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Urban Transformation Towards Premature Obsolescence Of Buildings

Beatrice Stolz, Jiajia Li and Steffen Wellinger

Abstract

A circular development in cities aims to create ecologically regenerative and resilient environments to transition towards a more sustainable future. This involves rethinking how we design, build, and disassemble, favoring reuse and regenerative cycles. The result is longer building lifespans and, therefore, helps reduce CO_2 emissions from the construction sector. For architects and city planners, the challenge lies in balancing between developing densification strategies to limit urban sprawl with preserving the built environment by extending lifecycles.

How does densification affect the demolition and lifespan of buildings in neighborhoods, and what are the possible circular transformations? The objectives of this research are to discuss changes in the built environment in relation to densification strategies and reflect on how these changes might support or hinder circular practices. The paper explores the evolution in building stock over time, using the city of Trondheim, Norway, as a case study. First, data on the existing building stock is analyzed to understand the location and age of various building types across different neighborhoods. Buildings are classified into five categories: low-density housing, high-density housing, public services, industrial and work-related buildings, leisure, and smaller constructions (such as garages, cabins, or sheds). This data is then compared with historical records of buildings being demolished and newly built structures from 2012 to 2021 to trace the transformation of the built environment. It includes information on building type, square meters, construction and demolition dates, and location. The data collected from the municipal cadaster is visualised using Geographical Information System (GIS) software to support a spatial neighborhood-based analysis. The results first present differences in the number of demolitions, building projects, and densification across city areas. Next, the study examines the age distribution within the five building categories. Two main findings emerge: variations in the neighborhood densification over the past decade, and differences in building lifespans across areas. This analysis supports projections for future urban developments, and identifies opportunities for circularity. Additionally, comparing the age of the current building stock with that of demolished buildings highlights the premature obsolescence of certain building types. The findings show that some categories are more prone to demolition or new construction. These results are discussed alongside urban planning and densification strategies, offering policy insights and supporting a contextualised approach to circular development.

Keywords: Circularity; Densification Strategies; Demolition; Lifespan; Premature Obsolescence.

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Corresponding Author: Beatrice Stolz< beatrice.stolz@ntnu.no,> Jiajia Li> jiajia.li@ntnu.no,> Steffen Wellinger> steffen.wellinger@ntnu.no

1. INTRODUCTION

Many regions, particularly rapidly expanding cities, experience densification due to a combination of demographic change, economic pressure, and significant investment in transportation infrastructure (Teller 2021). To avoid urban sprawl, municipalities across Europe rely on several principles. Among them are walkability (Dovey and Pafka 2020), 15-Minute City models (Pozoukidou and Angelidou 2022), and sustainable transport strategies (Müller-Eie 2019), all of which promote access to a variety of facilities within short distances. These approaches help reduce reliance on private cars and aim to lower CO_2 emissions.

Building typologies and urban morphologies are affected: certain typologies tend to disappear and other are in trend, as they are often driven by planning regulations and the densification of specific areas. The way a typology connects to streets, plots, and the natural landscape significantly shapes urban morphologies (Oliveira 2013), and some of them are more conducive to dense environments. In architectural discourse, a typology is a framework for classifying buildings or built forms with shared characteristics (Grover et al. 2019), whether by style, epoch, size, form, program, or use. In this research, buildings are categorized by their type as registered in the Trondheim Cadaster.

Among the main drivers for demolition, demographic factors also have a strong influence on building stocks. Shifts in sociodemographic trends, such as fewer people per dwelling or population growth, are among the main reasons for the demolition and densification of neighborhoods (Berghauser Pont et al. 2021). The increasing challenge of accommodating more people in the future while avoiding urban sprawl puts pressure on actors involved in city development to find sustainable solutions. The re-development of neighborhoods also means a need for new amenities and services to ensure education, health, and connectivity to the rest of the city. This is closely linked to economic growth and governmental policies. The land value rises, resulting in socioeconomic changes, such as difficulties preserving affordable housing or gentrification of neighborhoods (Cole et al. 2021). Long-term residents struggle to keep up with rising costs in their area and are compelled to find other solutions, like moving or selling a part of their plot to developers, for example. This results in changes in the urban fabric, as new constructions are denser, higher, and connected strategically to different infrastructures.

Moreover, the growing awareness of climate change and natural resource depletion presents environmental regulations as another main driver. The use of technological tools increases energy efficiency in buildings to guide the transition towards environmentally sustainable cities (Ellen MacArthur Foundation 2017). They allow tracking of CO_2 emissions and facilitate building construction and use as a transparent process, accessible and understandable by all actors involved. For instance, Life Cycle Analysis (LCA) is a tool used to analyze a product's or service's environmental impacts from material extraction through transportation, production, and use to waste management (Curran 2013). It draws attention to the different lifecycle phases that can be optimized to reduce the consequences of building on the natural environment. Additionally, it facilitates the implementation of closed-loop systems by comparing cradle-to-grave and cradle-to-cradle systems (Rochat et al., 2013). Professionals rely on standards: ISO 14040 and ISO 14044, provided by the International Standardization Organization (ISO), to perform LCA. In the built environment, most LCA studies focus on the building scale (Seyedabadi and Eicker 2023), but emerging research suggests looking at a bigger scale; this is the case for urban LCA (Moiso et al. 2024) or territorial LCA (Loiseau et al. 2018) for example.

Nevertheless, most studies focus on creating new, high-energy-efficient buildings, ignoring the potential of the existing building stock (Marique and Rossi 2018). Thus, for existing buildings falling off the list of preserved buildings (such as heritage buildings), demolition and new construction seem to be the preeminent options for developers. This affects the lifespan of the building stock and can lead to premature obsolescence, often when demolished buildings are not yet at their end-of-life stage or have not yet reached the full potential of their lifecycle. Effectively, obsolescence is generally understood as a decline in buildings' performance over time, resulting in the end of the use phase, often leading to demolition (Thomsen and van der Flier 2011). Demolition and new construction also generate a considerable amount of waste, and consequently CO_2 emissions, raising the questions about waste management, recycling, and reuse, making it challenging to meet climate mitigation goals. In the European Union, waste related to the building industry represents circa forty percent of all waste produced (Damgaard et al. 2022). As a solution, circularity allows us to reuse our buildings, building components, or building materials. This means rethinking ways of designing, building, or disassembling existing buildings. The implementation of circularity in cities aims to reduce greenhouse gas emissions by minimising waste and keeping the buildings in use for a maximum amount of time (Ellen MacArthur Foundation 2017).

However, if the challenges presented above might be solved by circularity, research around implementing circular solutions presents some gaps. The city grows at a varying pace, and circularity must be adapted accordingly, contextualized to different neighborhoods. How can we ensure a just and sustainable application of circular principles in different neighborhoods? How might we reassess lifecycles and move beyond standardized values to better understand the full potential of circularity? Moreover, how can densification strategies be balanced with environmental values to prevent the premature obsolescence of the building stock?

