

Article

Historic Urban Manufacturing Territories as Metropolitan Metabolic Infrastructure: Balancing Circular Economy, Environmental Justice, and Healthy Cities

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Abstract

Historic urban manufacturing territories are increasingly being reconsidered as strategic components of metropolitan sustainability rather than obsolete remnants of industrial economies slated for redevelopment. While these districts have long been associated with pollution, environmental degradation, and post-industrial decline, growing interest in circular economy strategies, Urban Resource Recovery (URR), and climate adaptation has renewed attention to their territorial significance. Using the North Brooklyn Industrial Business Zone and the Newtown Creek watershed as a case study, this paper argues that certain historic manufacturing territories possess an inherent capacity to evolve into Metropolitan Metabolic Infrastructure because of inherited geographic, infrastructural, and institutional characteristics, including waterfront access, freight networks, industrial zoning, large industrial parcels, and utility systems. Drawing upon research developed through the New York City Department of Design and Construction's Town+Gown Urban Resource Recovery Working Group, the study combines historical analysis, spatial interpretation, planning policy, and case-study research to examine the evolving relationship among urban metabolism, circular economy, environmental justice, and Healthy Cities. Rather than advocating industrial preservation irrespective of environmental performance, the paper argues that these territories can support metropolitan material circulation while advancing cleaner industrial practices, environmental remediation, and more equitable urban development. The Metropolitan Metabolic Infrastructure framework offers a planning perspective for understanding how inherited manufacturing landscapes may contribute to resilient, circular, and healthier metropolitan regions while informing future comparative research on industrial territories undergoing similar transitions worldwide.

Keywords: urban manufacturing; Urban Resource Recovery; urban metabolism; circular economy; environmental justice; healthy cities; industrial geography; North Brooklyn



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1. Introduction

The role of urban manufacturing is being fundamentally redefined in the twenty-first century. Historically understood as landscapes of production, industrial districts are increasingly expected to perform a broader range of environmental, economic, and social functions that extend well beyond conventional manufacturing. Circular economy strategies, climate adaptation policies, construction and demolition (C&D) material recovery, renewable energy systems, and resilient metropolitan supply chains have collectively transformed the way planners and policymakers evaluate industrial land. Rather than

viewing manufacturing territories as remnants of an obsolete industrial economy slated for redevelopment, they are increasingly recognized as strategic components of metropolitan infrastructure capable of supporting the circulation of materials, energy, and resources that sustain contemporary urban life [1–3].

This transition reflects a broader evolution in planning theory. Throughout much of the twentieth century, manufacturing districts were primarily assessed through measures of industrial productivity, employment, and economic output. Their physical geography—ports, rail corridors, waterfronts, warehouses, factories, and utility infrastructure—was understood principally as supporting industrial production and metropolitan economic growth. Simultaneously, these same territories accumulated many of the environmental externalities associated with industrialization, including contaminated waterways, petroleum storage, hazardous industries, truck traffic, combined sewer overflows, deteriorating air quality, and extensive brownfields. As manufacturing employment declined following the Second World War, deindustrialization reinforced the perception that industrial districts represented obsolete landscapes awaiting redevelopment into residential or mixed-use neighborhoods [4–6].

During the past two decades, however, this narrative has begun to shift. Increasing concern over climate change, resource scarcity, embodied carbon, and urban resilience has renewed interest in the strategic role of manufacturing within metropolitan regions. Construction material recovery, recycling industries, wastewater treatment, logistics, renewable energy infrastructure, and industrial ecology all require extensive industrial land, transportation networks, and utility systems that remain concentrated within historic manufacturing districts. Consequently, industrial geography has re-emerged as an essential component of metropolitan sustainability rather than a residual condition of twentieth-century urbanization [2,7,8].

This renewed interest coincides with the rapid development of urban metabolism as a framework for understanding cities through the circulation of materials and energy. Wolman’s seminal essay [9]) introduced the concept of the city as a dynamic system sustained by continuous flows of water, food, fuel, materials, and waste. Subsequent research expanded this perspective by demonstrating that urban sustainability depends upon understanding how these interconnected flows shape the environmental performance of metropolitan regions [7,10]. Urban metabolism has since become one of the principal theoretical frameworks through which scholars examine resource efficiency, industrial ecology, infrastructure, and circular urban systems.

Despite this growing body of research, comparatively little attention has been devoted to the territorial geography that enables metropolitan metabolism to occur. Material flows are inherently spatial. Construction materials require storage yards, recycling facilities, freight terminals, industrial buildings, waterfront access, transportation corridors, utility infrastructure, and manufacturing ecosystems capable of processing recovered resources. Cities cannot become circular through policy alone; they require places where circular processes physically occur. This observation suggests that historic manufacturing territories possess a significance extending well beyond their traditional economic role [3,10].

The central argument of this paper is that certain historic manufacturing territories possess an inherent territorial capacity to evolve into metropolitan metabolic infrastructure. This proposition differs from much of the existing literature on urban metabolism and circular economy. Rather than arguing that industrial districts are themselves metabolic infrastructure, the paper contends that inherited geographic, infrastructural, logistical, and institutional conditions increasingly align with the spatial requirements of Urban Resource Recovery (URR), industrial ecology, and circular material systems. Waterfronts, freight infrastructure, industrial zoning, large manufacturing parcels, utility networks, and

proximity to regional construction markets constitute territorial assets that have acquired renewed importance as cities seek to reduce dependence upon virgin material extraction while strengthening local and regional material cycles.

This conceptual distinction has important implications for planning. It suggests that the future of industrial land should not be evaluated solely through redevelopment potential, property values, or traditional employment metrics. Instead, planning must also consider the strategic contribution that manufacturing territories make to metropolitan environmental performance, resource security, and long-term resilience. At the same time, these territories remain places where generations of residents have experienced the cumulative environmental burdens associated with industrialization. Consequently, any planning framework capable of supporting Urban Resource Recovery must simultaneously address environmental justice, public health, and equitable economic development rather than treating these objectives as competing priorities [11,12].

The relationship between manufacturing, sustainability, and environmental justice is therefore considerably more complex than either industrial preservation or redevelopment alone can explain. Industrial districts remain among the few urban landscapes capable of accommodating recycling industries, logistics facilities, environmental infrastructure, and construction material processing at metropolitan scales. Yet these same districts frequently coincide with communities that have historically experienced disproportionate environmental exposure and unequal access to environmental benefits. The challenge facing contemporary planning is not whether industrial territories should continue to exist, but how they can be transformed to support metropolitan sustainability while improving the environmental quality and health of surrounding neighborhoods [13,14].

It is within this broader context that North Brooklyn and the Newtown Creek Industrial Business Zone assume particular significance. As one of New York City's oldest and most extensive manufacturing districts, North Brooklyn illustrates both the opportunities and contradictions associated with the transition from industrial production toward metropolitan resource recovery. Its inherited industrial geography provides exceptional capacity for supporting Urban Resource Recovery and circular material systems, while its environmental history demonstrates the necessity of integrating industrial policy with environmental justice, remediation, and healthy-city principles. Although this study is grounded in North Brooklyn, the conceptual framework developed here is intended to inform planning in historic manufacturing territories undergoing similar transitions toward circular urban economies in metropolitan regions worldwide [15–17].

1.1. Urban Metabolism, Circular Economy, and the Territorial Foundations of Urban Manufacturing

The concept of urban metabolism has profoundly influenced contemporary understandings of urban sustainability by shifting attention from the physical form of cities toward the flows of energy, water, materials, nutrients, and waste that sustain urban life. In his seminal essay [9] proposed that cities could be understood as living systems whose viability depends upon the continuous exchange of resources between urban settlements and their surrounding regions. Although originally conceived as a conceptual model for improving urban environmental management, urban metabolism has since evolved into a major analytical framework within planning, industrial ecology, and sustainability science [7,10].

