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Re-weaving threads for a circular economy: Spatio-temporal dynamics of the textile and clothing sector in Rotterdam

Minalies Rezikalla[1], Younghyun Kim[2], Karel Van den Berghe[1], Mariangela Lavanga[2], Willem Korthals Altes[1] and Amanda Brandellero[2]

Abstract

The ambition of achieving a circular economy (CE) brings with it renewed challenges in implementing systemic change in a context reluctant to abandon 'business as usual', but in which the urgency to transform linear production patterns into circular ones grows ever stronger. Taking a holistic ecosystem approach to circularising economies, re-localising key supply chain activities offers opportunities, while also challenging the system. This article maps the businesses active in the textile and clothing (T&C) sector in Rotterdam (the Netherlands) between 1996 and 2022 to uncover the geography of the circular T&C supply chain in and around Rotterdam and to find potential hotspots for localised resource flows. The T&C sector offers insights into the potential re-territorialisation of manufacturing supply chains and the spatial distribution of CE in Rotterdam.

Keywords

textile and clothing sector, re-territorialisation, localisation, circular manufacturing, urban planning, Rotterdam

Introduction

The European Industrial Strategy published in 2020 announced a European transition towards climate neutrality, aiming to support Europe's ambition to become the first climate-neutral continent by 2050 (European Commission, 2020a). It integrates the goals of the 2015 Circular Economy Action Plan (European Commission, 2015) towards a circular economic transition, additionally addressing the decoupling of economic growth from resource use. This strategy fits within a renewed appreciation of industry in Europe, coming after decades of post-industrial planning (Batty, 1991; Lux, 2021). Textiles are particularly highlighted as the fourth highest-pressure category (European Commission, 2020b: 10; European Commission, Directorate-General for

[1]TU Delft, The Netherlands
[2]Erasmus University Rotterdam, The Netherlands

Corresponding author:
Minalies Rezikalla, Faculty of Architecture and the Built Environment, TU Delft, 2628 BL Delft, The Netherlands.
Email: m.m.rezikalla@tudelft.nl

Internal Market, Industry, Entrepreneurship and SMEs, 2023; European Environment Agency, 2024), while, simultaneously, the goal of 'strengthening industrial competitiveness and innovation in the [textile and clothing (T&C)] sector' is stated (European Commission, 2020b). The strategy is echoed in the New Leipzig Charter (European Commission, Directorate-General for EU Regional and Urban Policy, 2020), where the concept of the Productive City encourages engaging with industry and manufacturing as the infrastructure for resilient, sustainable, and inclusive urban socio-economic development.

These wider Commission goals are embedded into circular practices at the urban level (Rijksoverheid, 2020). One of the key aspects of such localisation is the shortening of supply chains and increasing the level of transparency and sense of control that is needed to enact a circular economy (CE; Norris, 2019; North, 2010). Key challenges to localisation include the presence of often conflicting or competing stakeholder interests and interpretations, and a lack of information about the locational attributes of supply chain actors who enact CE (Bucci Ancapi et al., 2022; van Bueren and Priemus, 2002). Scholars also indicate that to reach CE, the local conditions that support a linear economy need to be transformed to enable alternative production and consumption models (Norris, 2019; Williams, 2020). Acerbi and Taisch (2020) define circular manufacturing as manufacturing strategies that reduce resource consumption, extend resource lifecycles, and close resource loops to meet stakeholders' needs (p. 11). Research by Arfaoui et al. (2025) points to the importance of localised interactions as a stimulus for the adoption of circular practices.

Rotterdam presents an ideal case to explore the spatial patterns of CE, as it started the post-industrialisation processes later compared to other large cities in the Netherlands (Custers and Willems, 2024; Meyer, 2018). Today, CE is a main policy goal in Rotterdam, alongside attracting more innovative manufacturers (Municipality of Rotterdam, 2021). The CE strategy aims to adapt the existing industrial infrastructure to re-integrate manufacturing value chains locally, within a spatially embedded circular production and consumption network. With national, regional, and municipal efforts to expand local, circular manufacturing facilities, this research investigates the extent to which the 'Industrious' (Schaefer, 2021) paradigm is spatially progressing in Rotterdam. Furthermore, we focus our analysis on the evolution of the T&C sector in a city that is not recognised as a fashion capital yet has attracted and retained an increasing number of fashion designers in the last decade because of the availability of cheaper working spaces compared to the more famous fashion capital, Amsterdam (Brydges et al., 2021). In particular, we study the clustering dynamics of the T&C sector over the past 27 years and determine the potential locations where circular manufacturing initiatives are likely to emerge.

The central research question is *What hotspots emerge over time as potential areas for facilitating proximate circular T&C manufacturing initiatives in Rotterdam?* To answer it, we employ a hotspot analysis of the business distribution of T&C businesses in Rotterdam between 1996 and 2022 to map the proximity dynamics of T&C supply chain actors. We discover the key neighbourhoods that host (or are near) a diversity of supply chain actors, having the presence needed to facilitate a localised T&C CE.

Literature review

Urban space for circularity: Beyond post-industrialisation

In the 'Industrious City' (Schaefer, 2021), space is no longer seen as a passive container of urban activities but as a dynamic relational construct, continuously shaped by and shaping social, economic, and environmental processes. This extends beyond the 'traditional' geographic understanding of space, as delineated by fixed regional classifications or administrative definitions, following the relational approach where space is considered fluid, interconnected, and networked (Bathelt and Glückler, 2003; Paasi, 2010). A relational perspective of entities in space questions the post-industrial city planning that externalises manufacturing activities from urban cores alongside labour and spatial divisions and is amplified by the (re-)recognition that energy, materials, and manufacturing processes matter socio-economically, regaining policy relevance.

