS was joined to the parcels to identify the universe of parcels with manufacturing land uses. Of these, converted parcels are identified by absence of establishment in 2010 and if the land use is non-industrial. Based on this definition of conversion, we identified 989 parcels that converted in Mecklenburg County and 3,748 parcels that converted in Cook County.

Data construction/sources for key independent variables

We measured location characteristics by calculating each parcel's proximity to various amenities in the county that affect the accessibility and ultimately the suitability of the land for competing uses. For each location factor, the "near" tool in ArcGIS was used to calculate the distance from each parcel to the nearest location factor. Location factors were: the central business district, airports, multi-modal freight transfer facilities, highway on-ramps and interchanges, transit stations and rail facilities. For Mecklenburg County, the central business district polygon was defined as the area inside the I-277 loop in Charlotte. For Cook County, the central business district polygon was downloaded from data.cityofchicago.org. Freight facility shapefiles were accessed using the National Transportation Atlas Database 2011 from the Bureau of Transportation Statistics. Public use airports, multi-modal terminal facilities, railway network (nodes only) and highway on-ramps were extracted from the file U.S. Major Roads 2008 from the ESRI Data & Maps 9.3 data set. Specifically we used the feature class codes A60 (Special road feature, Name = "ramp") and A63 (Access ramp or limited access interchange). Transit Station locations are from the Center for Transit Oriented Development's TOD database of existing stations.

To capture the real estate dynamics in the neighborhoods surrounding each parcel we attempted to assess changing property values over a ten year period, approximately 2000-2010. For Mecklenburg County, since tax assessor's data was available, we could measure the changes in value of all parcels (not just sales) between 2001 and 2011. We calculated the change in value over this period as our primary measure of land price appreciation for all parcels within a ¼ mile buffer zone of each parcel. For Cook County, we used data from Record Information Services—a private data provider that gathered all public residential sales from 2000 through 2010 at the address level. For Cook County we calculated the change in average sales price at the census tract level and applied this value to each parcel based on which tract contained the centroid of the parcel. To calculate buffer around each parcel for Cook county would have exhausted our computational power. As an additional measure of real estate activity, we identified parcels that were subdivided between 2000 and 2011 (2001 and 2011 for Mecklenburg) by comparing two sets of parcel boundary maps, because identifying information (such as Parcel Identification Numbers) changes over time.

To assess the establishment/industry competitiveness at the parcel level, we constructed two different variables. First, we conducted a shift-share analysis for each county's manufacturing industries relative to the United States for the broad 1990-2008 (pre-recession) period, using data from the Quarterly Census of Employment and Wages (QCEW) from the U.S. Bureau of Labor Statistics. The shift-share analysis was conducted only for all 4-digit NAICS industries within the manufacturing super-sector. The purpose of shift-share analysis is to identify sectors which are competitive locally, accounting for broad national trends in manufacturing overall ("national shift"), and the relative performance of each industry nationally (i.e. the "industry mix"). We used the industry mix variable as a measure for the industry's expected performance nationally. Then we matched the industry mix variable to the parcel-level, based on the NAICS code of the last industrial establishment

listed in the NETS. While we expect parcels that are home to industries that are outpacing the national average to be less likely to convert, there may be some individual establishments that are growing or declining for idiosyncratic reasons. For this reason we also calculated the net change in jobs at the establishment level.

To assess the impact of land use policies and regulations, we generated a simple dummy variable that indicates whether a parcel is included in a designated industrial area. For Cook County, we used a shapefile of the City of Chicago's Industrial Corridors obtained from the City's GIS Portal (See https://data.cityofchicago.org/Community-Economic-Development/Boundaries-Industrial-Corridors/vdsr-p25b). These areas were designated beginning in 1992 and offer strong protection against speculative conversions by requiring that any zoning change obtain approval from a full vote of the Plan Commission. For Mecklenburg we used information obtained from the 2008 comprehensive plan and coded the areas where industrial development was encouraged. Thus, the variable for Mecklenburg County represents a weaker policy compared to Chicago's Industrial Corridor program. As an additional policy variable, we also created an indicator for whether a parcel fell within one of Chicago's Federal Empowerment Zones (none were found in Mecklenburg).

