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A Data Processing Methodology to Analyze Construction and Demolition Dynamics in the European Metropolis of Lille, France

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Abstract: In the absence of industry data, organisms, and researchers leverage free and available data, specifically building and demolition permits. Geospatial processing is essential to integrate information from various files into a single GIS layer containing all relevant attributes for analysis. This article proposes a Geographic Information System (GIS) processing model aimed at monitoring construction and demolition dynamics in the European metropolis of Lille to quantify the urban production of mineral waste from buildings. Author methodology is based on that that the deposit potential can be analyzed using the observation of the spatiotemporal dynamics of building and demolition permits. The results demonstrate that combining construction and demolition (C&D) permits with other GIS layers allows us to produce data to quantify demolition surfaces per year in a given French area. The applicability of this methodology extends to all French regions, providing insights into the impact of crises on deconstruction activities and C&D waste generation. The study focuses on C&D French public data bases (French government and European Metropolis of Lille) attributed to the region (area) of the European Metropolis of Lille (MEL) between 2013 and 2022. Some data for 2022 were incomplete due to ongoing treatment, emphasizing the importance of understanding the dynamics of demolition rates or surfaces to identify data gaps or errors. Historical trajectories of C&D permits were quantified and analyzed, revealing over 21,000 permits granted from 2013 to 2022, categorized by site type (new construction, rehabilitations, prior declarations, and demolitions). Construction sites during this period covered approximately 3,345,948 m^2, constituting 20% of the MEL's building stock, while demolition sites amounted to 1,977,911 m^2, equivalent to 5% of the total area of buildings in the metropolis. Employing GIS allowed for a spatial analysis, visualizing data by municipality, urban fabric, and year. The analysis highlighted territories with high and low potential for demolition and construction, as well as the most impacted urban fabrics and dynamic periods. The article discusses potential crisis impacts (e.g., COVID-19 or economic downturns) and the implications of incomplete data. Finally, the study demonstrates how these findings can be utilized to quantify C&D waste, leveraging GIS and the production rate calculation method (GRC).

Keywords: construction and demolition permits; geospatial processing; GIS; urban fabric; spatial analysis; MEL; waste quantification; worksite

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1. Introduction

Building construction and demolition wastes represent major environmental and economic issues. Indeed, construction and demolition activities generate significant waste amounts, largely recyclable and reusable [1–3]. The monitoring data of construction and demolition wastes provides information on urban growth, rehabilitation, and/or urban renewal. In France, this data can be used to assess the success of the energy transition policies for green growth (LTECV, 15 August 2015) and the circular economy government roadmap (FREC). The quantification of building waste is indeed a prerequisite for an effective waste management implementation. The availability of comprehensive and high-quality data is, therefore, a prerequisite for achieving the national policies' objectives for the recovery, prevention, and management of building construction and demolition waste.

Several studies have recently been reported on the characterization and quantification of mineral waste from building demolition on an urban scale [4–7]. Several methods, tools, and approaches have been proposed to provide accurate waste quantities [8–13]. GIS-based methods have been developed at different scales and for different geographical areas: a town (Vienna by [14]), a region (Macedonia by [15]), and a country (Iran by [15–17] for Portugal). The building sector generated in France over 227 million tonnes of waste in 2014 [18,19]. A significant portion of the generated waste can be reused to substitute for primary materials. The waste recovery approach, which is part of a circular economy logic, has the potential to reduce the demand for primary resources [20]. The approach requires in-depth knowledge of available or potential waste quantities and substitution rates, which requires exhaustive and high-quality building data. However, one recurring drawback of building waste quantification, which has been reported in the literature, is the lack of exhaustive and quality data [12]. Many developing countries do not have a fairly representative building database with all the necessary data for the analysis of the sector [21]. Several authors have proposed approaches to generate or estimate missing data such as building height, construction and demolition years, material types, floor area, materials' weight per unit area, materials' lifespan estimate, etc. [9,16]).