The resurgence of small-scale, localised production systems, such as in the T&C sector, highlights that

manufacturing can contribute to socio-economic diversity and sustainability (Bressanelli et al., 2022; Van den Berghe and Verhagen, 2021). These systems demand spaces that are flexible, interconnected, and embedded within broader urban ecosystems, enabling proximity to labour, fabrics, and consumers (Ferm et al., 2021). Urban spaces designed to accommodate such manufacturing activities become facilitators for circular transitions by creating opportunities for symbiotic networks of production, reuse, and innovation.

However, achieving urban spaces for circularity requires rethinking about urban planning and spatial policies. Post-industrial cities often prioritise commercial and residential development, trivialising industrial activities (Ferm and Jones, 2017). To facilitate circular transitions, urban planners must find a new balance between land uses to ensure that designated manufacturing spaces are protected from gentrification and large-scale redevelopment (Van den Berghe and Verhagen, 2021). Moreover, the urban structure must actively support circular manufacturing, fostering connections between supply chain actors and embedding manufacturing within broader cultural and socio-economic contexts (Brandellero and Naclerio, 2024). Urban spaces for circularity have a dual function as a network of relationships and a physical locus for transformative urban activities.

Developing CE in urban areas

CE is a system's solution framework where materials are kept at their highest value, avoiding becoming waste (Ellen MacArthur Foundation, 2015; Kirchherr et al., 2017). By decoupling economic activity from the consumption of finite resources, CE aims to tackle global challenges such as climate change, biodiversity loss, waste, and pollution (Ellen MacArthur Foundation, 2015). Within this framework, actions to achieve circular resource consumption are ranked on a ladder-like form referred to as R-strategies (Potting et al., 2017), where the peak (R0 – refuse) is the most circular state of resource consumption, and the bottom (R9 – landfill) is the current, linear economy. The R-strategies provide insight into the level of circularity that a business is engaging in and act as a proxy for innovation; activities higher on the ladder align with more innovative methods for retaining resource value, bringing supply chains closer to CE (Malooly and Daphne, 2023). Businesses' positions across the urban fabric can therefore influence cross-sectoral CE practices through the localisation strategies enacted.

Three concepts frame the CE transition in urban planning practice: re-territorialisation (bringing activities within territorial boundaries), proximity dynamics (network relationships between business activities), and clustering (locating certain business activities closer to one another).

Re-territorialisation

For decades, globalisation guided the major economic pathways (Hatzichronoglou, 1996), resulting from deregulation and the development of information and communication technology, sustaining global supply chains. In the European textile industry, the 'beginning of the 1990s has seen an unprecedented wave of restructuring involving relocation to non-EU countries with low production costs and enhanced subcontracting' (Scheffer, 1995: 477). In 1999, an OECD working paper concluded: 'One of the most internationalised low-technology industries is the textiles/clothing industry' (Hatzichronoglou, 1999: 40). Brenner (1999) further points out that globalisation has a profound impact on the territorial governance of cities and states because it comes with a new territorial organisation of urban areas and a rescaling of activities.

Although globalisation has developed further since the 1990s, a counter-movement towards re-territorialisation emerged. Re-territorialisation aims to bring production back within territorial boundaries, while utilising local qualities and features to do so, thereby reinforcing social ties and strengthening the relationship between places, producers, and consumers (Dansero and Pettenati, 2018). This shift contributes towards the transformation needed to combat climate change and loss of biodiversity (e.g. decreasing energy consumption in transportation, decreasing land use for production), reduce resource use (e.g. by re-using existing products and reducing waste), and promote equity (e.g. by disincentivising low quality work in mass production, by which 'labour is informalised, fragmented, and made disposable by the globalisation of production'; Crinis and Vickers, 2016: 4).

Re-territorialisation can, for example, be found in agriculture where, as a counter-movement to large farms producing for the world market, alternative models of farming have developed, promising short chains between producers and consumers and developing the idea of urban agriculture (Liu, 2024). Governance plays an important role in the development of globalisation and in the process towards localised production (Liu, 2024). In their literature, Dansero and Puttilli (2013) analyse re-territorialisation through the dimensions of:

i. space (absolute proximity vs. increasing distance),
ii. resources (specific vs. standardised), and
iii. relations (communitarian vs. market-oriented).

These dimensions are relevant for territorialising T&C as well, where first, spatially, absolute proximity can be achieved when garments are made at their use point, and people reuse fabric to make new products, opposing the distance of mass-produced T&C. Second, regarding resources, tailoring and crafting can result in unique products, contrasting the standardised garments of the global market. This is more pronounced in clothing than in food, as both what one eats and wears reflect their identity (as per the saying 'You are what you eat and what you wear'), and in both, there is a conflict between hedonic behaviour and pro-environmental self-identities (Stancu, 2020). Third, relationship-wise, for communities that share and exchange with each other, the value of the enduring relationship is higher than the value of an individual deal. This stands against the practice of purely transactional relationships and brings into question the weight of proximity in cementing relationships. Re-territorialisation, therefore, encompasses these dimensions; it entails an orientation towards unique products of a proximate community and an acknowledgement of these territorial values in action.

Clustering and proximity

By re-territorialising CE, scholars have increasingly focused on the role of proximity in supporting circular economic activities. Proximity can be conceptualised as both geographical and organised, which together elucidate the spatial and relational dynamics that underpin collaboration and innovation among economic actors (Boschma, 2005; Torre and Gallaud, 2022; Torre and Gilly, 2000). In the case of CE initiatives, both dimensions of proximity are vital for coordinating resource flows and collaboration efforts (Chembessi et al., 2024; Kim, 2024; Veyssière et al., 2021), although geographical proximity is of particular interest in this article for localising CE practices. Industrial symbiosis programmes and eco-industrial parks illustrate how proximity fosters agglomeration economies and enhances cost efficiencies through the spatial concentration of businesses, resources, and consumers (Domenech et al., 2019; Tapia et al., 2021).