First, a gap is identified in the literature in balancing the positive effects of densification with the circulation speed of materials resulting from urban transformation. Densification involves new infrastructure, new mix-use typologies, or higher density housing. Demolition and waste from those changes accelerate the flow of waste and resource. This can give opportunities for circularity, as waste could be transformed into new resources, but a balance should be made between densification benefits and building lifecycles. In effect, densification and compactness are arguments for reducing greenhouse gas emissions (Dymén and Langlais 2013); on the other hand, demolition and waste generate considerable emissions. Consequently, transformation should consider the current state of building lifecycles to avoid premature obsolescence.

Another gap appears in assessing building lifecycles, leading to potential errors in using standardized values for Life Cycle Analysis (LCA) (Curran, 2013; Ji et al. 2021), and forecasting circular possibilities. In the Norwegian context, the lifespan of buildings is defined as fifty years (TEK 17 and NS 3720:2018), and this is used as a reference for energy calculations. In the past, it was set to sixty years but has been changed to fifty years after 2018 to align with other countries in Europe, using European standards (EN 15978:2011). Nevertheless, buildings can have different lifespans according to their type or construction period, which should be considered when performing energy calculations (Ji et al. 2021).

Considering the presented gaps, this paper investigates the demolition and new construction activity in different neighborhoods of Trondheim, Norway, and the average age of the different building types. It highlights the potential downside of densification and provides a reference for future lifespan studies. The aim is to support the idea that circularity is not a one-size-fits-all solution and that a more context-based approach is needed. Consequently, the research proposes an analysis of demolition and building activity in different city areas and a reflection on the resulting changes along with planning strategies. The question is the following: How does densification affect the demolition and lifespan of buildings in neighborhoods, and what are the possible circular transformations?

After introducing the environmental challenges resulting from changes in the built environment and potential solutions to limit CO_2 emissions and resource depletion, gaps around densification strategies and circularity were exposed. A second part explores in depth the concepts of densification, demolition, and obsolescence, adapted to Trondheim: our case for the study. Planning strategies in Trondheim and the municipality's goal to sustainably develop the city are discussed. Then, the method for this research is presented: a collection of data about the current building stock, new projects, and demolished buildings from January 2012 to December 2021 sheds light on changes in Trondheim's built environment. It offers a reflection on buildings' lifespan and densification strategies. Two types of results are discussed: variation in densification across neighborhoods and differences in the lifespan of demolished buildings compared to the average lifespan of the building stock. The results indicate a need for a neighbourhood approach to contextualize circularity.

2. TRONDHEIM CONTEXT AND DENSIFICATION STRATEGIES

In the Norwegian context, the most common urban patterns are nineteenth-century brick apartment blocks of three to five stories; detached apartment blocks of three or four stories; detached houses or semi-detached houses from the 50s and 60s; and dense single-family housing development of one or two stories(Aamo et al. 2021). These patterns answer the needs of today's citizens and keep evolving, creating constant change in the built environment. Trondheim is a growing city on the coast of mid-Norway, with an increasing number of inhabitants, forecasting a growth of 20.7 percent of the population by 2050 and a need for approximately 29,000 new homes (TR2022M, report from the Trondheim Municipality 2022). This results in a change in the built environment, with new buildings being built and other buildings being demolished to give way to new urban developments. Additionally, Trondheim's municipality attempts to address these challenges sustainably, promoting a denser, liveable city (Byutviklingsstrategi for Trondheim 2020).

In 2020, the municipality developed an urban development strategy, stating the need for a more attractive and climate-friendly city (Byutviklingsstrategi for Trondheim 2020). To answer the needs of a growing population, some goals are set for 2050. Among them, the municipality emphasises the need to develop areas of high quality. This means promoting a green structure throughout the city for citizens and biodiversity to thrive, as well as attractive facades and architectural identity markers. The development of areas should promote human experiences at street level, through varied building design, different volumes and textures, and safe pedestrian zones along active facades, with extensive use of trees and other features connected to a blue-green structure (Kommuneplanens arealdel 2022-2034, 2024). Indeed, the municipality mentioned in its reports the challenges of densification, particularly the lack of acceptance from residents, or the loss of urban qualities. This resistance is present in different cities in Norway, for example in Bergen or Oslo where citizens feel oppressed and concerned about the change of character of their neighborhoods. For instance, areas targeted for densification around local public transportation may transform from traditional detached housing settlements into more diverse and denser neighborhoods. Therefore, in Trondheim, the strategy must involve maximum citizen participation and must consider the preservation of cultural and historical values, together with enhancing the blue-green structure, to ensure the preservation or development of new features or architectural qualities in areas undergoing densification.

Mobility and connectivity are also topics of strong focus. People's mobility should be just and safe, facilitated by well-connected areas. To support that, the municipality has set up a Zero Growth Target, as part of the Urban Growth Agreement, stating that "increasing passenger transport demand caused by the rapid population growth (…) shall not cause growth in passenger road-traffic volumes" (Tennøy & Hagen, 2020). Therefore, a sustainable transportation plan must be developed alongside densification strategies. favoring accessibility to walking, cycling, and public transportation. To achieve this, the municipality wants to integrate satellite local centers (bydelssentre) into the urban fabric. The local centres should be connected to the city centre through public transportation and supply their areas with the necessary facilities to reduce the need for travel. Over the past decade, new housing has been built across the city. About a third is located in areas where it is possible to live without a car and use public transportation, cycle or walk in everyday life. A third is built in areas where many people will choose to drive a car, but it is still possible to use public transportation. The final third is built in areas where most people choose to travel by car as they must commute long distances to work, shopping and leisure activities (Kommuneplanens arealdel 2022-2034, 2024). Better public transportation and connections between places and densifying the built environment around local centres are thus the core principles of sustainably developing the city (Byutviklingsstrategi for Trondheim, 2020). Another point of focus in relation to this development of local centres is the transformation of industrial sites in the city and the redeployment of commercial areas.

Overall, reducing CO_2 emissions depends on the Zero Growth Target, combining local centres and public transportation in an active and attractive development. However, it is essential to contrast this with the environmental impact generated by waste and the negative impacts of densification.

3. METHOD

This study utilizes the Norwegian Building Cadastre as a primary source of data. The data collection is limited to the Municipality of Trondheim, the third largest city in Norway, with 210,496 registered inhabitants and 77,347 buildings (Office of Norwegian Statistics 2023), spanning twenty-five neighborhoods. The Trondheim Cadastre includes 138 different building types that are classified into eight categories: dwellings; industrial buildings and warehouses; offices and industrial buildings; transport and communication buildings; hotel and restaurants buildings; buildings used for education; public entertainment and religious activities; hospitals and institutional care buildings; and prisons (SSB Classification of Building Type, 2000).