This paper presents a new approach to building a building waste quantification database that relies on construction and demolition territorialized dynamics. The quantitation is conducted by analyzing construction and demolition permits (C&D). It is assumed that there is a link between building construction and demolition dynamics and a territory waste production rate. The aim of the paper is to quantify, and model waste flows in the building sector on a local scale. The deposit potential is then quantified by observing the spatio-temporal dynamics of the allocation of building and demolition permits. The authors show how C&D permits can be used to quantify building construction and demolition waste. The approach uses GIS and database tools to process and analyze construction and demolition permit data. A GIS data processing model is developed for the quantification and monitoring of building demolition of waste on construction sites.

The first part of the manuscript presents the datasets and describes the methodological approach and data processing. On the other hand, the second part describes and analyzes the results and discusses the method and the difficulties encountered. The uniqueness of the proposed research lies in using a data pre-processing technique to assess the yearly surface area of construction and demolition buildings on a regional scale, which can be replicated for every French region and area. The outcomes include a spatialization approach for building permits related to demolition and construction, which has the potential to refine waste management policies specifically for construction sites within the building sector.

2. Methodology

2.1. Collection and Presentation of Datasets

- Study area

This research was conducted in the European Metropolis of Lille (MEL), located in the Hauts-de-France region, which encompasses 95 municipalities (Figure 1). The 2018 Insee data shows that both the population and urban areas in this region have continued to grow. MEL is a vibrant EPCI (Public Establishment for Intercommunal Cooperation) in France. Notably, it is the second-largest urban area in France, with a population density of 1748 inhabitants per square kilometer. Moreover, MEL occupies the fourth position in geographical size after Paris, Lyon, and Marseille, covering 672 square kilometers [22].

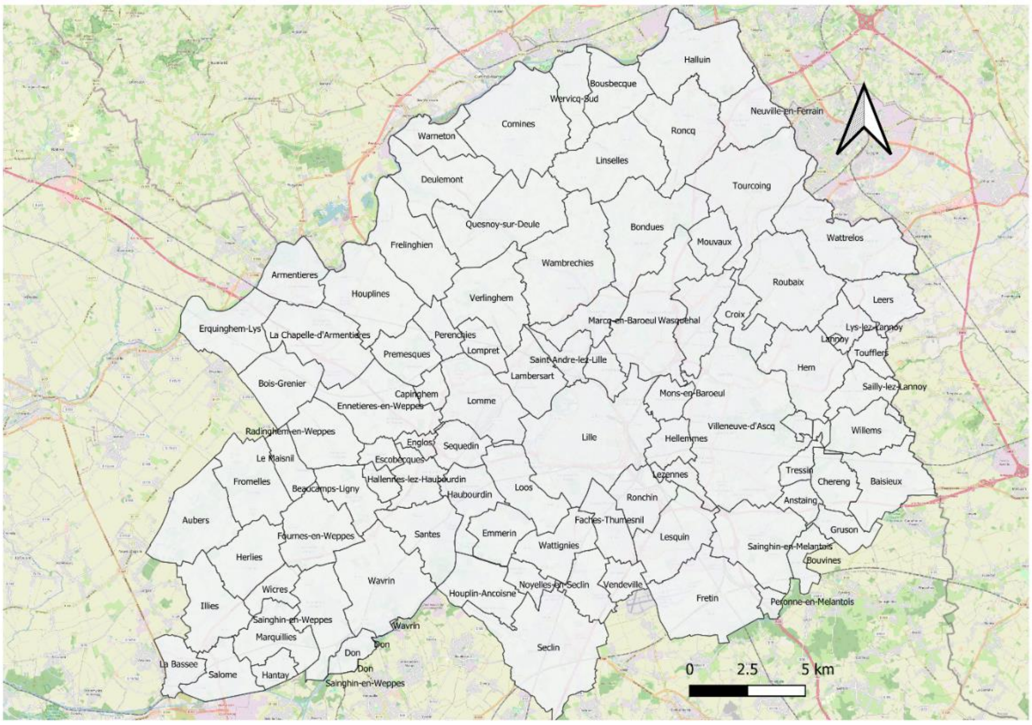


Figure 1. Study Area Location: The European Metropolis of Lille (France) and its municipalities (The light blue color corresponds to the Lille metropolitan area).