Geographical proximity improves accessibility to and sharing of infrastructure, alongside the circulation of secondary and waste materials, optimising the allocation of resources and logistic processes in circular initiatives (Chembessi et al., 2024; Tapia et al., 2021). This is especially necessary for advancing circular initiatives in the T&C sector, creating local production networks, facilitating consumer engagement, and encouraging upcycling initiatives and recycling innovation, thereby shaping collaboration across the production, consumption, and end-of-life phases of fashion products (Kim, 2024). The fashion sector particularly benefits from geographical proximity, which fosters tacit knowledge exchange and social learning among businesses, the majority of whom are micro-enterprises (Lavanga, 2020; Rantisi, 2002; Williams and Currid-Halkett, 2011). Clustering of fashion businesses is especially strong in the urban context, as demonstrated in the development of prominent fashion cities, including global fashion capitals and second-tier fashion cities (Casadei et al., 2021), as cities host diverse businesses and communities that could form a critical mass to enable the experimentation and proliferation of circular practices (Tapia et al., 2021). Hereby, businesses can form a stronger awareness of their local sectoral community, while developing circular collaboration infrastructure and business models to both differentiate themselves from the sector at large and to progress sectoral innovation.

While the organised dimension of proximity (such as shared knowledge bases, institutional alignment,

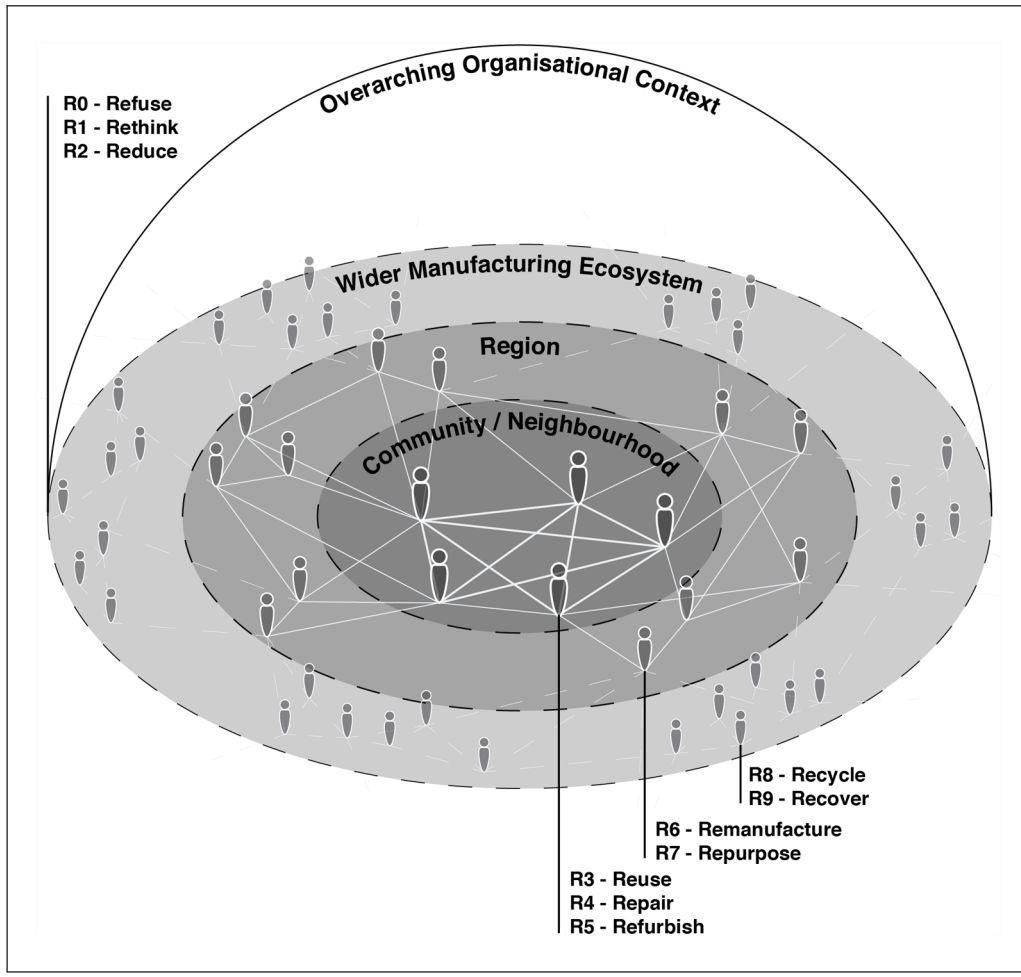


Figure 1. Conceptual framework showing the spatial networks between supply chain actors and the R-strategies they perform.
Source: Authors.

and organisational structures) is essential in supporting circular fashion initiatives (Kim, 2024), the geographical proximity of T&C sector businesses warrants further investigation in light of strong outsourcing practices and supply chain fragmentation, which hamper the sustainability transition of the T&C sector. Hence, to support re-territorialisation of T&C supply chains and integrate CE principles (Norris, 2019; Real et al., 2020), it is key to monitor and ensure the availability of space and infrastructure for circular activities in cities, as highlighted in discussions on circular urban development (Williams, 2020).

Conceptual framework

To localise circular manufacturing value chains, a complex inter-relation between actors, resources, and space emerges, which is visualised in this conceptual framework from the perspective of a sector's actors and their relations within a region (Figure 1).