To reduce the complexity of the study, we grouped some categories in this paper. Our study then comprises five main categories: residential buildings; public services; offices and industrial buildings; leisure; and smaller constructions. Table 1 presents more detailed information on the building distribution.

The Norwegian Building Cadastre includes data about each building in Norway, such as its type, floor area, year built, current function, and status (in use, approved for construction, approved for demolition, etc.). In this study, the primary variables investigated included the number of buildings, square meters, building type, location and year built, as well as the status of the building and year demolished, when applicable. First, a historical dataset of all buildings that from January 2012 to December 2021 received the status of either demolished or approved for demolition was used from the cadaster. This consisted of 3,977 buildings. The primary data fields and characteristics were gathered in a CSV file, presenting identification numbers, coordinates, building type, number of floors, floor area, date of construction, and date of demolition. Second, a comparative data set containing information on all current buildings as of December 2021, with the same data fields, and another dataset about new buildings constructed during this period were gathered to compare the rate of demolition with the rate of new buildings. This made it possible to analyze the densification of different areas and their correlation with building lifespan.

Including building coordinates allowed mapping of the spatial distribution of the demolished buildings in a GIS software and understanding their distribution by neighbourhood. A densification rate was defined

Main type categories	Sub-type categories
Residential buildings	Low-density housing: detached houses, houses with two dwellings, row houses High-density housing: multi-dwelling buildings, residences for communities
Public services	Transport and communication buildings Buildings used for education: schools, universities Buildings used for public entertainment: museums, libraries Buildings used for religious activities: churches, mosques, monasteries Hospitals and institutional care buildings Prisons, buildings for emergency preparedness
Offices and industrial buildings	Industrial buildings Buildings for power supply Warehouses Agricultural buildings Offices and business buildings
Leisure	Hotel buildings Restaurant buildings
Smaller constructions	Garages Cabins Boat houses

Table 1. buildings distribution

by calculating the growth in square meters for every neighbourhood. For that, the amount of square meters being demolished and built between 2012 and 2021 was compared to the total amount of square meters in the neighborhoods in 2021. This allowed us to observe different rates of densification in different parts of the city. A second analysis gave a finer understanding of the average age of every type being demolished. By subtracting the built date from the demolished date, the lifespan of each building was calculated. For each neighbourhood, the building types with the highest demolition factor were analyzed. The two degrees of analysis: first looking at the densification rate, and then looking at the age of different building types being demolished, offered a critical overview of possible opportunities for circular developments.

The data from the cadastre contains some uncertainties that must be considered. Every building type corresponds to a number, for example: 111 in the cadastre corresponds to detached houses; 181 corresponds to garages; 212 to workshop buildings; and so on. However, one building type is not defined ("999=??") and represents 0.01 percent of the current building stock and 0.004 percent of the demolished buildings. As it was not possible to identify the type of building, we filtered it out from our study. In addition, some construction or demolition dates are missing. Collecting data about demolished buildings was challenging as availability of historical data is sometimes uncertain. Sixty-six percent of the demolished buildings have a construction date, and seventy-one percent have a demolition date. However, the buildings without a demolition date in 2021 only had the status "approved for demolition" and had not yet been demolished. For these buildings, the age is estimated by assuming they were demolished at the end of 2021, which is the end of the study period. Buildings with a missing construction date were also filtered out, as it was not possible to calculate their lifespan. This represents an important limitation in our study that we address further below.

4. RESULTS

Demolition, new constructions, and densification in different neighborhoods

The empirical data collected from the cadastre and mapped in QGIS allowed us to identify some patterns of transformation. The distribution of building types is represented in Figure 1. The city is divided into twenty-five districts, and the spatial distribution of building types shows that most of the city has been developed as low-density residential areas (Figure 1). However, the historical city center (Midtbyen) has a dense structure with various building types (mostly offices, public services, and high-density houses), which reflects a mixed-use neighborhood. We can also observe three main industrial areas in the city: in the south (Tiller-Hårstad); along the river in Nardo and Nidarvoll-Leira; and in the northern part of the city from Lademoen to Strindheim. We also observe a concentration of high-density housing from Rosenborg-Møllenberg to Lademoen, as well as a few high-density typologies spread across the different districts (mainly in Ila-Trolla, Sverresborg, Hallset, Flatåsen-Saupstad, Risvollan-Ottilienborg). Public services (libraries, schools, kindergartens, museums) are also spread across the city; however, we notice two clusters in Øya-Singsaker, close to the historical city center. These correspond to the university campus and the hospital.

A second dataset allowed us to map the buildings registered as demolished or approved for demolition in the cadastre between 2012 and 2021. The heat map (Figure 2) shows the spatial distribution of demolished and newly constructed projects. Compared to the previous map (Figure 1), we observe that demolition occurs mainly in the industrial areas. In the northern part of Lade and in Lademoen, many industrial buildings and offices have been demolished, as well as in Strinheim, Øya-Singsaker and Nardo, along the river. In Byåsen and Sverresborg, some detached houses and garages have been demolished, as well as in the eastern part of Strinheim and north of Berg-Tyholt. If we look at new construction in the same period (Figure 2), we observe that the building activity is more diffuse across Trondheim. However, the area between Lademoen and Lade is being developed with the largest amount of new built floor area (m^2).

Rosenborg-Møllenberg, on the other hand, shows a low densification percentage. This is due to the area already being dense in 2012, with 770,602 m^2 of build floor area in a small neighbourhood. Since then only 4,773 m^2 have been demolished (leisure buildings and smaller structures) and 43,229 m^2 have been built