The primary variable that proxy's for our environmental hazard factor is the location of each parcel in relation to officially designated brownfield sites. Location data on brownfields was derived from the U.S. Environmental Protection Agency's (EPA) Facility Registration System. We limited our analysis to sites that were coded specifically as brownfields rather than every entry in the registry (see http://www.epa.gov/enviro/html/frs_demo/geospatial_data/geo_data_state_single.html) . For descriptive statistics see Table A.

Table A. Descriptive Statistics

Variable	Cook County		Mecklenburg County	
	Mean	St.Dev	Mean	St.Dev
Distance to Airport	11,226.10	5,436.40	44,014.33	18,347.70
Distance to Multimodal Facility	13,627.70	12,498.40	17,191.97	14,585.80
Distance to Rail	3,296.10	3,413.30	8,119.09	7,076.03
Distance to Hwy. Ramp	2,877.00	2,137.80	3,239.43	2,856.88
Distance to CBD	61,568.00	39,091.10	33,261.53	22,862.26
Change in Neighborhood Residential Price (2000-10)*	-6,524.40	211,574.90	-29,294.03	125,418.40
Net Employment Change in Industry (jobs)	-6,550.40	7,201.00	-5,342.57	13,330.75
Industry mix	0.04	0.2	0.016	0.218
Parcel Size (acres)	1.4	2.3	4.038	22.17
Distance to Nearest Subdivided parcel	8,476.80	39,832.10	19,438.02	46,329.63
Distance to Nearest Transit station	6,224.40	5,295.20	26,793.74	23,909.75
Distance to Nearest Brownfield	7,211.10	6,501.50	3,410.38	3,413.34
N	6,702		2,698	
Parcels in Empowerment Zone	4.80%			
Parcels in Industrial Corridor/Center	10.98%		8.33%	

*Calculated differently for Cook and Mecklenburg Counties, due to data limitations. In Mecklenburg County, quarter mile is used as a neighbourhood and in Cook County, the census tract is used as a neighbourhood. All distances are in feet.

Data Limitations and Caveats

Data preparation required significant effort because of changes to parcel boundaries over time and changing definitions of land uses and errors in data. While care has been taken to assure data quality systematic but undiagnosed errors might still remain (especially with regards to geocoding, NAICS codes etc.). Furthermore, we only consider manufacturing uses, while industrial land uses might include a more expansive definition of Production, Distribution and Repair. These ancillary uses are complementary to manufacturing and any comprehensive examination of industrial land should include these uses. Furthermore, because of agglomerative effects and spatial spillovers, industrial parcels are also usually clustered and the spatial clustering is not taken into account in the statistical model.

While this research focussed on industrial parcels that are likely to convert, we did not focus on the implications of such conversion on socio-economic landscape of the city. For lack of space and time, we did not exhaustively explore the environmental as well as environmental justice aspects of industrial conversion. Another caveat is the endogeneity issue that might potentially bias the importance of certain variables in predicting the vulnerability index. The methodology described here should be considered as an input into deliberating what areas of the city need to be preserved as industrial land and what are the opportunity costs of such preservation.

Another potential limitation of the study is the lack of depth of the real estate processes such as parcel assembly and subdivisions included in the analyses. Large industrial sites in the central cities should be more competitive for residential and mixed use

redevelopment than assembling parcels from fragmented commercial owners. Such parcel assembly might suffer from holdout problems and make industrial parcels more appealing for redevelopment. However, our analyses suggest that size of the lot is not associated with the risk of conversion suggesting other mitigating factors, or inadequate specification of the model. All these areas are ripe for further research and can only help make our index more robust.

Statistical Analysis.