Spatially, the lower the R-strategies act on the ladder, the wider the territory in which they operate, since these activities rely more on economies of scale and regional systemic infrastructures to function optimally than higher R-strategies do. These infrastructures and networks can be repurposed from the existing linear ones but they need slight adaptation to suit the needs of the new economic system, such as more investment in shared facilities. To operate at the highest R-strategies, more input and agreements are needed at a broader organisational level. The absolute proximity of the R-strategies is therefore relative in scale across the ladder; the higher up the ladder, the more personal absolute proximity becomes. Within the immediate network of the central actors in this framework, the activities and products are more specific and tailored to various needs. For actors farther outside the central actors' network, processes become more standardised, and actions become more market-oriented. The lower R-strategies and their interconnected infrastructures for operation are necessary to support actors at higher-order R-strategies (closer to the centre of the network) to operate within a full CE.

For every R-strategy stretching further outside the network, more (and different) actors are involved in the material retrieval process. Therefore, understanding the proximity and clustering of local businesses in Rotterdam can show us to what extent different R-strategies may be achievable. Higher R-strategies are typically proximal to urban life, while lower R-strategies are tied to the infrastructure networks that physically connect them beyond the metropolis. We expect similar patterns to emerge in Rotterdam, although the question is to what extent T&C businesses co-locate within the same areas to facilitate circular activities.

Methodology

Dataset and selection

The research is conducted using the Dutch National Employment Information System (*Landelijk Informatiesysteem van Arbeidsplaatsen*, LISA) dataset for the earliest and latest years available between 1996 and 2022. LISA is a dataset of all business branches registered in the Netherlands' business register and includes information on the business' activities, employees, and location. The columns relevant to the analysis are the geographical coordinates of the companies, the Standard Industrial Classification (Standaard Bedrijfsindeling/SBI, the Dutch equivalent of the European statistical classification of economic activities/NACE codes) at the most detailed level, and the number of employees.

We performed two business selections by filtering SBI codes: first, T&C businesses are categorised according to their supply chain position, referencing the report 'Mode in Rotterdam' ('Fashion in Rotterdam'; Munoz Grootveld and Geveke, 2022), and supplemented with extra SBI codes based on their description and what the authors determined is relevant for this research. Second, selecting T&C businesses performing R-strategy activities (R3 – reuse, R4 – repair, and R5 – recycle), referencing the Netherlands Environmental Assessment Agency's (Planbureau voor de Leefomgeving, PBL) background report on mapping CE in the Netherlands (Kishna et al., 2019; see Supplemental Appendix A for the full list of selected SBI codes and their origin).

Data analysis: R

R programming language is used for data analysis; filtering, forming tables, and extracting charts, with the [tidyverse] package are used for all computational needs, and the [here] package is used for file sharing between authors. For each data file, filtered data are exported in the following manner:

1. The file is imported.
2. For categorisation and filtering, data frames are defined using the SBI codes relevant for each category of activities, creating collective activities (T&C and circular) and subcategories such as supply, maintenance, and reuse (R3; see Supplemental Appendix A).
3. The data are classified by industrial class by filtering the base file using the data frames from step 2.

4. Finally, the data are exported in .csv file format for spatial analysis in QGIS, an open-source geographical information system software.

For making temporal charts, the following steps are undertaken:

5. Using the categories from step 2, separate data frames are defined for:
   a. the whole T&C sector,
   b. the circular T&C sector (overlap of T&C and R-ladder SBI codes), and
   c. the supply chain categories of T&C activities.
6. These data frames are individually plotted along the *y*-axis, with the *x*-axis representing the years between 1996 and 2022.

By combining the statistical data computed above into tables and filtering them for Rotterdam, an overview of the number of businesses (number of rows) and employees (sum of total employees) in Rotterdam's T&C sector is made. Separating the T&C sector categories and representing their numbers as a percentage of the sector shows the transformation of the city's dominant supply chain categories.

Data analysis: QGIS

After importing the .csv files from step 4 into QGIS, the temporal maps are organised in groups for all T&C businesses in the Netherlands, T&C businesses by categories, and circular T&C businesses by R-strategy.

Using these groups, three hotspot maps are made, which indicate locations with significant business concentrations relative to their surroundings:

1. Relative hotspots for the most dense cluster per year.
2. Absolute hotspots for density across the years.
3. Absolute hotspots configured to job distribution, defining which areas employ the most people.

The first two are used to answer the main research question of the paper, identifying the hotspots, while the third provides more insight into the distribution of the businesses, their nature, and reasons for fluctuations in the sectoral charts.

Both relative and absolute hotspots are visualised, as the visible scope depends on the map's scale. Relative hotspots provide a focal point for comparing clusters by category, and absolute hotspots provide more accurate insight into the annual fluctuations (e.g. a cluster may be the densest across years in the relative view but, in the absolute view, may have hosted 15 businesses in 1 year and have dwindled down to 10 in another). In this research, a 1:50,000 scale shows the detailed distribution across the urban fabric of Rotterdam, a 1:100,000 scale shows the direct context of Rotterdam's clusters, and a 1:200,000 scale shows the extent of clustering outside major city boundaries. These exported graphics are compiled into .gif files to view the spatial changes easily. When combined with the job distribution, information on the spatial and network needs of activities across the supply chain may be deduced. By identifying the neighbourhoods wherein a diversity of business activities, and particularly R-ladder activities, colocate over time, we may find where opportunities for R-ladder development in Rotterdam's T&C sector may be fostered further.