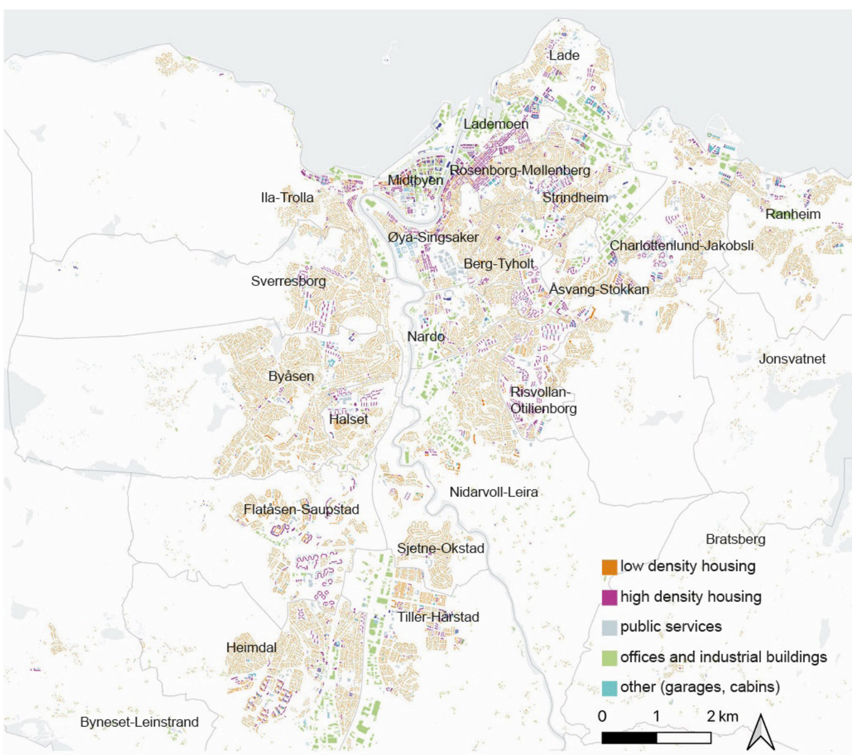


Figure 1. Distribution of building types in Trondheim in 2021

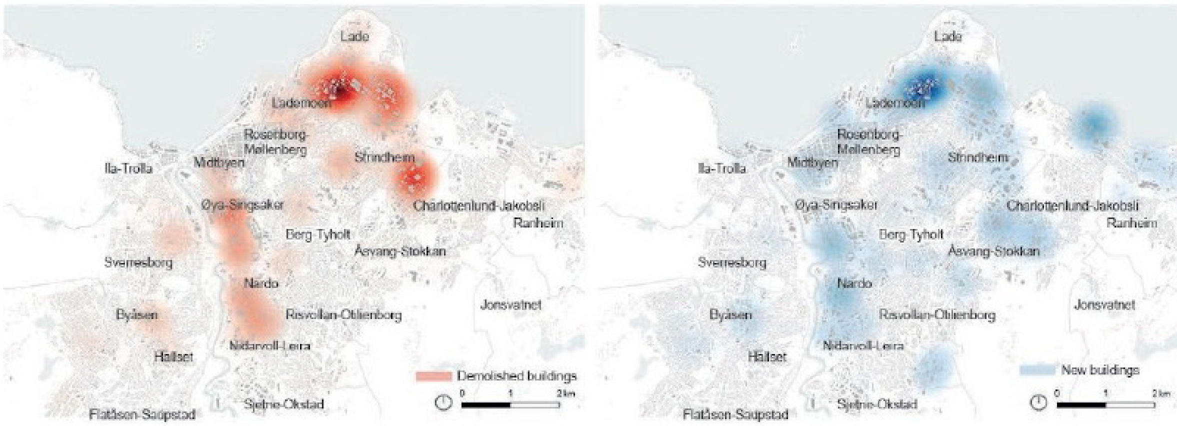


Figure 2. Heat map of demolished (left) and newly built (right) floor area (m²) in Trondheim, 2012–2021

(mostly offices and high-density housing) giving a total of 833,987 m² in 2021 and a densification rate of eight percent.

In Lade and Lademoen, the heat maps (Figures 2 and 3) showed high transformation activity. However, the densification percentages remain around the average level across neighborhoods. In Lade, the building stock in 2012 was 691,042 m². It was mostly low-density housing in the northern part and industrial buildings on the southern part (as shown in Figure 1, one of the city's main industrial areas). 84,292 m² have been demolished (mostly industrial buildings), and 266,626 m² have been built (mostly high-density housing), resulting in a densification rate of thirty-four percent. In Lademoen, the stock in 2012 was 604,107 m², consisting mostly of high-density housing, industrial buildings, and offices (as shown in Figure 1). Since then, 65,482 m² have been demolished (nearly 60,000 m² were industrial buildings), and 248,576 m² have been built (about half were high-density housing, followed by new industrial buildings). The densification rate in Lademoen was forty-three percent.

Overall, although demolition patterns are identifiable in Trondheim, new construction is more dispersed, and the level of densification across neighbourhoods is uneven. This is due to many factors such as the city already being built up and increased interest in developing transitional areas. Neighborhoods with primarily residential buildings like Byåsen, Hallset and Møllenberg have a low densification percentage. In contrast, neighborhoods such as Lade, Lademoen, Strindheim or Nardo, located near industrial zones, show higher densification percentages. Finally, the case of Charlottenlund-Jakobsli appears to be an outlier. However, this is justified by its original low-density residential character, combined with minimal demolition activity. Over the past years, it has evolved into a higher-density residential neighborhood.

Change in building types

After observing patterns of transformation in Trondheim, we chose six neighborhoods to analyze changes in building types. We looked specifically at the number of each building type being demolished and built in different districts We investigated the neighborhoods undergoing the most demolition: Lade, Lademoen, Øya-Singsaker and Nardo, and two additional neighborhoods with a low densification percentages and a low-density residential character: Sverresborg and Hallset. In line with the densification strategies in Trondheim, these six neighborhoods are planned to host local centers connected to the city center by public transportation and are designated for densification and urban transformation (Byutviklingsstrategi for Trondheim, 2020).

In Lade, Lademoen, Nardo, Øya-Singsaker, and Hallset, industrial and office buildings are the most commonly demolished building types. In Sverresborg, mostly public services (such as schools or other educational buildings) and low-density houses (detached homes) are demolished. Low-density houses are also demolished in Nardo (thirteen percent of the total demolished buildings). Small constructions such as garages are mostly demolished in Sverresborg, Hallset and Nardo, and a small portion of high-density houses is also demolished in Øya-Singsaker (fifteen percent) and in Nardo (eight percent). The results are presented in Table 2.

In all six neighborhoods, the primary type of buildings being constructed are high-density housing and industrial and office buildings. In Lade, over half of the new buildings are high-density housing; twenty percent are small constructions; and fourteen percent are public services. In Lademoen forty-three percent of the new constructions are high-density housing; thirty-one percent are industry and office buildings; and nineteen percent are small constructions. The distribution of new building types in Nardo and Hallset is quite similar to Lademoen, with around forty percent high-density housing, thirty percent industrial and office buildings, eleven percent (Nardo), and fifteen percent (Hallset) of small constructions, and a small amount of low-density residential housing. In Øya-Singsaker, most new buildings are industrial (forty-three percent) and public services (thirty-five percent). A small amount of high-density housing (fourteen percent has also been built. In Sverresborg, an equal amount of low-density and high-density housing has been built (twenty-seven percent of each type), along with twenty-one percent of public services, fourteen percent of offices and industrial buildings, and eleven percent of small constructions.

In this section, we showed that some building types are more prone to demolition, while others are more likely to be newly constructed. In the next section, we will investigate different building categories and compare their age at the time of demolition with the overall age of the building stock.