Below we describe the dataset and present the results of the statistical analysis. Correlations between categorical variables and real variables are not statistically correct and therefore we show the distributional similarities and differences of various explanatory variables between converted and non-converted parcels. In Cook County, while airport distance variable has similar distribution between converted and non-converted parcels, there is a significant difference in the distance to the CBD variable (Figure A). Furthermore the transit distance is also skewed to the left (though with long right tail) for converted parcels suggesting that parcels that are closer to the transit stations are likely to convert. On the other hand, transit distance variable has roughly the same distribution between converted and non-converted parcels in Mecklenburg County (Figure C). The correlation matrices suggest that multicollinearity is not a major issue in Cook county (Figure B), whereas there is worrisome correlation between CBD and transit distance variables mostly because the proximity of transit stations to CBD (Figure D). However, we included these variables in the model for cross case comparison and because the purpose of the model is to have predictive power to construct the index rather than isolating the effect of individual variables.

Once the variables are constructed, we scaled the variables based on their standard deviation and a logit model is used to predict the risk of conversion. The results of the model are documented in Table B.

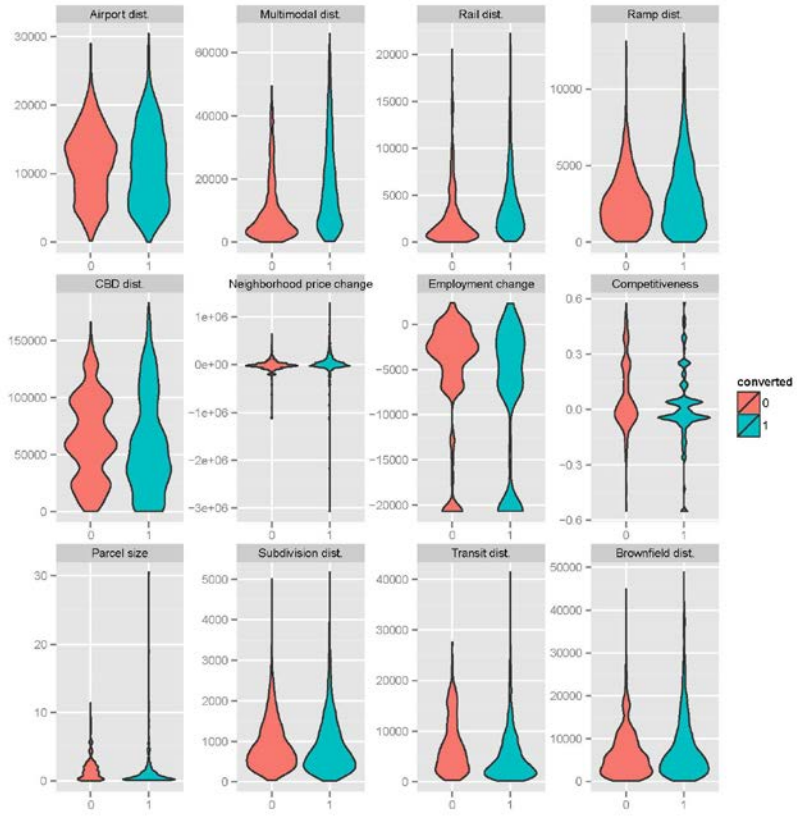

Figure A Distributional differences of explanatory variables in Cook County based on the conversion status