Results

For each industrial class (see Supplemental Appendix A), the charts depicting the number of businesses (solid line) and employees (dashed line) are compared to the cartographic distribution and clustering of the businesses by category, contextualising the results seen in Rotterdam (Figures 2 and 3). By overlapping the T&C codes and R-ladder codes, three categories stand out, where they align nearly exactly: second-hand retail (named 'retail-reuse' in the analysis) with R3 (reuse), maintenance with R4 (repair), and waste collection with R5 (recycle).

Supply chain dominance

In Rotterdam's T&C sector, the number of active businesses declined between 1996 and 2006 before increasing over the consecutive 16-year period, ranging from 1340 (2006) to 2180 (2022) businesses.

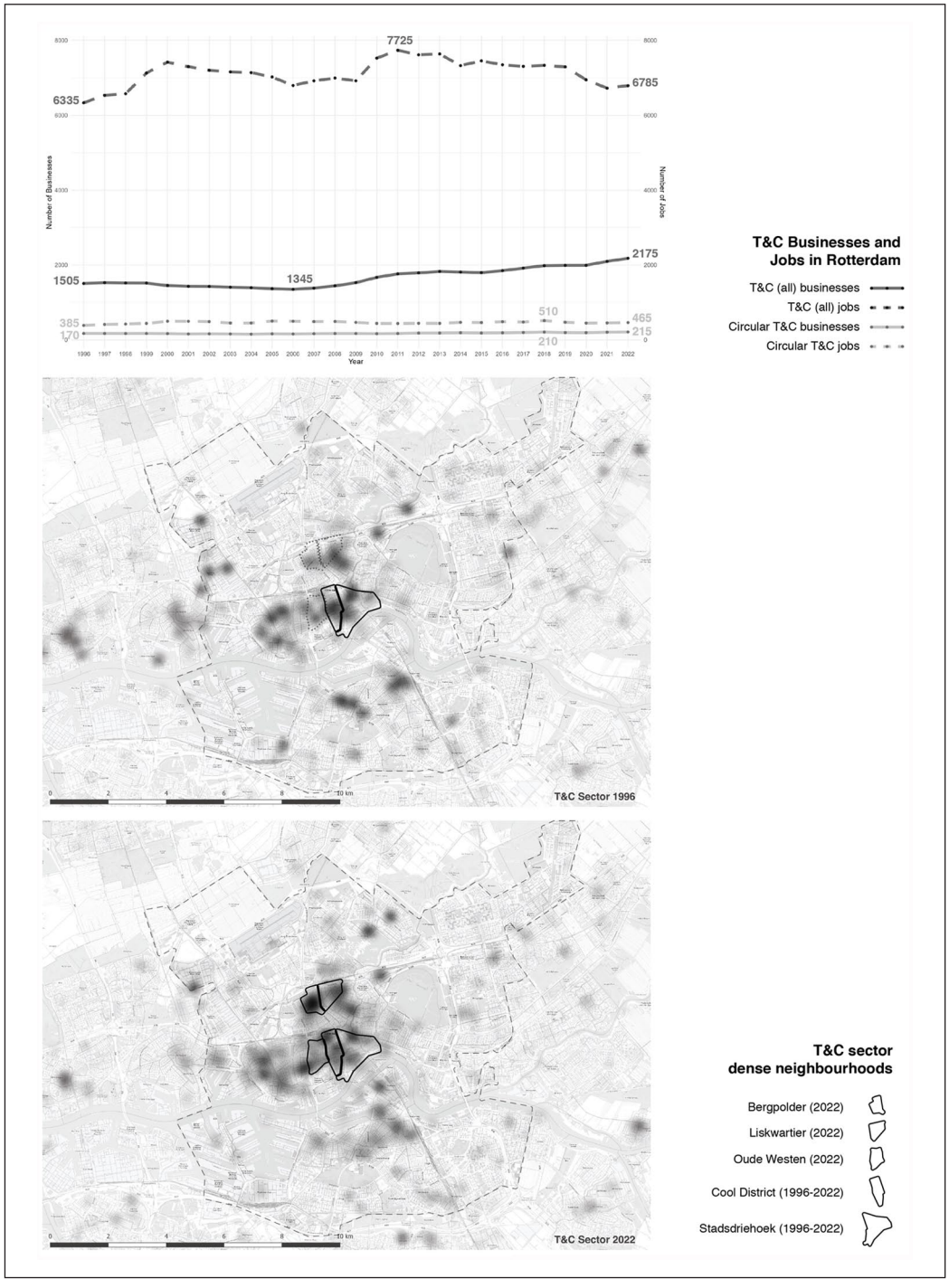


Figure 2. The number and distribution of T&C businesses in Rotterdam.
Source: Authors.
T&C: textile and clothing.