Much of this scholarship has focused on quantifying material and energy flows, evaluating resource consumption, measuring carbon emissions, and developing indicators capable of assessing urban sustainability. These studies have demonstrated that cities function as highly interconnected socio-ecological systems whose environmental performance depends upon the efficient circulation of materials through increasingly complex

metropolitan networks. Urban metabolism has therefore become central to discussions of climate adaptation, resource efficiency, industrial ecology, infrastructure planning, and environmental policy [7,10].

Parallel to this development, the concept of the circular economy has emerged as one of the dominant paradigms guiding contemporary sustainability policy. Circular economy seeks to replace the traditional linear model of extraction, production, consumption, and disposal with systems that prioritize reuse, repair, remanufacturing, and recycling in order to retain material value for as long as possible [2]. Within the built environment, these principles have become particularly significant because construction and demolition activities generate one of the largest waste streams in industrialized economies while simultaneously accounting for substantial embodied carbon and resource consumption.

Despite the considerable growth of research on urban metabolism and circular economy, relatively limited attention has been devoted to the territorial geography that makes these systems possible. Material cycles do not occur independently of place. Construction materials require industrial land, storage facilities, transportation infrastructure, marine terminals, freight corridors, recycling operations, utility networks, and manufacturing ecosystems capable of processing secondary resources before they can re-enter productive use. In other words, circular material systems require a physical geography that is often overlooked within broader discussions of resource efficiency [7,8].

Historic manufacturing territories represent precisely this geography. The industrial landscapes that developed during the nineteenth and twentieth centuries were shaped by access to navigable waterways, railroads, ports, utilities, large industrial parcels, and regional transportation networks. Although the character of manufacturing has evolved substantially, many of these territorial conditions remain intact. Increasingly, they provide the spatial foundation upon which Urban Resource Recovery, recycled construction materials, industrial symbiosis, environmental infrastructure, and metropolitan logistics continue to depend [1,15].

This observation suggests an important theoretical shift. Rather than interpreting historic manufacturing districts exclusively through narratives of industrial decline or redevelopment, they may also be understood as strategic territorial assets within emerging circular urban systems. Their significance lies not simply in their industrial heritage but in their continuing capacity to support the circulation of metropolitan resources. Consequently, industrial geography should be viewed not as a residual consequence of previous economic cycles but as an essential component of future urban sustainability [1,11].

The planning implications are substantial. Cities seeking to reduce embodied carbon, strengthen regional supply chains, increase material recovery, and improve resource resilience cannot rely exclusively upon technological innovation or policy reform. They must also preserve and adapt the industrial landscapes capable of accommodating these activities. Historic manufacturing territories therefore emerge as critical interfaces between metropolitan metabolism and urban planning, linking industrial land policy directly to broader sustainability objectives [2,3,8].

Yet this reinterpretation also raises important questions concerning environmental justice. Many of the districts best suited to accommodate Urban Resource Recovery are also neighborhoods that have experienced generations of environmental burdens associated with industrial production. Planning for circular economies must therefore move beyond technical optimization to address the spatial distribution of environmental benefits and environmental costs. This challenge is particularly evident in North Brooklyn, where the same inherited industrial geography that enables contemporary resource recovery also reflects a long history of environmental contamination and community exposure [13,14].

Accordingly, this paper proposes that the relationship between urban metabolism and industrial geography should be reconsidered through a territorial planning perspective. Rather than focusing exclusively on the movement of materials, it argues that planners must also understand the inherited landscapes through which those material flows occur. This territorial dimension has received comparatively limited attention within the literature and forms the principal theoretical contribution developed in this research.

1.2. Environmental Justice, Healthy Cities, and the Social Value of Urban Manufacturing

The renewed recognition of manufacturing territories as components of metropolitan sustainability cannot be separated from their historical relationship with environmental justice. Industrial districts have long occupied an ambiguous position within urban planning. On one hand, they have provided employment, supported regional economies, and accommodated essential infrastructure. On the other, they have concentrated many of the environmental burdens associated with metropolitan development, including contaminated waterways, hazardous industries, truck traffic, waste facilities, deteriorating air quality, and unequal exposure to environmental risks [13,14].

North Brooklyn illustrates this dual condition particularly well. During the twentieth century, the district became one of New York City's principal centers of industrial production while simultaneously accumulating many of the environmental consequences associated with petroleum refining, chemical manufacturing, maritime industry, waste processing, and heavy transportation. The designation of Newtown Creek as a federal Superfund site reflects the cumulative impacts of more than a century of industrial activity rather than any single environmental event. Consequently, discussions concerning the future of manufacturing in North Brooklyn inevitably intersect with broader questions of environmental justice and public health [16–18].

At the same time, manufacturing remains an important component of social and economic resilience. As documented by Curran [6], industrial displacement has often accompanied rapid redevelopment, reducing opportunities for productive employment while accelerating land-value pressures within historically industrial neighborhoods. Similarly, Battle's historical analysis of New York's post-war industrial restructuring demonstrates that deindustrialization fundamentally reshaped both the city's economic geography and the communities that depended upon manufacturing employment [5]. More recently, organizations such as the Association for Neighborhood and Housing Development (ANHD) and the Industrial Jobs Coalition have emphasized the continuing importance of industrial land in supporting middle-income employment, workforce diversity, and economic mobility for immigrant and working-class communities [5,6,12,19].

These observations reinforce a central principle of the Healthy Cities movement: health is produced not solely through medical care but through the quality of urban environments, employment opportunities, housing, transportation systems, environmental conditions, and equitable access to resources [20–22]). Within this framework, industrial employment, environmental quality, and neighborhood well-being should not be considered independent variables but interconnected determinants of urban health.

Urban Resource Recovery complicates these relationships further. Recovering construction materials within metropolitan regions can substantially reduce landfill disposal, decrease transportation emissions, conserve natural resources, and lower embodied carbon. However, the facilities required to support these activities—including recycling plants, aggregate processing facilities, material storage yards, and logistics operations—must occupy physical space within cities. Frequently, they are located in precisely those industrial neighborhoods that have historically experienced disproportionate environmental burdens [2,8,23].

This tension exposes one of the principal planning dilemmas associated with circular urbanism. The environmental benefits generated at the metropolitan scale may coincide with localized environmental impacts if planning does not simultaneously prioritize cleaner industrial technologies, environmental remediation, improved freight management, community participation, and equitable investment. Urban Resource Recovery therefore cannot be understood solely as a technical strategy for increasing recycling rates. It must also be evaluated as a question of environmental governance, distributive justice, and territorial planning [14,24,25].

Accordingly, this paper argues that the future of historic manufacturing territories should be assessed through a broader framework integrating metropolitan metabolism, industrial resilience, environmental justice, and healthy-city principles. Rather than viewing industrial preservation and environmental quality as competing objectives, planning should seek to transform inherited manufacturing landscapes into places capable of supporting metropolitan sustainability while simultaneously improving environmental conditions for adjacent communities.

This integrated perspective provides the foundation for the case study presented in the following sections. By examining North Brooklyn through the combined lenses of urban metabolism, circular economy, industrial geography, environmental justice, and healthy cities, the paper demonstrates that the future of manufacturing territories depends not only upon preserving industrial capacity but also upon redefining the social and environmental role these districts play within the contemporary metropolis.

2. Research Framework and Methods

2.1. Research Design

This research adopts an interdisciplinary planning approach that integrates historical analysis, spatial interpretation, policy analysis, and applied research developed through the New York City Department of Design and Construction (NYC DDC) Town+Gown Urban Resource Recovery (URR) Working Group. Rather than evaluating the technical performance of individual recycling technologies or conducting a life-cycle assessment of specific construction materials, the study investigates how historic manufacturing territories may contribute to emerging metropolitan systems of material circulation while simultaneously addressing environmental justice, public health, and sustainable urban development [3,26].

The research is positioned at the intersection of urban design, planning, industrial geography, environmental planning, and urban metabolism. Its principal objective is to examine how inherited industrial territories can be reinterpreted as strategic components of metropolitan environmental infrastructure while recognizing the social and environmental legacies that continue to characterize these districts.