This section investigates the average age of different building types at the time of demolition and compares it to the average age of the stock. The results are presented in Figure 5. The first graph shows the average age of all building types combined for the twenty-five neighborhoods, with Klæbu having the youngest building stock. The average age of demolished buildings there is also young, twenty years. This is also true for Risvollan–Othilienborg and Tiller–Hårstad.In general, the average age of the stock does not exceed forty years, except in Ila–Trolla, Lade, Lademoen, Midtbyen, Øya–Singsaker, Rosenborg–Møllenberg, and Sverresborg. Midtbyen has the oldest stock, with an average age above one hundred years. The average age at the time of demolition also varies—between twenty years (Klæbu and Risvollan–Othilienborg) and nearly

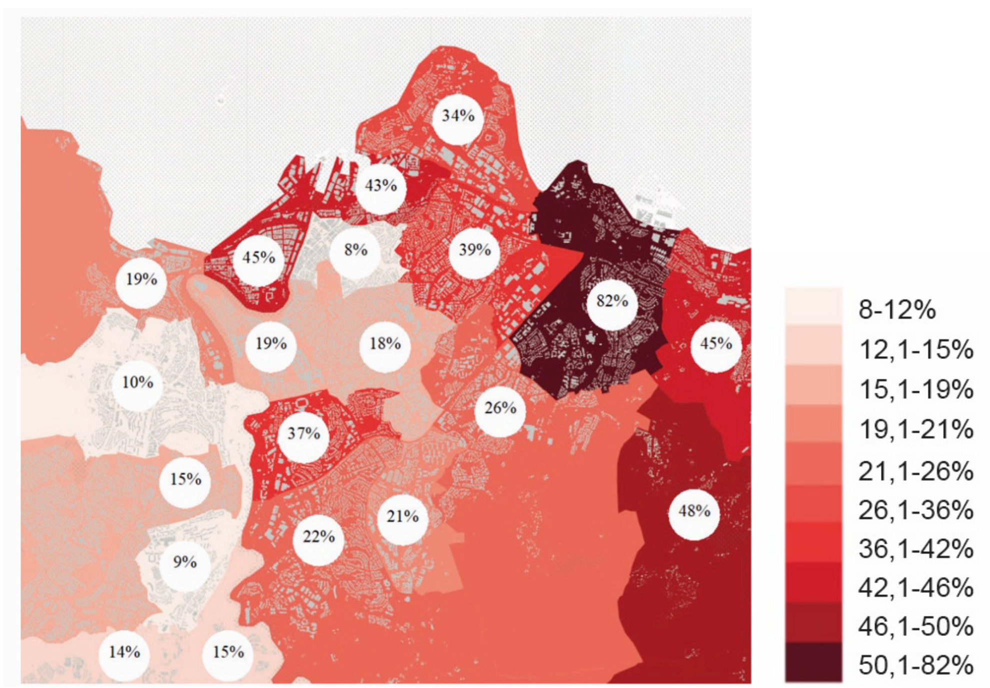


Figure 3. Densification percentages in Trondheim, between 2012 and 2021

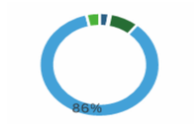
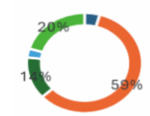
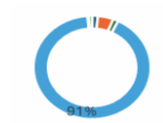
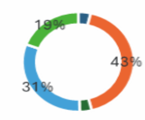
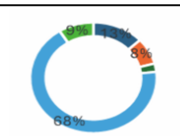
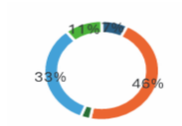
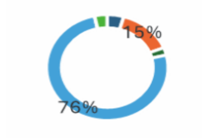
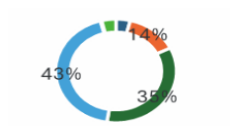
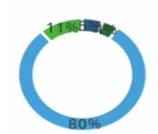
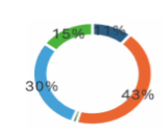
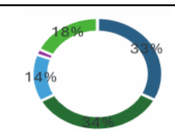
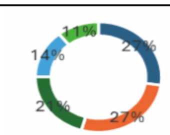
Neighbourhood name	Demolition	Construction
Lade		
Lademoen		
Nardo		
Øya-Singsaker		
Hallset		
Sverresborg		

Table 2. Change in building types in six neighborhoods in Trondheim, 2012 and 2021

sixty years (Bratsberg). Most neighborhoods have an average demolition age between thirty-five and forty-five years. An important observation is that in some neighborhoods, the average age of demolished buildings is younger than the average age of the stock. This is the case for Byneset–Leinstrand, Ila–Trolla, Lademoen, Midtbyen, Øya–Singsaker, Risvollan–Othilienborg, and Rosenborg–Møllenberg.

The second and third graphs show a similar comparison but narrowed to specific types of buildings. We chose the two most frequently demolished categories across the city: low-density housing and industrial and office buildings. We did not consider the category "smaller constructions/other" (garages and cabins). For low-density housing, we observe that the stock generally ranges between forty and sixty years in most neighborhoods, with five neighborhoods exceeding sixty: Ila–Trolla, Lademoen, Midtbyen, Øya–Singsaker, and Rosenborg–Møllenberg. Midtbyen has the oldest low-density housing stock at one hundred forty years, followed by Rosenborg–Møllenberg (ninety years) and Øya–Singsaker (eighty-five years). The age of demolished buildings in this category is generally above the average age of the stock, except in four neighborhoods: Åsvang–Stokkan, Hallset, Øya–Singsaker, and Rosenborg–Møllenberg. For industrial and office buildings, the average stock age generally ranges between twenty and forty years, with two neighborhoods under twenty (Klæbu and Risvollan–Othilienborg) and four well over forty: Ila–Trolla (forty-five), Midtbyen (one hundred ten), Øya–Singsaker (forty-five), and Rosenborg–Møllenberg (sixty-five). The average age of demolished buildings in this category also falls between twenty and forty years, with only one neighborhood—Ranheim—strictly under twenty, showing an average of ten years. Three neighborhoods have an average demolition age above forty: Berg–Tyholt (sixty years), Midtbyen (forty-five), and Øya–Singsaker (just over forty).In this category, eleven neighborhoods show a lower age at the time of demolition than the stock average: Byneset–Leinstrand, Flatåsen–Saupstad, Hallset, Ila–Trolla, Lade, Midtbyen, Nardo, Nidarvoll–Leira, Øya–Singsaker, Ranheim, and Rosenborg–Møllenberg. There is a substantial gap in Midtbyen, where the average stock age of industrial and office buildings is one hundred ten years, compared to forty-five years for those demolished. In Rosenborg–Møllenberg, the stock averages sixty-five years, while demolished buildings are under thirty.