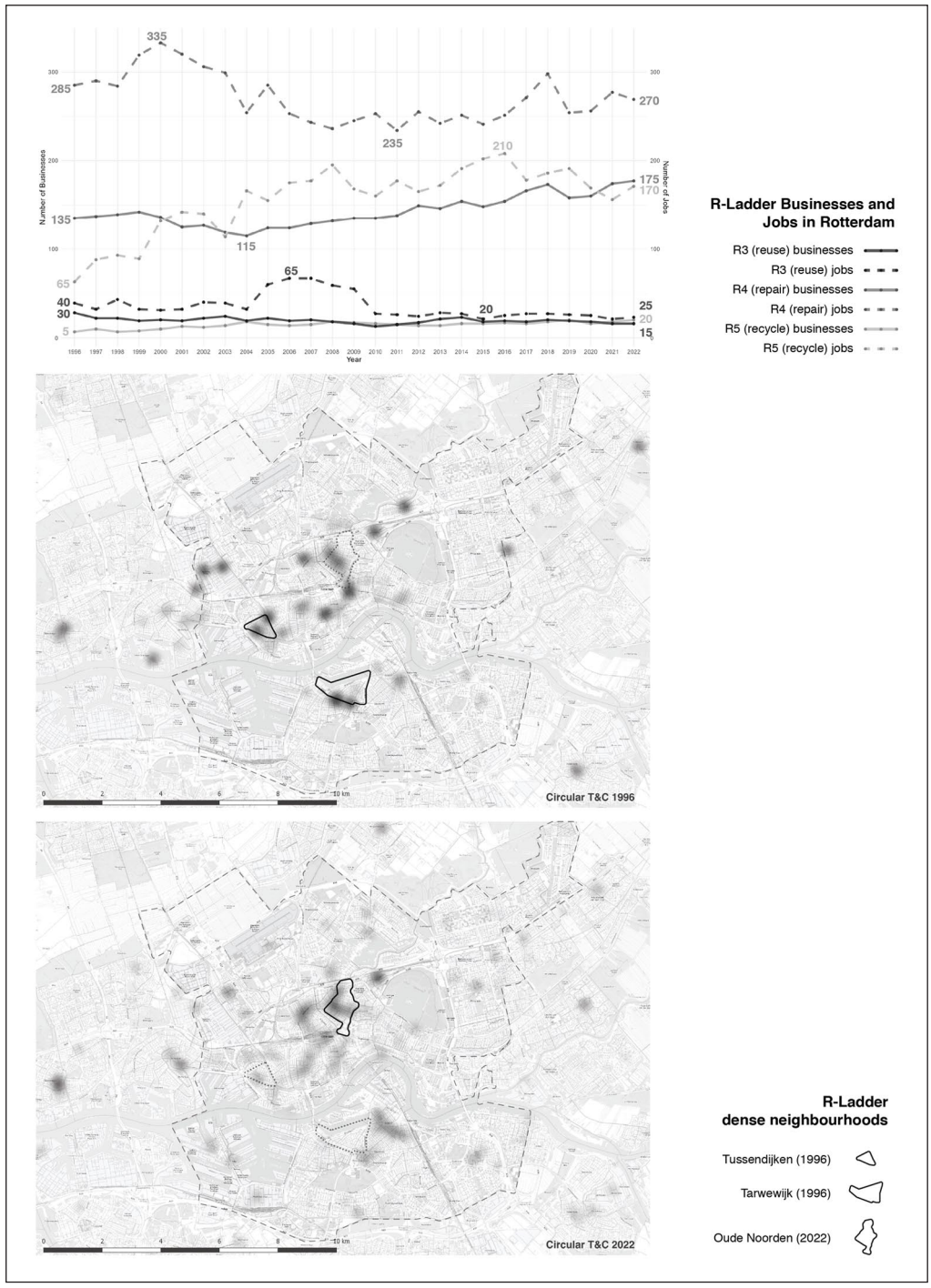


Figure 3. The number and distribution of circular T&C businesses in Rotterdam.
Source: Authors.
T&C: textile and clothing.

The number of employees overall fluctuated more heavily; it reached a peak in 2011 (7730), mirroring the increase in businesses at the time, and thereafter consistently declined from 2015 onwards. The number of businesses engaging in circular T&C activities fluctuated between 1996 and 2011, ranging from 170 businesses (1996) to 150 (2004), gradually increasing during the last decade to 215 in 2022. In recent years, SMEs have become more prominent in the sector, as indicated by the increasing number of registered businesses (1505–2175 – increase of 44%), combined with a comparatively stable number of employees (6335–6785 – increase of 7%) from 1996 to 2022.

The sector's spatial distribution shows that hotspots were denser in central urban areas compared to peripheral ones. This is particularly the case for the period of 1996–2010. Between 2015 and 2022, business presence in Rotterdam's centre bled across the north side of the river in a hollow star-shape (Figure 2). The spatial distribution of hotspots in the southern part of the city appears to remain consistent since 1996 but has become four defined cores in 2022 as opposed to two in 1996. The spread of business presence in the south is not as pronounced as it is in the north.

The clustering dynamics indicate the potential spatial needs of businesses for operationalising circular activities. The T&C sector in Rotterdam is led by consumption-related activities, defining the main cores of T&C activities at the city centre. However, when differentiated within, we can see the diversity of how businesses at different stages of the supply chain position themselves in the city and which spaces they prioritise for their activities, and even more so for R-ladder activities.

The charts of business categories show that of the 11 categories identified, 5 increased in the number of businesses, jobs, or both (supply, design, waste collection, network, and education), 2 declined in both businesses and jobs (maintenance and technology), and the remaining 4 fluctuated or stagnated through the 27-year period (manufacturing, wholesale, retail, and second-hand retail). Activities prioritising access to consumers, namely retail activities, cluster in predefined commercial zones like the Cool District and malls. While their distribution is consistent over the years, their density decreased. Consequently, the increase in the number of active manufacturing, supply, and wholesale businesses may be attributed to this.

Second-hand retail, maintenance, and wholesale activities cluster around the main retail activities, in areas that may have lower costs due to being peripherally beside the city centres, yet still along major infrastructural corridors. These include Tussendijken, Middelland, Hillesluis, and Oude Noorden, among others. These areas pertain to Rotterdam's historically working-class neighbourhoods, seen as areas of resilience and opportunity in the development vision document 'The City of Change' (De Veranderstad; Municipality of Rotterdam, 2021). Manufacturing activities used to be located adjacent to shopping centres, but in the late 2000s, their presence diminished across the city before occupying central spaces in both Cool District (alongside retail) and Kralingen. Now they lie in more affordable locations within shopping centres, with easy access to retailers and consumers.