Unlike engineering-based investigations of construction and demolition (C&D) waste management, this paper examines Urban Resource Recovery primarily as a territorial planning challenge. Material recovery depends not only upon technological innovation but also upon the geographic distribution of industrial land, transportation infrastructure, logistics networks, waterfront access, industrial zoning, and institutional capacity. Consequently, planning decisions concerning the preservation and transformation of manufacturing territories increasingly influence metropolitan resilience, circular economy implementation, and environmental justice [3,8].

Figure 1 summarizes the research framework, linking the theoretical foundations and research questions to the methodology, North Brooklyn case study, principal findings, and proposed Metropolitan Metabolic Infrastructure framework.

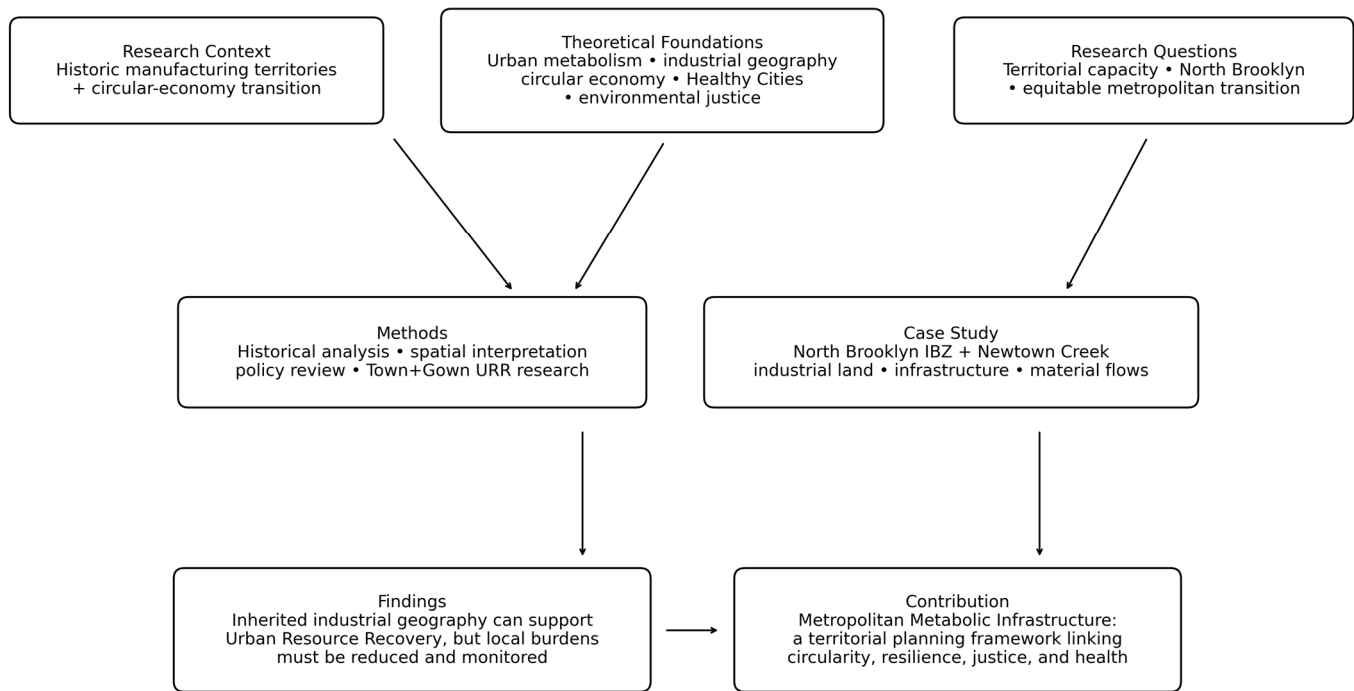


Figure 1. Research framework developed by the author, showing the relationship among research context, theoretical foundations, research questions, methods, case-study analysis, principal findings, and the proposed Metropolitan Metabolic Infrastructure framework.

2.2. Research Questions

The paper addresses four interrelated research questions that emerge from the convergence of urban metabolism, industrial geography, and Urban Resource Recovery.

RQ1. Which inherited geographic, infrastructural, and institutional characteristics enable historic manufacturing territories to support Urban Resource Recovery and metropolitan material circulation?

RQ2. How does North Brooklyn illustrate the transition from a traditional manufacturing landscape toward Metropolitan Metabolic Infrastructure while balancing circular economy objectives, environmental justice, and public health?

RQ3. How can planning better integrate industrial geography, Urban Resource Recovery, environmental justice, and Healthy Cities to guide the future transformation of historic manufacturing territories?

Collectively, these questions shift the discussion from individual technologies toward broader questions concerning industrial land policy and metropolitan planning.

2.3. The Town+Gown Urban Resource Recovery Working Group

The conceptual foundation for this research emerged through participation in the Urban Resource Recovery Working Group, established as part of the New York City Department of Design and Construction's Town+Gown Program. The Town+Gown initiative was created to foster collaboration between municipal agencies, universities, professional organizations, and industry in addressing complex urban challenges through applied research [3].

Within this framework, the Urban Resource Recovery Working Group investigated opportunities to increase the recovery and reuse of construction and demolition materials generated through New York City's capital construction program. The Working Group brought together architects, planners, engineers, environmental scientists, contractors,

policy makers, municipal agencies, and academic researchers to examine barriers and opportunities associated with circular construction practices [3,8].

Rather than limiting discussions to recycled material specifications or engineering performance, the Working Group considered broader planning questions including: [3]

- preservation of industrial land;
- metropolitan logistics;
- procurement policy;
- transportation infrastructure;
- environmental permitting;
- industrial capacity;
- material supply chains;
- governance;
- implementation strategies.

These interdisciplinary discussions highlighted that Urban Resource Recovery cannot be understood exclusively as a technical challenge. Successful implementation depends upon maintaining sufficient industrial territory capable of accommodating material recovery, processing, storage, and redistribution at metropolitan scales [3,8].

Although this paper does not present the technical findings of the Working Group itself, it builds upon these discussions to develop a broader planning interpretation of Urban Resource Recovery.

2.4. Case Study Selection

North Brooklyn was selected because it represents one of the most comprehensive examples in North America of a historic manufacturing district undergoing simultaneous industrial transition, environmental remediation, rapid urban redevelopment, and implementation of circular economy initiatives [15,16].

Several characteristics make North Brooklyn particularly appropriate for this investigation.

First, the district possesses one of New York City's largest concentrations of industrial land, waterfront infrastructure, freight facilities, recycling operations, construction-related industries, wastewater treatment infrastructure, and marine transportation [15,19].

Second, the area continues to support a diverse manufacturing economy while simultaneously experiencing significant redevelopment pressures and active planning proposals to introduce a broader mix of commercial, community, and potential residential uses within portions of the industrial district. These proposals create a direct tension with the findings of the NYC DDC Town+Gown Urban Resource Recovery Working Group, which emphasize the need to retain sufficient contiguous industrial capacity for material recovery, processing, storage, logistics, and redistribution [3,6,15].

Third, Newtown Creek represents one of the nation's most significant urban environmental remediation projects following its designation as a federal Superfund site, illustrating the cumulative environmental impacts associated with more than a century of industrial production [16,17].

Finally, the district has become central to municipal discussions regarding Urban Resource Recovery because many of the facilities necessary to support circular construction already exist within the area [3,8].

These overlapping conditions make North Brooklyn an ideal laboratory for examining how inherited industrial landscapes may evolve into metropolitan metabolic infrastructure.

2.5. Research Materials

The analysis combines multiple complementary sources of evidence in order to develop a comprehensive understanding of the relationship between industrial geography and Urban Resource Recovery [3,8,15].

These include:

- historical maps documenting the evolution of industrial land use;
- Geographic Information Systems (GIS) analyses illustrating manufacturing districts, transportation infrastructure, and metropolitan material flows [8,27]
- municipal planning documents, including Industrial Business Zone policies and Urban Resource Recovery reports; [11,15]
- reports produced through the NYC DDC Town+Gown Program; [3]
- publications by the Association for Neighborhood and Housing Development (ANHD), the Industrial Jobs Coalition, and other advocacy organizations; [12,19]
- historical research documenting industrialization, deindustrialization, and environmental change in North Brooklyn; [5,6,16]
- planning and environmental policy documents related to Newtown Creek; [17,27]
- design investigations and planning analyses undertaken by the author through participation in the Town+Gown initiative.