Figure 5. Diagrams showing the average age at demolition and the average age of the building stock for the twenty-five neighborhoods of Trondheim

5. DISCUSSION

The results presented above reflect the consequences of urban transformation in Trondheim. Mapping demolition and new projects allows identification of transformation patterns in the city and comparison of Trondheim's densification strategies with the actual densification percentages observed. Change in building types highlight which typologies are more prone to demolition and which are currently favored. The lifespan analysis revealed that some building types are demolished before reaching the age of the stock, depending on the neighbourhood and context. These results invite reflection on the potential premature obsolescence of certain building types and suggest the need for a contextualised evaluation of lifecycles. The term premature obsolescence is used here to describe buildings demolished before reaching their expected end of life, varying by building type and context. This section discusses premature obsolescence in relation to densification strategies and proposes different potentials for densification. Finally, examining demolition and lifecycle opens a discussion on circularity as a means to extend the lifespan of buildings threatened with demolition.

Densification and premature obsolescence

Referring to the densification strategies in Trondheim, the municipality advocates reducing CO_2 emissions by promoting the development of public transportation and connecting several satellite centers. These satellite centers are developed due to limited land availability in the city center and are intended to serve as secondary hubs within Trondheim. In addition, encouraging public transportation connections between satellite centers allows residents of each neighbourhood to access essential facilities without relying on private cars, either by walking, or using public transit. This approach aims to reduce carbon emissions from the transport sector, including those generated by private vehicle use.

The municipality's idea is to densify and develop mixed-use neighborhoods, creating more attractive and vibrant environments. However, the analysis results show that most neighborhoods in Trondheim have a single-use character. Low-density residential housing and industrial hubs are dominant patterns in the city. Therefore, urban strategies require the redevelopment of each neighborhood with new and adaptable typologies. This often results in demolition, primarily of low-density housing and industrial buildings. The positive intention of densification is thus counterbalanced by the adverse effects of demolition. Our results show that several demolished buildings do not reach the lifespan of the stock in the same neighborhood. Buildings are demolished at a younger average age, reflecting premature obsolescence of the building stock.

To mitigate this, a planning strategy could apply the concept of "deepening territories" introduced by landscape theorist Sébastien Marot in 2003 (Marot, 2003). He explains that past urban sprawl resulted in the spread of single-use neighborhoods, often residential, with facilities concentrated around car-accessible shopping centers and sealed soil (impermeable surfaces such as parking lots). Consequently, deepening our territories would involve working in these areas to establish radical mixed-use development, enforce moratoriums on soil sealing to promote ecological development of unbuilt areas, and focus on more intense use of already built areas by reusing, repairing, and caring for existing buildings and infrastructure.

Contextualizing lifecycles

Another observation reveals a paradox between the intentions of densification and the demolition outcomes. The results show that the age at demolition varies significantly between building types and neighborhoods. Several buildings are demolished before reaching the age of the building stock in the same area or before reaching their full potential, leading to premature obsolescence. This has implications for estimating climate gas emissions through methods such as Life Cycle Analysis (LCA). This method assesses the environmental impact of a product or process (in this case: a building) from the extraction of raw material to transportation to the building site, building, use, and up to its demolition and waste management (Curran 2013; Finnveden et.al. 2009). In Norway, such energy calculations are based on the NS3720 standard, which sets an average building lifespan to fifty years. However, our findings show that many building types in different areas across Trondheim are demolished before reaching fifty years. This suggests that lifespan differences should be incorporated when performing LCA and energy calculations.

The age of demolished buildings differs considerably between residential and non-residential buildings and depends on their location. This research supports more accurate lifecycle calculations by estimating lifespans according to building types and considering the context (location, planning strategies). Therefore, a context-based approach to LCA would enable greater flexibility, allowing adjustments based on specific circumstances. Curran (2013) noted that considering context by reporting qualitative information alongside quantitative evaluation was already recognized in the late 1990s. However, this qualitative aspect was often overlooked as the focus shifted toward presenting environmental impacts through quantifiable results. This issue was revisited in 2018 by Loiseau et al., who studied the emerging concept of territorial LCA and compared it to the general principles of traditional LCA applications. A territorial LCA takes a holistic approach to environmental impacts, connected to planning policies, considering the local character, and differentiating the impacts at various scales. They suggest that an important challenge is the consideration of the territorial material dimension: the availability of different types of materials in different territories (or geographically defined areas). They explain that using GIS tools could support this development (Loiseau et al. 2018). Our research takes part in this logic by mapping out geographically different types of buildings, demolished and new projects. A further step would be to estimate the quantities of materials in each building type, according to their building year and original function. In addition, our research offers empirical evidence through spatial analysis of urban transformation, illustrating how generic LCA assumptions (such as fixed building lifespans) can lead to inaccurate environmental assessments. Therefore, we emphasize the need for dynamic lifespans in LCA models, perhaps integrating spatial and temporal variables into LCA practices.

A reflection on contextualizing lifecycles has been ongoing among researchers, analysing different possibilities of geographically bounded calculations, or proposing different frameworks of applications. However, gaps persist between research suggestions and policy implications at a national and European level. In addition, with the pressure of an ever-growing climate crisis, this paper suggests opportunities for circular developments in neighborhoods. This will be discussed in the following section.

Opportunities for circular developments in neighborhoods

To deal better with the challenges of demolition and new construction, applying circular principles would allow us to extend the lifecycles of buildings. The concept of circularity originates from Circular Economy (CE) thinking, which aims to develop strategies for eco-efficiency by reusing a product at its end-of-life phase (Kirchherr et al., 2017). Applied to the built environment, it means expanding the lifecycle of buildings by rehabilitation or reuse of the building itself, or reusing buildings' components and recycling materials after demolition, to close the loop of materials. Different design principles ease the way towards circularity of the built environment: design for disassembly, or design for reuse, working with digital twins also allows to keep track of changes happening in buildings and helps forecast the future availability of materials. However, most progress has been made at the building scale. Our research suggests that a neighborhood scale gives a broader perspective, looking into different building types and changes, and could lead to studies on potential material availability in the same neighbourhood. Therefore, the research stands for a contextualization of circularity. As changes in cities occur at a different pace, circularity is not a one-size-fits-all solution, and circular principles should be tailored to specific contexts. This implies moving beyond the building scale and considering the material and intangible resources present in a site. A parallel reading of the results with densification strategies supports the idea of developing different circular solutions. In areas subject to high densification and where the demolition rate is also high, reusing components and materials from demolished buildings could be applied. Areas with a slower pace of demolition and aiming to preserve the built environment longer could reuse and repurpose buildings, creating a slow circularity.