Education and design activities experienced similar growth patterns and occupied similar spaces in the city throughout their development. Both activities span Rotterdam's Western and Northern districts, defining the zone of the 'knowledge industry' side of T&C activities, and cementing Rotterdam's creative identity. These areas are predominantly residential and mixed-use, having been urbanised between the 1910s and 1940s. While they fall outside of business and commercial districts, they are well serviced by public transport connections (particularly in the West) and major infrastructure. Design activities follow a pattern similar to educational activities; the latter follow their own needs in locating in areas accessible to residents. Not surprisingly, supply activities locate along major infrastructural corridors. The most resilient of these supply-occupied spaces are found in the municipality of Schiedam and in the Stadsdriehoek neighbourhood. For these activities, access to the final consumer is not of high importance; therefore, being near designers and maintenance services is of a higher priority.

Waste collection and technology activities are located in peripheral zones. The former are to be found in (urban) industrial zones, occupying the

buffer space between large infrastructure and the living environment. The latter lie predominantly on the edges of commercial zones, providing a niche service due to the decreased number of businesses. Locating in these areas indicates the importance of large spaces and/or road connections for their activities, or the levels of nuisance their activities generate that, in regulations, are only tolerated in these zones.

The circular T&C sector

Looking at the circular activities within the T&C sector, the number of businesses active in repair (R4) and recycling (R5) activities increased over the years under review, whereas reuse (R3) displayed a downward trend in both the number of businesses and jobs.

Reuse activities tend to locate on the edges of commercial areas, mostly on the north side of Rotterdam, not deviating much from their positions. Repair activities cluster in a circular formation around the station area, occupying shopping centres and main infrastructural axes in the city centre and on the north side of Rotterdam. They also cluster on the south side of the river, particularly along major roads in the Feijenoord district. Many recycling businesses are established in or near Rotterdam, although some of them move frequently. The ones fixed to their establishments are those in the industrial zones on Rotterdam's edges, including Waalhaven and Kralingen. Establishments close to Schiedam spread more across the area than those in Rotterdam. Meanwhile, the most enduring recycling clusters are those in Dordrecht and Moerdijk, connected to Rotterdam through waterways.

Discussion

While most businesses cluster north of the Maas, a major reason for doing so in recent years may be related to the Feijenoord area redevelopment plans in the south, emphasising residential over manufacturing land use functions. The clustering of activities also falls just outside the borders of urban renewal in the northern Crooswijk area. Interestingly, many T&C activities do not occupy the Makers District (M4H/RDM – see Jansen et al., 2021) fostered in Waalhaven and Nieuw-Mathenesse, instead they prioritise a location in Oude Noorden.

From the findings, we can conclude that the neighbourhoods of Bergpolder, Oude Westen, Cool District, Stadsdriehoek, and Liskwartier (to a lesser degree) contain the strongest clustering dynamics within the T&C supply chain. Meanwhile, areas like Agniesebuurt, Blijdorp, and around Oostplein and Coolhaven constantly remain underoccupied by supply chain actors. Simultaneously, for R-ladder activities, *Oude Noorden* represents the neighbourhood within which reuse and repair activities take place, with recycling activities bordering the neighbourhood on two sides, making this neighbourhood a true 'hotspot' where all three activities take place in proximity to one another. Oude Noorden is an area where a large diversity of supply chain actors are within an accessible range of one another; hence, it is informally identified as the garment district in Rotterdam, which increases the attractiveness for businesses to locate there. This neighbourhood therefore has the potential to facilitate (innovative) T&C manufacturing ecosystems in Rotterdam, after further spatial investigation.

Through this research, we illustrate that CE activities are spatially differentiated between higher- and lower-order R-strategies, meaning that circular practices do not follow a single locational pattern in the urban context. This points to the need to conceptualise the circular transition as a differentiated process of spatial proximity across the R-ladder, rather than a uniform one. This therefore signifies the need for further analysis, and it raises doubts about whether, as Brandellero and Naclerio (2024) highlight, the urban structure is supporting circularity sufficiently. As the research has shown, drawing insights from literature, different R-strategies are in need of different locations within the city and are therefore dispersed based on the activity they engage in. R-strategies higher on the ladder fit better in the urban fabric compared to lower strategies, which can be found in areas with segregated functions. This aligns with the conceptual framework (Figure 1).

However, not all neighbourhoods show the R-strategies that can be expected here. Specific neighbourhoods are better suited for different strategies. The results suggest that this relates to market

potential; proximity to the city centre with retail functions is a better location for R-strategies that need a private customer base (such as repair and reuse), and neighbourhoods that are developed as mixed working and living areas (like Oude Noorden) are better suited for hosting diverse R-strategies than mono-functional areas, thereby supporting research by Dansero and Puttilli (2013).

The neighbourhoods where businesses cluster matter not only in relation to property values but also in their potential to reach the necessary customer base. The re-territorialisation of circular T&C businesses is therefore guided not only by the availability and value of property but also by specific territorial qualities, clustering activities, and proximity to other businesses and customers. In the re-territorialisation of circular T&C activities across the R-strategies (including integrating manufacturing), the transition towards a CE in T&C requires a backwards shift for cities along the trends Casadei et al. (2021) have observed. This would require a thorough consideration of the neighbourhoods within which CE is localised so as to increase the chances of success. The increased clustering of circular T&C businesses over time indicates that while geographical proximity may not in itself drive innovation as much as organised proximity (Arfaoui et al., 2025), existing small clusters may be perceived as spaces of opportunity and therefore pose as attractive locational features for businesses to agglomerate to.