Rather than relying upon a single data source, the research synthesizes these materials to examine the territorial evolution of North Brooklyn across multiple temporal and spatial scales.

2.6. Analytical Framework

The analysis proceeds through four complementary stages.

The first examines the historical evolution of North Brooklyn as a manufacturing landscape, emphasizing the geographic factors that initially supported industrial development.

The second investigates the district's transformation through deindustrialization, industrial preservation initiatives, and contemporary Urban Resource Recovery strategies.

The third evaluates the environmental consequences of this transition by examining cumulative pollution, environmental justice, and healthy-city considerations associated with Newtown Creek and surrounding neighborhoods.

Finally, the paper synthesizes these observations into a broader planning framework that conceptualizes historic manufacturing territories as potential forms of metropolitan metabolic infrastructure.

Figure 1 summarizes the planning framework through which the inherited industrial territory is evaluated in relation to Urban Resource Recovery.

2.7. Limitations

The paper should be understood as a qualitative planning investigation rather than an engineering or life-cycle assessment study. It does not quantify material flows or evaluate the environmental performance of individual recycling technologies. Nor does it seek to model carbon reductions associated with specific Urban Resource Recovery interventions.

Instead, its contribution is conceptual and territorial. By combining planning theory, industrial geography, environmental justice, and Urban Resource Recovery, the paper proposes a framework through which historic manufacturing districts may be understood as strategic components of metropolitan environmental infrastructure. Although developed through the North Brooklyn case study, this framework may also provide a basis for interpreting similar industrial territories in metropolitan regions undergoing transitions toward circular urban economies. The absence of original quantitative environmental performance metrics, including life-cycle assessment, carbon accounting, and cumulative

exposure modeling, represents a limitation of this qualitative planning investigation. Future research should integrate these methods with the territorial planning framework proposed here to evaluate Urban Resource Recovery more comprehensively.

3. Results: North Brooklyn as an Emerging Metropolitan Metabolic Territory

Rather than presenting North Brooklyn solely as an industrial district or an environmental justice landscape, the following analysis demonstrates how its historical evolution has created the territorial conditions necessary to support contemporary Urban Resource Recovery (URR) and circular material systems. The results reveal that the same geographic, infrastructural, and institutional characteristics that once supported manufacturing increasingly position North Brooklyn as a strategic component of metropolitan metabolism. At the same time, they illustrate that realizing this potential depends upon simultaneously addressing environmental remediation, public health, and equitable urban development [8,14,15].

3.1. Historical Evolution of North Brooklyn's Industrial Landscape

North Brooklyn emerged during the nineteenth century as one of New York City's principal manufacturing districts because of a unique combination of geographic and infrastructural advantages. The East River and Newtown Creek provided navigable waterways that supported maritime commerce, while expanding rail corridors, industrial zoning, and proximity to Manhattan enabled the concentration of manufacturing, warehousing, shipbuilding, petroleum refining, and heavy industry. These conditions established an industrial landscape that would shape the economic geography of New York for more than a century [5,15,16].

Unlike many industrial districts that developed around a single economic sector, North Brooklyn evolved as a highly diversified manufacturing ecosystem. Food processing, metal fabrication, chemical industries, construction materials, transportation, maritime activities, and energy production coexisted within a dense network of industrial parcels connected by freight infrastructure and marine transportation. The resulting landscape represented not merely a concentration of factories but an integrated territorial system supporting metropolitan production [1,5,16].

Figure 2A,B illustrate the historical consolidation of manufacturing activities and the persistence of industrial zoning in North Brooklyn, from the 1922 industrial map to the current concentration of M3-1 districts.

Beginning after the Second World War, however, globalization, technological change, containerization, suburban industrial expansion, and changing transportation systems fundamentally altered New York City's manufacturing economy [5]. Manufacturing employment declined dramatically while large areas of industrial land experienced disinvestment, abandonment, or redevelopment pressure. Similar transformations occurred throughout North America and Europe, where industrial decline frequently encouraged planners to view manufacturing districts primarily as opportunities for residential redevelopment [4–6].

Despite these changes, North Brooklyn retained many of the territorial characteristics that originally supported industrial production. Industrial zoning remained largely intact, waterfront infrastructure continued to serve maritime functions, freight corridors persisted, and substantial industrial parcels survived within the metropolitan core. Although manufacturing activities evolved, the territorial framework itself proved remarkably resilient. This persistence forms the foundation of the argument advanced throughout this

paper: historic manufacturing territories possess inherited spatial characteristics whose contemporary value extends beyond traditional industrial production [11,15,19].

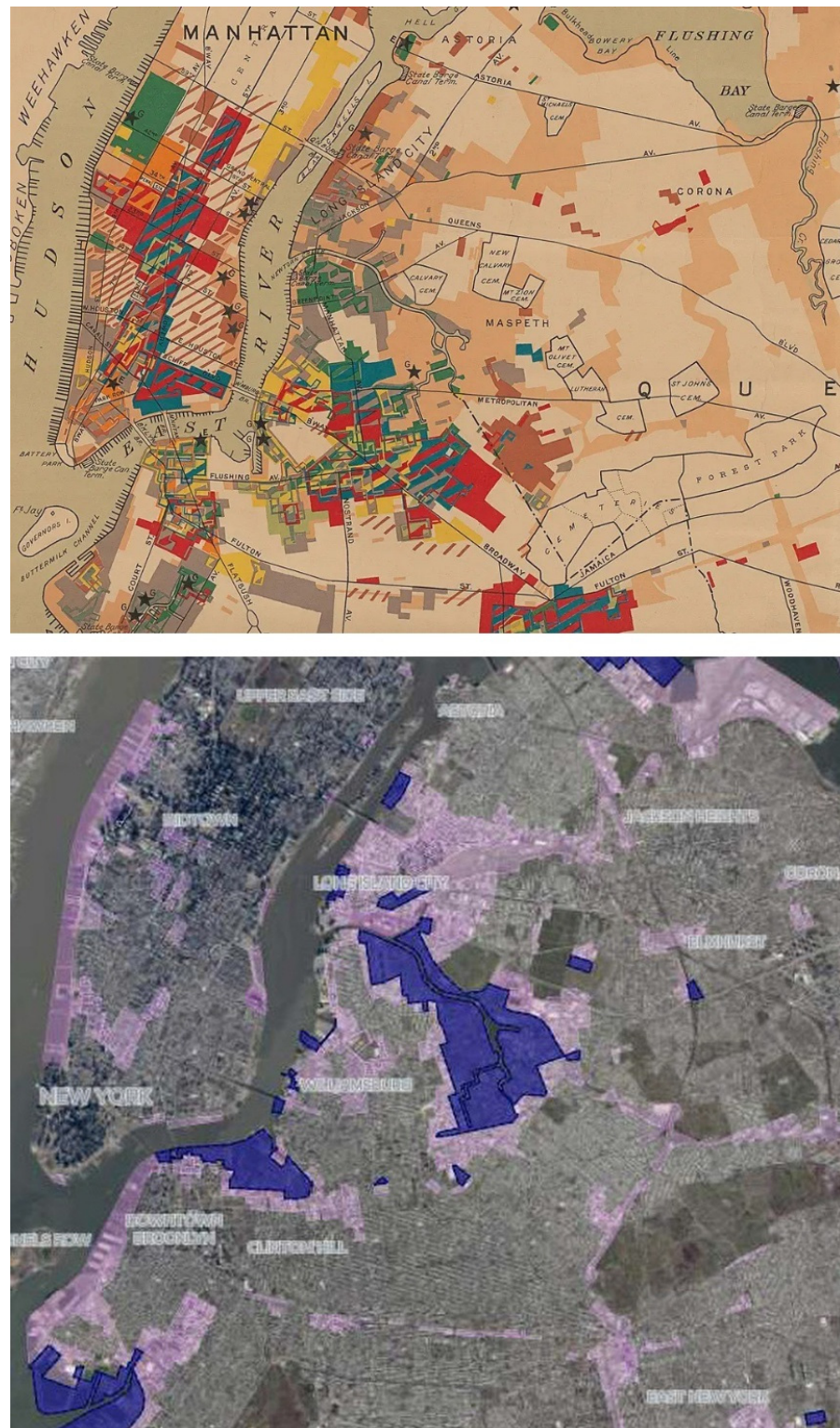


Figure 2. (A—Top): Historical persistence of industrial territory in New York City. (a) Industrial Map of New York City, showing the concentration of industrial activity around Newtown Creek and the East River in 1922. (B—Bottom): Contemporary zoning and land-use geography, highlighting in deep purple the remaining M3-1 heavy-manufacturing districts in North Brooklyn, several of which are under consideration for rezoning. Sources: (a) Merchants' Association of New York, Industrial Map of New York City [28]; (b) NYC Department of City Planning, ZoLa Zoning and Land Use GIS [29].