For architects and professionals of the building sector, facing a constantly changing environment is an opportunity to implement more circular design strategies. Reuse of materials and building elements can be implemented directly from the design phase, with designing for disassembly, modularity, or layering for example. The paradox exposed in this paper between densification strategies for the sustainable development of cities and the resulting premature obsolescence could be mitigated by a slow circularity. A slow circularity would imply that circularity is not necessarily about closing the loop of materials, but primarily about slowing down the loop, keeping buildings in use until they reach their full potential lifecycle. Additionally, this reflection underlines the importance of interdisciplinarity around circularity, to better approach the complexity of cities. Architects must work together with planners to understand problems from the building to the neighbourhood and city scales. Engineers must be part of the discussion to consider the complexities of a city and handle energy challenges accordingly. Governing bodies must consider the broad spectrum of disciplines that city development encompasses. A successful application of circularity in cities relies on the competencies of different disciplines, working simultaneously towards holistic sustainable futures.

This discussion has highlighted the consequences of urban transformations and suggested further pathways for sustainable development of cities. Urban transformation inevitably occurs as a city grows over time, adapting to demographic and economic changes. One common solution is to limit urban sprawl through densification strategies; however, this sometimes comes at the cost of premature obsolescence. This discussion suggests that contextualized lifecycle evaluation and neighborhood-level circularity on a would mitigate the negative effects of densification.

Although this study focuses solely on the case of Trondheim, the same densification model is found in several Norwegian and European cities, making this study relevant beyond the local context. For example, densification is supported by the Zero-Growth Target (Trondheim Kommune 2020) in Norway, the Zero-Net Land take in France (Cormier and Cornet 2020) or the Compact City Policy in the Netherlands (Korthals Altes and Tambach 2008). These are all strategies aiming at densifying within city boundaries to limit urban sprawl and favor the preservation of arable land. However, as our study showed, these strategies do not prevent the premature obsolescence of buildings. We suggest stronger links between different policies, such as strategies for densification interlinked with for instance, reuse and circular economy policies.

To end the discussion around circularity and lifespans, we offer several recommendations. They can serve as an agenda for practice or for policy development, hoping to bridge the gap between research and practice. They are as follows: 1) an integration of lifespan data (construction date) of existing buildings in digital twins and planning tools would support informed decisions and better assumptions of future available materials in the city; 2) urban strategies could include indicators for assessing the reuse potential of buildings in areas undergoing transformation, acting like a material bank linking demolition and new constructions, supporting local material loops; 3) LCA methodologies could be adapted to specific contexts, building types, and functions. They could be supported by inter- and transdisciplinary work, among planners, architects, engineers, policymakers could work together to develop more integrated frameworks and understand better the importance of context and buildings lifecycles.

LIMITATIONS OF THE STUDY

The study delved into the lifespan of demolished buildings and compared them to that of the existing building stock. The data were collected from the Norwegian cadastre, where buildings are registered with an identity number, and a status. In most cases, the date of construction was available, but some dates were missing, mostly for small structures (especially garages). There are several possible reasons for this: either the date was not registered because the building was built before the digitisation of the cadastre and no historical records were available; or because it was self-built (probably the case for a small structure like a garage) and the date was omitted during the registration process. Another possibility could be that the building went through several changes, transformations or renovations and the original date couldn't be tracked. Our study provided evidence that lifespans vary significantly according to their building type and geographical context. However, conducting a sensitivity analysis on missing construction dates for demolished buildings could give more robustness to our results. We suggest further studies to look more deeply into data availability from different sources or estimations of construction dates by identifying, for example, building elements from a certain timeframe or epoch . This would give more accuracy and relevance to the research around building lifespans and contextualised Life Cycle Assessment.

CONCLUSION

To summarize, this paper delved into changes in Trondheim's building stock. As a growing city with an increasing number of inhabitants, the municipality proposed a densification strategy for 2050. Through this strategy, the municipality wishes to develop an attractive and liveable city, considering issues such as reducing energy emissions and promoting sustainable solutions. However, an analysis of demolition and new buildings showed that changes in the built environment often lead to premature obsolescence of specific building types in certain neighborhoods. Additionally, the research suggests reassessing building lifecycles based on their building types, and considering their location in the city along with the planning urban strategies they encompass. This will give more accuracy to energy calculations like Life Cycle Analysis, leading to more accurate assessments. Finally, this study contributes to the research on circular cities. Reassessing lifecycles informs city planners and policymakers on the possibilities of designing buildings more sustainably and in a more circular manner, as well as rethinking densification strategies, considering their effects on lifetimes and building types. This study also contributes to bridging the gap between demolition and circularity by locating and forecasting the availability of components and materials seen as new resources for urban mining (Koutamanis 2018; Wuyts et al. 2022), supporting the idea that circularity issues should be contextualised.

Further research would suggest a deeper analysis of the different neighborhoods, including qualitative methods to understand the qualities and values of places through the eyes of individuals. Looking into Neighborhood Sustainability Assessments (NSA) combining quantitative and qualitative methods would help get a more holistic and contextualise approach to urban development.

Data availability

We are not authorized to share raw data, but aggregated data can be made available on request.

Details of the GIS processing, used to conduct our spatial analysis, can be found here. Further guidance is available from the authors on request.

REFERENCES

Aamo Alv Skogstad, Bratseth Katja, Eilertsen Maiken Riis, Lindahl Markus Domaas and Støa Eli (2021) Bokvalitet og høy tetthet, Hvordan kombinerer vi de to? En kvalitativ studie av ni norske eksempler.

Befolkningsprognose for Trondheimsregionen 2022-2050 (TR2022M): Dokumentasjonsnotat, (2022)

Berghauser Pont, M., Haupt, P., Berg, P., Alstäde, V., & Heyman, A. (2021). "Systematic Review and Comparison of Densification Effects and Planning Motivations." Buildings and Cities, 2(1), 378–401. DOI: http://doi.org/10.5334/bc.125

Byggteknisk forskrift (TEK 17), Direktoratet for byggkvalitet, https://www.dibk.no/regelverk/byggteknisk-forskrift-tek17/17/17-1 (last consultation 28.02.2025)

Byutviklingsstrategi for Trondheim, 2020 Saksprotokoll - Sluttbehandling: Byutviklingsstrategi for Trondheim - strategi for areal- og transportutvikling fram mot 2050, Trondheim Kommune, 09.12.2020

Cole Helen V.S., Mehdipanah Roshanak, Gullón Pedro and Triguero-Mas Margarita (2021). "Breaking Down and Building Up: Gentrification, Its drivers, and Urban Health Inequality." Curr Envir Health Rpt 8, 157–166 (2021). https://doi.org/10.1007/s40572-021-00309-5

Cormier, T., Cornet, N (2020), Zero Net Land Take: An Unprecedented Challenge. Note Rapide, L'institut Paris Region. ISSN 2555-7165 ISSN online 2497-126X

Curran, Mary Ann. 2013. "Life Cycle Assessment: A Review of the Methodology and Its Application to Sustainability." Current Opinion in Chemical Engineering 2 (3): 273–277. https://doi.org/10.1016/j.coche.2013.02.002.