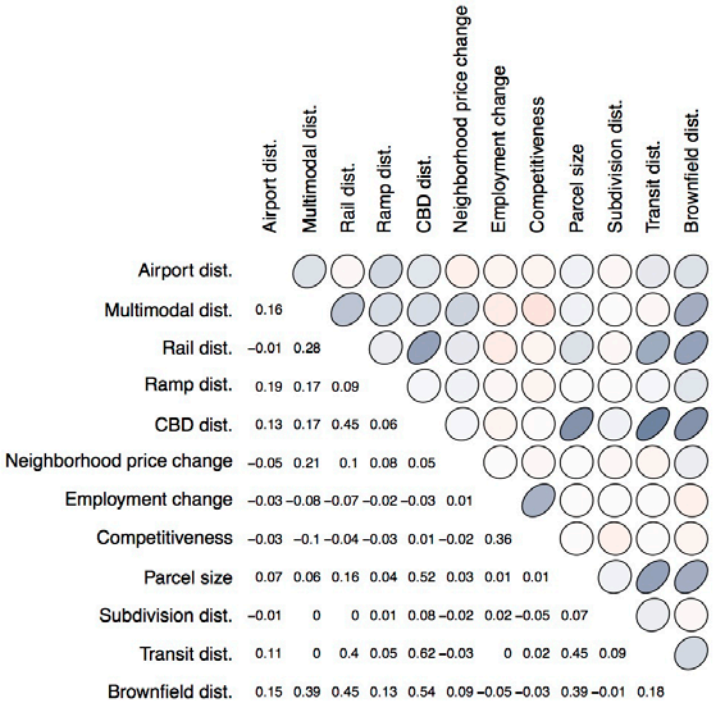

Figure B Correlation matrix among explanatory variables in Cook County

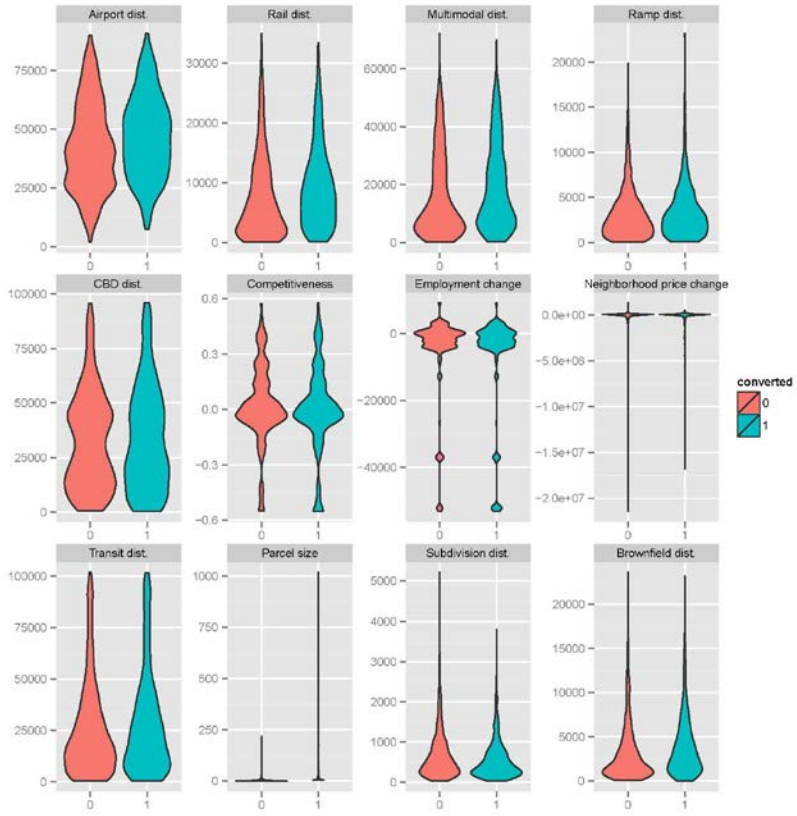

Figure C Distributional differences in the explanatory variables based in Mecklenburg County based on the conversion status