3.2. Manufacturing, Employment, and Social Infrastructure

The historical significance of North Brooklyn cannot be understood solely through industrial production. Manufacturing has also functioned as a critical component of the city's social infrastructure by providing accessible employment opportunities, supporting immigrant communities, and contributing to economic diversity. As documented by Curran [6], the gradual displacement of manufacturing through redevelopment has implications extending well beyond changes in land use, affecting workforce stability, neighborhood identity, and local economic resilience [1,5,6].

Organizations such as the Association for Neighborhood and Housing Development (ANHD) and the Industrial Jobs Coalition have consistently emphasized that Industrial Business Zones perform an important social function by preserving employment opportunities for workers who may not possess advanced educational credentials. These manufacturing sectors continue to provide middle-income jobs while supporting broader metropolitan economic resilience [12,19,30].

From the perspective of healthy-city planning, employment should be understood as an important social determinant of health. Stable employment contributes to housing security, household income, social mobility, and long-term community resilience. Consequently, preserving industrial capacity represents not only an economic objective but also a public-health consideration [20,22].

This broader understanding challenges simplistic distinctions between industrial preservation and environmental quality. Manufacturing districts simultaneously support employment, metropolitan services, and environmental infrastructure while requiring continuous environmental improvement to reduce historical pollution and improve neighborhood conditions [14,22].

Figures 3 and 4 illustrate the long-term transformation of industrial employment and the continuing role of community advocacy in protecting industrial land and employment.



Figure 3. Industrial employment in Brooklyn, 1969–2016, showing the long-term contraction of manufacturing employment and the changing composition of industrial and non-industrial jobs. Source: New York State Department of Labor, Quarterly Census of Employment and Wages [30]; graphic adapted by the author.



Figure 4. Community organizations continue to advocate for the protection of industrial land as a source of stable employment, economic mobility, and long-term community well-being. Source: Association for Neighborhood and Housing Development (ANHD) [12], Industrial Jobs Coalition.

3.3. Environmental Justice and the Legacy of Industrialization

The evolution of North Brooklyn has also produced profound environmental consequences. More than a century of petroleum refining, chemical manufacturing, maritime industry, combined sewer overflows, and heavy transportation has left a landscape characterized by contaminated soils, impaired waterways, deteriorated environmental quality, and significant public-health concerns [16–18].

The designation of Newtown Creek as a federal Superfund site reflects this cumulative environmental legacy. Unlike isolated pollution events, contamination within the creek resulted from successive generations of industrial activities that collectively transformed one of New York City’s most important waterways into one of its most environmentally degraded landscapes [16,17].

These conditions have disproportionately affected adjacent communities, illustrating many of the central concerns associated with environmental justice. Residents have experienced cumulative exposure to truck traffic, air pollution, hazardous industries, waste facilities, and contaminated environments while simultaneously living alongside infrastructure that serves the broader metropolitan region [13,14,25].

Figure 5 documents the contemporary planning pressures affecting the industrial territory and the legacy contamination associated with the Greenpoint Oil Spill.

Importantly, environmental remediation should not be interpreted as requiring the removal of manufacturing. Rather, the findings suggest that remediation, cleaner industrial technologies, improved freight systems, environmental restoration, and industrial preservation can be pursued simultaneously through integrated planning [15,22,24].

3.4. Urban Resource Recovery and Metropolitan Material Flows

Research conducted through the NYC DDC Town+Gown Urban Resource Recovery Working Group revealed that construction and demolition materials increasingly represent one of New York City’s largest untapped urban resources. Concrete, asphalt, masonry, soils, steel, timber, and other recovered materials possess considerable potential for reuse within metropolitan construction projects, reducing landfill disposal while decreasing dependence upon virgin material extraction [3,8,23].

Implementing these strategies, however, requires an extensive territorial infrastructure capable of supporting collection, transportation, sorting, processing, storage, manufactur-

ing, and redistribution. North Brooklyn already contains many of these facilities because of its historic industrial development [3,8].

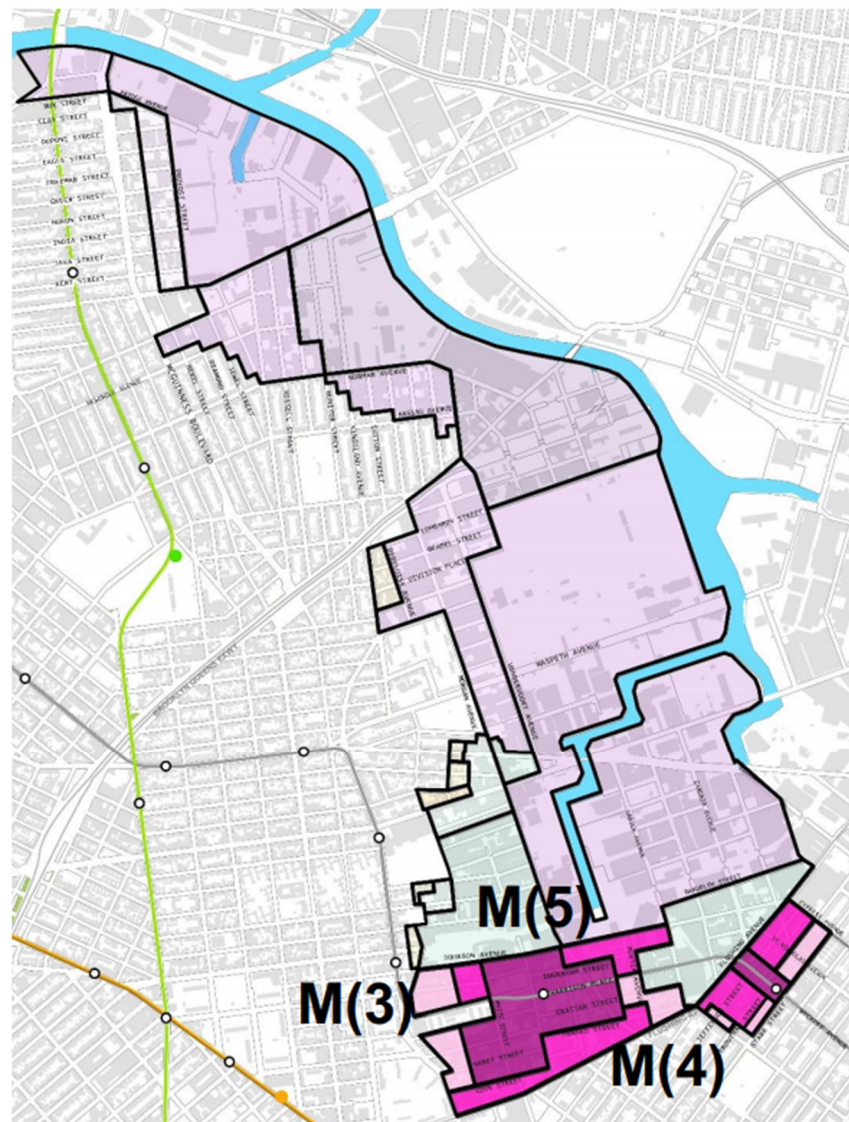


Figure 5. Proposed North Brooklyn planning framework, illustrating the City Planning Department’s effort to introduce a broader mix of commercial, community, and potentially residential uses within portions of the existing manufacturing district. The areas of heavier manufacturing zoning most directly related to the M3-1 territories shown in Figure 2B also correspond to the industrial capacity identified by the NYC DDC Town+Gown Urban Resource Recovery Working Group as necessary for material recovery, processing, storage, logistics, and redistribution. The figure therefore illustrates a central policy tension rather than a unified municipal objective. Source: New York City Department of City Planning [15], adapted by the author.