In the case of Rotterdam, the prevalence and clustering dynamics of businesses in the T&C sector indicate that there may be qualities in the neighbourhoods where they locate that aid in their operation. These areas may strike a qualitative balance between their centrality, affordability, spatial use guidelines (and how flexible these are), the transportation and road networks, and the opportunities to create relations with other nearby textile actors. However, it is clear through the chronological mapping of business presence in the city that, while some spaces have the capacity to host businesses, they do not necessarily lend well to hosting circular activities, or their capacity is not fully utilised due to the aforementioned qualitative reasons. The availability of space in Rotterdam is limited, but there is an opportunity for existing singular-use spaces to become multifunctional areas for diverse purposes.

In general, T&C businesses across the value chain do not tend to co-locate effectively across Rotterdam. CE requires the orchestration of resource flows and infrastructure at both the physical and digital levels (Kim et al., 2025). As of now, there are some areas that have the capacity to host CE businesses in a larger CE framework, namely, the Oude Noorden and Tarwewijk neighbourhoods, but this will require investment in the shared spaces for communication and transparency to effectively form a circular textile network. Mapping according to the current NACE directory indicates that circular T&C businesses opt for urbanised areas, despite municipal investments in CE developments further within industrial areas. Through their emergent clustering in Rotterdam, circular textile businesses have created the pre-conditions for the (re-)territorialisation of the textile ecosystem. Whether these conditions are harnessed lies both with the SMEs' willingness to engage in solidifying a collaborative CE infrastructure and with the willingness of institutional actors in providing opportunities for these SMEs to collaborate with one another across the textile value chain.

Urban planners can facilitate the co-location of these activities to further stimulate the symbiotic networks of production, reuse, and innovation. This will need to be done in a participatory way together with different stakeholders, especially circular businesses, as literature on creative clusters shows evidence that top-down approaches have a higher risk of failure.

Conclusion

To conclude, this article has addressed the key question of what hotspots emerge over time as potential areas for facilitating proximate circular T&C manufacturing initiatives in Rotterdam. By analysing business microdata through a spatial lens to look for areas of absolute proximity of textile actors and then narrowing this down to the specific context of the R-strategies (Potting et al., 2017), we show how higher R-strategy activities, namely reuse (R3) and repair (R4), locate in central urban areas, while lower R-strategy activities (recycle) move into peripheral industrial areas. R-strategy businesses were observed to co-locate

more over time in distinct neighbourhoods, making these areas key in facilitating further clustering of R-strategy activities.

These findings make two closely related contributions to research on the spatial organisation of the CE and T&C value chains. First, they extend the literature on re-territorialisation by showing that localisation does not entail a uniform return of economic activity to the urban core. Instead, the spatial form of re-territorialisation varies according to businesses' positions within the T&C value chain and the R-strategies they perform, as indicated by Figure 1. Across the wider T&C value chain, retail and other consumer-oriented activities cluster in and around central commercial areas; design and education concentrate in accessible mixed-use districts; and supply activities follow major infrastructural corridors. Within the circular subset, reuse and repair are re-embedded in urban neighbourhoods through proximity to consumers and other T&C actors, whereas recycling remains tied to industrial sites and regional infrastructure. The T&C case therefore demonstrates that re-territorialisation constitutes function-specific re-embedding of value-chain activities and R-strategies across the urban space. Second, the findings refine the literature on proximity and clustering by showing longitudinally that patterns of geographical clustering develop unevenly across neighbourhoods and that the clusters identified depend on the activities considered. Oude Noorden, for example, emerges over time as an R-strategy hotspot because reuse and repair activities are concentrated within the neighbourhood, and recycling activities border it, while it is not among the neighbourhoods displaying the strongest clustering dynamics across the wider T&C value chain. This distinction shows that sector-wide clustering does not necessarily identify the same locations as an analysis disaggregated by circular activity. Disaggregating clusters by value-chain function and R-strategy can therefore reveal different neighbourhood-level opportunities and identify places that may provide the spatial preconditions for local circular networks.

Regarding opportunities for future research, this article shows that longitudinally plotting business microdata can provide useful insights into the nature and development of specific sectors in an area over time. Although NACE does not provide in-depth categorisation, plotting how different business uses occupy city spaces gives additional insights into how different sectors use and traverse their cities, and how proximity dynamics across sectors are embedded in urban spaces. This is especially relevant in relation to the R-strategies, as it enables one to map out how cities give shape to the CE. In combination with socio-economic data and other territorial data such as development plans and environmental quality assessments, this may give more insight into the specific opportunities and barriers faced by businesses that are part of the CE transition.

Nonetheless, more research is needed to understand the context behind the locations and clustering dynamics of CE businesses, especially in the T&C sector. Recommendations for future research include delving into urban policy and its impacts on the neighbourhoods where clustering is more prevalent, as well as areas where the policy intervention was not successful, thereby addressing the effectiveness of top-down and bottom-up approaches. Further future research may include additional qualitative methods, such as ethnographic studies in selected neighbourhoods and co-creation workshops with urban planners and designers, alongside local T&C actors and the municipality, to grasp the spatial needs of (circular) T&C actors.

ORCID iDs

Minalies Rezikalla https://orcid.org/0009-0007-8124-032X
Younghyun Kim https://orcid.org/0000-0002-2304-6250
Karel Van den Berghe https://orcid.org/0000-0001-8395-0586
Mariangela Lavanga https://orcid.org/0000-0001-5925-9509
Willem Korthals Altes https://orcid.org/0000-0002-2745-0007
Amanda Brandellero https://orcid.org/0000-0003-0872-2166

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Supplemental material

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