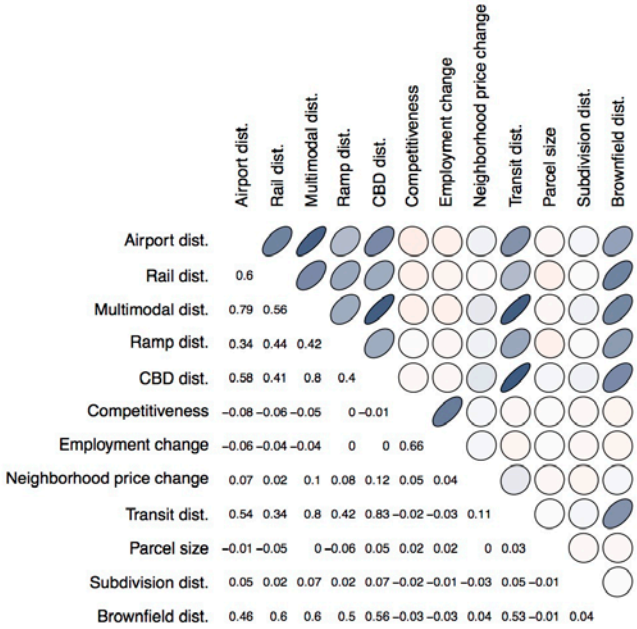

Figure D Correlation Matrix among explanatory variables in Mecklenburg County

Table B. Full set of Results of Logistical Regression Model of Industrial Land Conversions in Mecklenburg, NC and Cook County, IL 1990-2010.

	Cook County	Mecklenburg County
Location Factors		
Distance to Airport	−0.152***	0.059
	(0.031)	(0.074)
Distance to Multimodal facility	0.452***	0.037
	(0.029)	(0.112)
Distance to Rail	0.576***	0.152*
	(0.031)	(0.060)
Distance to Hwy. Ramp	0.182***	−0.020
	(0.030)	(0.055)
Distance to CBD	−0.413***	−0.242**
	(0.045)	(0.093)

Distance to Transit Station	−0.743***	0.136
	(0.045)	(0.089)
Industry/Firm competitiveness		
Net Employment Change	−0.333***	−0.072
	(0.032)	(0.055)
Competitiveness of industry	−0.121***	−0.055
	(0.034)	(0.058)
Neighborhood price dynamics		
Change in Neighborhood Residential Price	0.079***	−0.008
	(0.026)	(0.041)
Distance to Nearest Subdivision	0.079*	−0.035
	(0.041)	(0.044)
Environmental hazards		
Distance to Brownfield	−0.105***	0.068
	(0.034)	(0.060)

Policy variables		
Empowerment zone (Yes)	−0.739***	
	(0.177)	
Industrial Corridor/Center (Yes)	−2.969***	−1.864***
	(0.162)	(0.324)
Controls		
Parcel Size	−0.016	0.045
	(0.030)	(0.046)

Notes: All estimates are standardized based on the standard deviation of each variable. Standard errors in parentheses below each estimate. Significance levels are indicated by: * for 10%, ** for 5%, and *** for 1%. The number of observations (N) for was 6,702 for Cook and 2,698 for Mecklenburg County. Intercepts were negative and significant for both models but are not listed. McFadden R^2 was 0.67 for Cook and 0.22 for Mecklenburg County.

[i] Total U.S. manufacturing employment grew by 729,668 from 11.3 million in January 2010 to 12.1 million in June 2013 based on data from the Bureau of Labor Statistics' Quarterly Census of Employment and Wages (QCEW). Manufacturing exports grew by $429 billion from $918 billion in 2009 to $1.35 trillion in 2012, according to data from the International Trade Administration, U.S. Department of Commerce.
[ii] City of San Francisco, Planning Commission. March 13th 2014. Executive Summary of Planning Code Text Changes (document # 2013.1896T) http://commissions.sfplanning.org/cpcpackets/2013.1896T). .
[iii] http://charlottechamber.com/emerging-industry/a-robust-manufacturing-region/ (Accessed March 31, 2014).

[iv]http://communityinnovation.berkeley.edu/presentations/industrial/OR-promote-posperity.pdf (Accessed March 31, 2014)

[v] Average annual earnings per worker in manufacturing was 22.9% higher than the overall average earnings across all private sector industries ($60,496 versus $49,200) in 2012. Source: Quarterly Census of Employment and Wages (QCEW), US Bureau of Labor Statistics.
[vi] http://communityinnovation.berkeley.edu/industrial-land-report.html (Accessed January 11, 2014)
[vii] https://data.cityofchicago.org/Community-Economic-Development/Boundaries-Industrial-Corridors/vdsr-p25b (Accessed June 20, 2013)
[viii] http://charmeck.org/city/charlotte/planning/AreaPlanning/CentersCorridorsWedges/Pages/Home.aspx (Accessed June 20, 2013)