Rather than representing a new industrial geography, Urban Resource Recovery largely builds upon inherited territorial conditions. Existing industrial land, marine terminals, freight corridors, recycling industries, and logistics infrastructure provide the physical foundation necessary for metropolitan material circulation [8,15].

Figures 6–10 illustrate the relationship among metropolitan environmental infrastructure, construction and demolition material flows, the scale of recoverable building materials, and the industrial facilities required for Urban Resource Recovery.

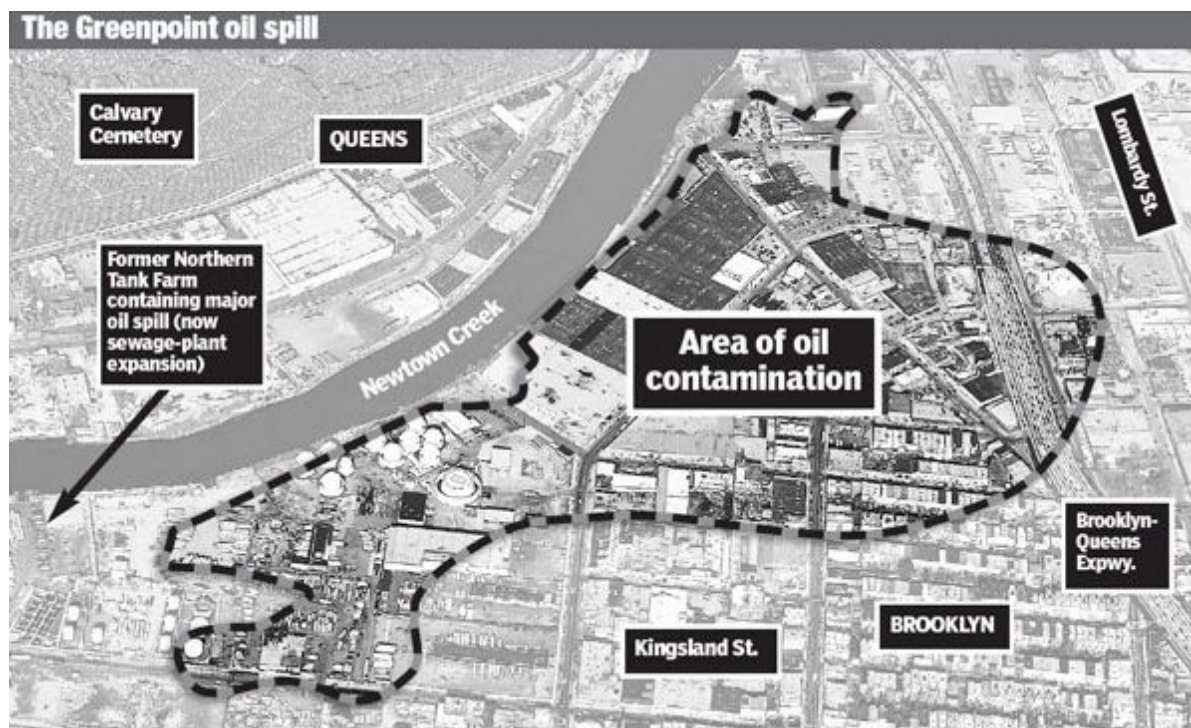


Figure 6. Approximate extent of the Greenpoint Oil Spill, an enduring example of the legacy contamination that continues to shape environmental policy and planning throughout the Newtown Creek corridor. Source: map reproduced in public reporting on the Greenpoint Oil Spill; see Navarro [18] and U.S. Environmental Protection Agency [17].



Figure 7. Newtown Creek Wastewater Resource Recovery Facility, illustrating the role of large-scale environmental infrastructure within New York City's urban metabolism. Image: Jeff Goldberg/Esto, courtesy of Ennead Architects.

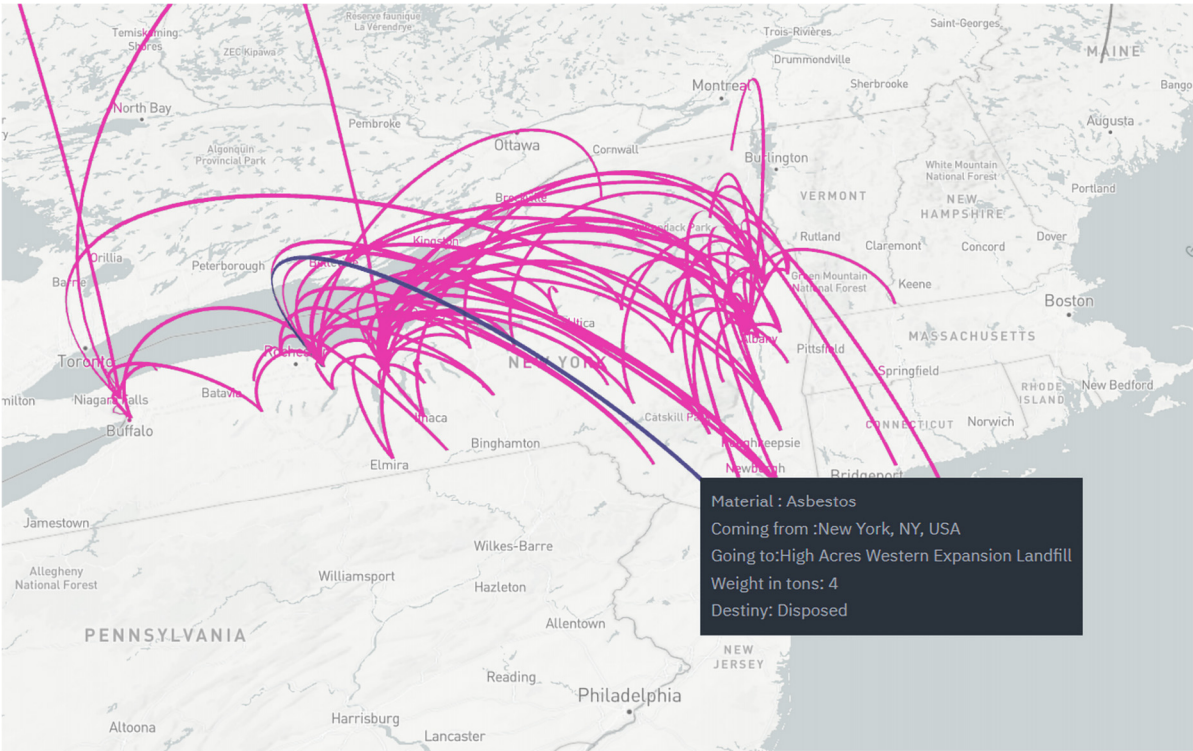


Figure 8. Mapped construction and demolition waste movements originating in New York City, demonstrating the regional distances through which recoverable materials may travel before disposal or processing. The figure is important to the argument because it makes visible the territorial scale of the material system: when recoverable C&D materials are exported for distant processing or disposal, transportation becomes part of their environmental footprint. This supports the planning rationale for retaining strategically located industrial capacity capable of shortening material loops while subjecting local processing to rigorous environmental safeguards. Source: McKay, Singhal, and Wagdy [8], NYU CUSP/NYC DDC Town+Gown.