Damgaard, A., C. Lodato, S. Butera, T. Fruergaard Astrup, M. Kamps, L. Corbin, D. Tonini, and T. F. Astrup. 2022. "Background Data Collection and Life Cycle Assessment for Construction and Demolition Waste (CDW) Management." EUR 31323 EN. Luxembourg: Publications Office of the European Union. https://doi.org/10.2760/772724.

Dovey, K., and E. Pafka. 2020. "What Is Walkability? The Urban DMA." Urban Studies 57 (1): 93–108. https://doi.org/10.1177/0042098018819727.

Dymén, Christian & Langlais, Richard. (2013). Adapting to Climate Change in Swedish Planning Practice. Journal of Planning Education and Research. 33. 108-119. 10.1177/0739456X12463943.

Ellen MacArthur Foundation, Cities in the circular economy: An initial exploration (2017). https://www.ellenmacarthurfoundation.org/cities-in-the-circular-economy-an-initial-exploration . Last consulted the 09.07.2025

European Committee for Standardization. 2011. EN 15978: Sustainability of Construction Works—Assessment of Environmental Performance of Buildings—Calculation Method. Brussels: European Committee for Standardization.

Finnveden, G., M. Z. Hauschild, T. Ekvall, J. Guinée, R. Heijungs, S. Hellweg, A. Koehler, D. Pennington, and S. Suh. 2009. "Recent Developments in Life Cycle Assessment." Journal of Environmental Management 91 (1): 1–21. https://doi.org/10.1016/j.jenvman.2009.06.018.

Grover, R., S. Emmitt, and A. Copping. 2019. "The Language of Typology." Architectural Research Quarterly 23 (2): 149–156. https://doi.org/10.1017/S1359135519000198.

Kirchherr, J., D. Reike, and M. Hekkert. 2017. "Conceptualizing the Circular Economy: An Analysis of 114 Definitions." Resources, Conservation & Recycling 127: 221–232. https://doi.org/10.1016/j.resconrec.2017.09.005.

Korthals Altes, W. K., and M. Tambach. 2008. "Municipal Strategies for Introducing Housing on Industrial Estates as Part of Compact-City Policies in the Netherlands." Cities 25 (4): 218–229. https://doi.org/10.1016/j.cities.2008.04.005.

Koutamanis, A., B. van Reijn, and E. van Bueren. 2018. "Urban Mining and Buildings: A Review of Possibilities and Limitations." Resources, Conservation and Recycling 138: 32–39. https://doi.org/10.1016/j.resconrec.2018.06.024.

Loiseau, E., L. Aissani, S. Le Féon, F. Laurent, J. Cerceau, S. Sala, and P. Roux. 2018. "Territorial Life Cycle Assessment (LCA): What Exactly Is It About? A Proposal Towards Using a Common Terminology and a Research Agenda." Journal of Cleaner Production 176: 474–485. https://doi.org/10.1016/j.jclepro.2017.12.169.

Marique, A.-F., and B. Rossi. 2018. "Cradle-to-Grave Life-Cycle Assessment within the Built Environment: Comparison between the Refurbishment and the Complete Reconstruction of an Office Building in

Belgium."

Marot, Sébastien. Sub-urbanism and the Art of Memory. London: Architectural Association, 2003.

Moisio, M., E. Salmio, T. Kaasalainen, S. Huuhka, A. Räsänen, J. Lahdensivu, M. Leppänen, and P. Kuula. 2024. "Towards Urban LCA: Examining Densification Alternatives for a Residential Neighbourhood." Buildings and Cities 5 (1): 581–600. https://doi.org/10.5334/bc.472.

Müller-Eie, D. 2019. "Geographic Transport Planning Principles in Norwegian City Regions: The Case of Work Travel in Stavanger." In Data Analytics: Paving the Way to Sustainable Urban Mobility, edited by E. Nathanail and I. Karakikes, 879–894. Advances in Intelligent Systems and Computing, vol. 879. Cham: Springer. https://doi.org/10.1007/978-3-030-02305-8_94.

Norwegian Standards Institute. 2018. NS 3720:2018 – Method for Greenhouse Gas Calculations for Buildings. Standard Norge, https://standard.no/fagomrader/energi-og-klima-i-bygg/bygningsenergi/klimagassberegninger/ . Last consulted on 09.07.2025

Oliveira, Victor. (2013). Morpho: A methodology for assessing urban form. Urban Morphology, 17(1), 21–33.

Pozoukidou, Georgia, and Margarita Angelidou. 2022. "Urban Planning in the 15-Minute City: Revisited under Sustainable and Smart City Developments until 2030." Smart Cities 5 (4): 1356–1375. https://doi.org/10.3390/smartcities5040069.

Rochat, David, Claudia R. Binder, Jaime Diaz, and Olivier Jolliet. 2013. "Combining Material Flow Analysis, Life Cycle Assessment, and Multiattribute Utility Theory Assessment of End-of-Life Scenarios for Polyethylene Terephthalate in Tunja, Colombia." Journal of Industrial Ecology, May 10. https://doi.org/10.1111/jiec.12025.

Seyedabadi, M. R., and U. Eicker. 2023. "A Critical Review of Urban Scale Life Cycle Assessment of the Built Environment." Sustainability Analytics and Modeling 3: 100026. https://doi.org/10.1016/j.samodel.2023.100026.

Statistics Norway (SSB). 2000. "Classification of Building Type." Accessed January 24, 2024. https://www.ssb.no/en/klass/klassifikasjoner/31.

Ji, Sukwon, Bumho Lee, and Mun Yong Yi. 2021. "Building Life-Span Prediction for Life Cycle Assessment and Life Cycle Cost Using Machine Learning: A Big Data Approach." Building and Environment 205: 108267. https://doi.org/10.1016/j.buildenv.2021.108267.

Teller, J. 2021. "Regulating Urban Densification: What Factors Should Be Used?" Buildings and Cities 2 (1): 302–317. https://doi.org/10.5334/bc.123.

Tennøy, A., and O. Hagen. 2020. "Reallocation of Road and Street Space in Oslo: Measures for Zero Growth in Urban Traffic." International Transport Forum Discussion Papers, no. 2020/14. Paris: OECD Publishing.

Trondheim Kommune. 2020. Byutviklingsstrategi for Trondheim: Saksprotokoll - Sluttbehandling: Byutviklingsstrategi for Trondheim - Strategi for Areal- og Transportutvikling fram mot 2050.

Trondheim Kommune. 2024. Kommuneplanens Arealdel 2022–2034: Bestemmelser og Retningslinjer. Trondheim Kommune

Wuyts, Wendy, Alessio Miatto, Kronnaphat Khumvongsa, Jing Guo, Pasi Aalto, and Lizhen Huang. 2022. "How Can Material Stock Studies Assist the Implementation of the Circular Economy in Cities?" Environmental Science & Technology 56 (24): 17523–17530. https://doi.org/10.1021/acs.est.2c05275.