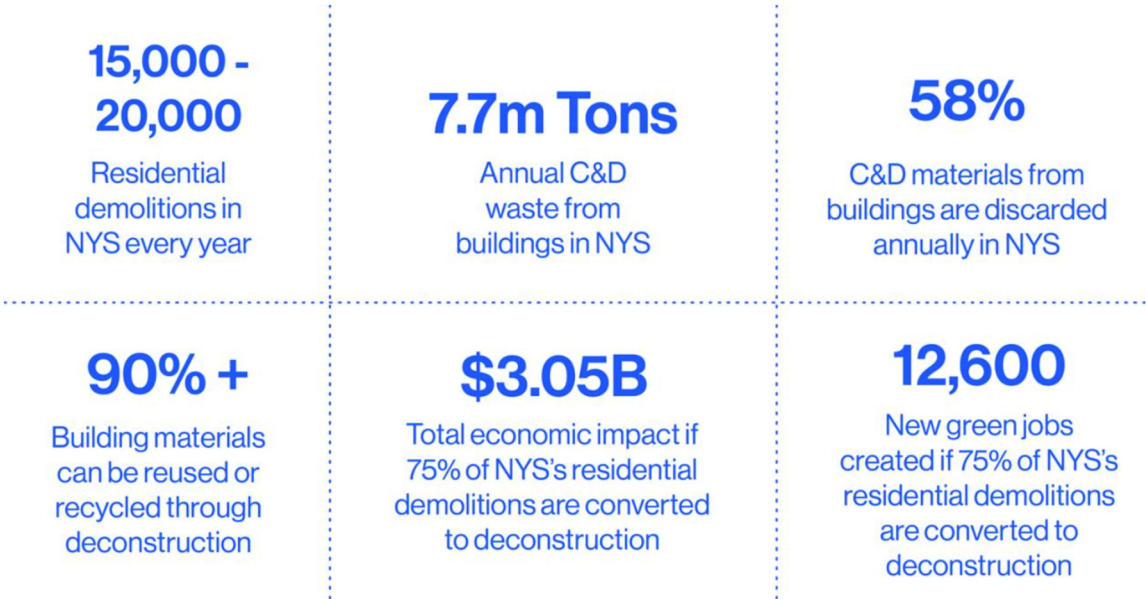


Figure 9. Scale and potential value of construction and demolition materials in New York State, including annual waste generation, recoverable material, economic impacts, and potential green employment associated with deconstruction. Source: Circular Construction Lab, Cornell University, white paper graphic [31].



Figure 10. Contemporary construction and demolition waste recycling facility, illustrating the industrial land, equipment, storage, and processing capacity required to implement urban circular-economy strategies. Source: Author.

These observations demonstrate that Urban Resource Recovery should be understood not merely as a waste-management strategy but as a metropolitan planning framework linking industrial geography, logistics, environmental infrastructure, and circular economy [2,7,8].

3.5. *Historic Manufacturing Territories as Metropolitan Metabolic Infrastructure*

The preceding analysis supports the central proposition of this paper.

Historic manufacturing territories should not be viewed solely as remnants of industrial economies nor exclusively as redevelopment opportunities. Instead, they represent inherited territorial systems whose geographic, infrastructural, logistical, and institutional characteristics increasingly align with the requirements of metropolitan material circulation [7,8,15].

This inherited territorial capacity distinguishes manufacturing districts from many other urban landscapes. Waterfront access, freight infrastructure, industrial zoning, large industrial parcels, utility systems, transportation networks, and specialized industrial ecosystems cannot easily be recreated elsewhere within mature metropolitan regions. Their continued existence therefore constitutes an important strategic asset for implementing Urban Resource Recovery, industrial ecology, and circular economy initiatives [1,11,15].

Taken together, Figures 2B and 4 show how the inherited industrial geography and current planning framework establish the territorial conditions within which material recovery, environmental services, logistics, and manufacturing can operate.

Importantly, recognizing manufacturing territories as metropolitan metabolic infrastructure does not imply preserving industrial activities irrespective of environmental performance. Rather, it suggests that future planning should simultaneously pursue industrial modernization, environmental remediation, cleaner technologies, climate adaptation, healthy-city objectives, and environmental justice [14,22,24].

Viewed through this perspective, North Brooklyn becomes more than a case study of industrial preservation. It represents an emerging model through which historic manufacturing landscapes can evolve into strategic environmental infrastructure supporting both metropolitan sustainability and community well-being.

4. Discussion: Reframing Historic Manufacturing Territories as Metropolitan Metabolic Infrastructure

The North Brooklyn case demonstrates that historic manufacturing territories cannot be adequately understood through the conventional dichotomy of industrial preservation versus urban redevelopment. Rather, they represent dynamic metropolitan landscapes whose inherited geographic, infrastructural, and institutional characteristics continue to provide critical support for contemporary urban systems. The findings suggest that the future value of these districts increasingly lies not only in their capacity to accommodate manufacturing, but also in their ability to facilitate metropolitan material circulation, environmental infrastructure, and circular urban economies [1,7,15].

This perspective extends current discussions of urban metabolism by emphasizing that material flows are inherently territorial. Urban metabolism has traditionally focused on quantifying resource inputs and outputs, measuring environmental performance, and improving resource efficiency. While these contributions have substantially advanced sustainability research, comparatively less attention has been given to the physical landscapes through which urban metabolism operates. Construction materials, recycled aggregates, wastewater, freight logistics, renewable energy systems, and industrial ecology all require land, infrastructure, and spatial organization. Historic manufacturing territories provide many of these conditions because they were originally developed to support large-scale production, transportation, and material exchange [7,9,10].

The findings therefore suggest that industrial geography should be recognized as an integral component of metropolitan metabolism rather than simply the location where industrial activities occur. This represents an important conceptual distinction. Urban metabolism is not only a system of material flows; it is also a system of places that enable those flows to occur. The inherited territorial structure of historic manufacturing districts—including waterfronts, freight corridors, utility systems, industrial parcels, and specialized industrial ecosystems—constitutes a form of metropolitan capital that has become increasingly valuable within circular economy strategies [1,7,8].

Importantly, this interpretation should not be understood as advocating the preservation of industrial land for its own sake. Industrial activities that continue to generate unacceptable environmental impacts, inefficient land use, or unnecessary public-health burdens cannot be justified solely on the basis of historical continuity. Instead, the argument advanced here is that historic manufacturing territories possess an inherent territorial capacity that can support emerging forms of Urban Resource Recovery, cleaner manufacturing, low-carbon logistics, renewable energy infrastructure, and industrial symbiosis. Their future therefore depends upon transformation rather than simple preservation [14,24].

In North Brooklyn, this tension is institutional as well as spatial. The New York City Department of City Planning has explored a broader mix of uses within portions of the industrial district, including commercial, community, and potentially residential uses, as illustrated in Figure 4. By contrast, the NYC Department of Design and Construction's Town+Gown Urban Resource Recovery Working Group has identified the continued availability of substantial and relatively contiguous manufacturing territory as a prerequisite for maintaining metropolitan material-recovery capacity. The two positions are not fully aligned: one seeks greater land-use flexibility and redevelopment, while the other highlights the risk that fragmentation or conversion of industrial land could erode the district's

capacity to function as metropolitan metabolic infrastructure. This policy divergence is central to the North Brooklyn case and should be understood as an unresolved planning conflict rather than as a shared municipal agenda [3,8,15].

This distinction is particularly significant within rapidly growing metropolitan regions where redevelopment pressures often threaten the remaining supply of industrial land. Once industrial waterfronts, freight corridors, and large manufacturing parcels are converted to residential or commercial development, recreating equivalent territorial capacity elsewhere becomes extraordinarily difficult. Consequently, planning decisions concerning industrial land have implications extending well beyond local land-use policy; they influence the long-term resilience of metropolitan resource systems and the capacity of cities to implement circular economy objectives [6,11,15].

The North Brooklyn case also illustrates the importance of integrating environmental justice into metropolitan resource planning. Historically, industrial districts have concentrated many of the environmental burdens associated with urban development, including contaminated waterways, waste processing, heavy transportation, hazardous industries, and degraded air quality. These cumulative impacts have disproportionately affected neighboring communities while providing metropolitan-scale economic and environmental services. Urban Resource Recovery therefore presents both an opportunity and a responsibility. Although recovering construction materials reduces landfill disposal, lowers embodied carbon, and conserves natural resources, these metropolitan benefits cannot come at the expense of communities that have historically borne disproportionate environmental costs [13,14,25].

An important tension nevertheless remains. Historically, manufacturing districts generated localized environmental burdens while producing metropolitan economic benefits. Contemporary Urban Resource Recovery risks reproducing this imbalance if additional processing activities are introduced without corresponding investments in cleaner technologies, emissions controls, remediation, and community health. At the same time, locating recovery facilities within established industrial territories can substantially reduce the long-distance transportation of construction and demolition waste, decreasing truck vehicle-miles traveled, fuel consumption, greenhouse-gas emissions, and the displacement of environmental impacts to distant communities. The planning challenge is therefore not simply whether these activities should occur, but how their unavoidable local impacts can be continuously reduced while maximizing their contribution to the overall environmental health of the metropolitan region through integrated planning, industrial modernization, and environmental restoration [3,8,20,23].

For this reason, environmental justice should not be viewed as a constraint on Urban Resource Recovery but as one of its fundamental design principles. Cleaner industrial technologies, remediation of contaminated land and waterways, electrification of freight systems, improved environmental monitoring, community participation, and equitable distribution of economic benefits must accompany the expansion of metropolitan material recovery systems. Planning for circular economies is therefore inseparable from planning for healthier and more equitable cities [20,22,24].

The findings further reinforce the relevance of the Healthy Cities framework. Historically, public health and industrial planning have often been treated as separate fields. Yet manufacturing districts influence many of the social and environmental determinants of health, including employment opportunities, environmental quality, transportation systems, access to infrastructure, and neighborhood resilience. As cities transition toward circular urban economies, industrial territories should therefore be evaluated according to their capacity to contribute simultaneously to environmental performance, economic opportunity, and community well-being [20–22].

Although developed through the case of North Brooklyn, the conceptual framework proposed in this paper has broader implications for industrial metropolitan regions worldwide. Former manufacturing districts in cities such as Rotterdam, Hamburg, Antwerp, London, Chicago, Toronto, Osaka, and Barcelona face similar tensions between redevelopment, industrial preservation, environmental remediation, and circular economy implementation. While each possesses distinct political, economic, and environmental conditions, many share inherited territorial assets whose strategic importance is likely to increase as metropolitan regions seek to strengthen resource resilience and reduce carbon emissions. Future research should therefore explore how the concept of metropolitan metabolic infrastructure may be applied comparatively across different planning contexts. Although these metropolitan regions differ considerably in governance, industrial history, and regulatory frameworks, they share inherited industrial waterfronts, freight infrastructure, and redevelopment pressures that make the proposed framework broadly applicable [2,7].

The framework also suggests several directions for future planning research. Greater integration between urban metabolism and industrial geography could improve understanding of how material flows depend upon spatial organization. Similarly, closer collaboration among planners, engineers, public-health researchers, economists, and environmental scientists may generate more comprehensive approaches to evaluating Urban Resource Recovery. Quantitative analyses of material flows, life-cycle assessments of recycled construction materials, spatial modeling of industrial logistics, and comparative studies of industrial districts would further strengthen the empirical basis for metropolitan resource planning. Future research should also translate this conceptual planning framework into measurable indicators integrating material recovery, transportation efficiency, carbon reduction, environmental quality, industrial employment, and public health outcomes, enabling more systematic evaluation of Urban Resource Recovery across metropolitan regions [7,8,14].

Ultimately, the discussion presented here argues for a shift in planning perspective. Rather than approaching historic manufacturing territories primarily as landscapes of industrial decline or redevelopment opportunity, planners should recognize them as strategic metropolitan infrastructures capable of supporting the transition toward more circular, resilient, equitable, and environmentally responsible urban futures. Their significance lies not only in what they once produced but increasingly in the metropolitan systems they are uniquely positioned to sustain [1,32].

5. Conclusions

Historic urban manufacturing territories are frequently characterized as landscapes of environmental degradation, economic decline, or redevelopment opportunity. While each of these perspectives reflects important aspects of their evolution, they no longer adequately explain the strategic role these districts can play within twenty-first-century metropolitan regions. As cities confront climate change, resource scarcity, decarbonization, and the transition toward circular economies, historic manufacturing landscapes are increasingly being called upon to perform new environmental, logistical, and social functions that extend well beyond traditional industrial production [2,4,5].

Using North Brooklyn and the Newtown Creek Industrial Business Zone as a case study, this paper has argued that certain historic manufacturing territories possess an inherent territorial capacity to evolve into metropolitan metabolic infrastructure. This capacity derives from the convergence of inherited geographic, infrastructural, institutional, and industrial characteristics—including waterfront access, freight systems, utility networks, industrial land, specialized manufacturing ecosystems, and established logistics corridors—

that increasingly align with the spatial requirements of Urban Resource Recovery and circular material systems.

The research further demonstrates that the future of these territories cannot be understood solely through industrial preservation or redevelopment. Rather, their continued relevance depends upon their ability to integrate environmental remediation, cleaner industrial technologies, circular resource systems, resilient logistics, economic opportunity, and public health within a comprehensive planning framework. Metropolitan sustainability therefore requires preserving and transforming industrial landscapes capable of supporting material circulation while simultaneously improving environmental quality and quality of life for surrounding communities [3,20,24].

A central contribution of this paper is the integration of urban metabolism, industrial geography, circular economy, environmental justice, and Healthy Cities into a single territorial planning framework. While urban metabolism has traditionally emphasized the quantification of material and energy flows, this research argues that these flows depend fundamentally upon the inherited geography of cities. Material circulation is not an abstract process; it occurs within physical territories whose spatial organization influences environmental performance, economic resilience, and long-term metropolitan sustainability. Recognizing this territorial dimension expands the application of urban metabolism from an analytical framework toward a planning framework capable of informing industrial land policy and metropolitan development [2,7,9,14].

The North Brooklyn case also illustrates that the transition toward circular urban systems must be guided by principles of environmental justice. Communities that have historically borne the environmental costs of industrialization should also benefit from cleaner technologies, environmental remediation, improved public spaces, healthier living conditions, and expanded economic opportunities. Urban Resource Recovery should therefore be understood not only as a strategy for reducing waste and embodied carbon but also as an opportunity to reshape the relationship between industry, environment, and society in more equitable ways [13,22,24].

Although this study focuses on New York City, its implications extend well beyond a single metropolitan region. Historic manufacturing districts throughout North America, Europe, and many rapidly urbanizing regions possess similar inherited territorial assets and face comparable pressures associated with redevelopment, industrial transformation, and climate adaptation. The conceptual framework proposed here offers a basis for evaluating these territories as strategic metropolitan infrastructure whose value increasingly lies in supporting resilient resource systems and circular urban economies [2,7].

Future research should build upon this work through comparative studies of industrial territories in different metropolitan contexts, quantitative analyses of material flows and Urban Resource Recovery networks, and assessments of how industrial land policies influence regional carbon reduction, economic resilience, and public health outcomes. Such investigations would further strengthen the relationship between planning theory and the practical implementation of circular urban systems. The framework proposed here should therefore be understood as a planning model intended to guide future interdisciplinary investigations rather than as a substitute for engineering-based environmental performance assessments, life-cycle analysis, or carbon accounting [7,8].

Ultimately, this paper argues for a broader shift in how planners understand historic manufacturing territories. Rather than viewing them as relics of the industrial past or merely as reserves for future redevelopment, they should be recognized as essential components of the metropolitan systems upon which sustainable cities increasingly depend. Their future lies not in preserving industrial history for its own sake, but in transforming

inherited industrial landscapes into resilient, equitable, and environmentally responsible infrastructure capable of supporting the metabolism of the twenty-first-century city.

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