All datasets pertain herein specifically to the MEL region and were collected across all its municipalities (Figure 1).

The construction and demolition permit datasets are available in two formats, namely, text (CSV) and vector files (SHP). The vector data encompasses building layers, administrative boundaries of the MEL, cadastral data (plots), urban fabric vectors generated by the Development Agency and Town Planning of Lille Métropole (ADULM), and the town hall of Lille. While most of them originate from the same source (BDtopo), these vectors vary in terms of the attribute data they contain. These datasets, either created by public or private experts, are freely accessible (Open Data), as shown in Table 1.

In the literature, there is a scarcity of studies that utilize building and demolition permit data to model and quantify the waste generated from construction activities. In France, specifically, these data are rarely employed in research endeavors, and their description, content, and scientific utilization are briefly mentioned in reported publications. This is primarily because these databases are relatively new, and the available and usable data only spans from 2013 onwards. Typically, the accessible information consists of methodological documents authored by administrators, which outline the procedures employed in developing these databases. The construction and demolition permit files have been uploaded to the Sitadel database, which is made accessible by the Statistical Data and Studies Service (SDES). It is worth noting that most of the data in these databases, including building and demolition permits, is sourced from local authorities and departmental directorates. Since June 2021, the lists of building and demolition permits have been distributed monthly. The data used herein is presented in the subsequent subsection.

Table 1. Data Typology and Sources.

Data Type	Format	Source	Updated	Download Link
Urban fabric *	Vector (shp)	ADULM et Mairie de Lille	Undated	https://box.mairie-lille.fr/sharing/i3x9BD3uo (last access12 August 2023)
Administrative boundaries * Cadastre *	Vector (shp)	Topographique Database	Undated	https://box.mairie-lille.fr/sharing/GKA4zdnxs (last access 12 August 2023)
Building (MEL) *	Vector (shp)	Topographique Database	Undated	https://box.mairie-lille.fr/sharing/GKA4zdnxs (last access 13 August 2023)
Building (BDNB)	Vector (shp)	CSTB	Undated	https://www.data.gouv.fr/fr/datasets/base-de-donnee-nationale-des-batiments-version-0-6/#description (last access 12 August 2023)
Demolition permits Construction permits	Text (csv)	Sitadel	Monthly	https://www.statistiques.developpement-durable.gouv.fr/liste-des-permis-de-construire-et-autres-autorisations-durbanisme (last access 15 August 2023)

* These vectors were downloaded from the open data website of Lille municipality but they are originated from the National Institute of Geography (IGN) BDTopo database.

2.1.1. Construction and Demolition Permit

Construction and demolition permits are essential permissions required for all construction and demolition activities. They are obtained by submitting forms that provide details and specifications about the proposed work, such as location, floor area, height, land area, beneficiaries, sponsors, and other relevant information. It is important to note that most of the information in these permits is provided by local authorities and departmental directorates. These data are then collected, processed, and condensed by the Statistical Data and Studies Department (SDES) in the SITADEL database (the national database of planning permission applications). Most of the information on building and demolition permits presented here comes from this database. It describes all processes and provides information on building and demolition permits. Building and demolition permit lists have been distributed monthly since June 2021 [23], (Sitadel see Table 1). The permit data is collected from completed applicant forms. The town planning authorization databases consist of three main files: (1) applications for building permits (CP) and prior declarations (PD), (2) demolition permits (DP), and (3) development permits (PA). These databases contain authorization application decisions and any subsequent administrative or judicial decisions such as modifications, withdrawals, cancellations, construction start declarations, and completion and conforming declarations.

- Permit obtainment and validity duration deadlines

Article R 424-17 of the French Town Planning Code considers the building, development, or demolition permits to expire if the work is not initiated within two years from the notification or tacit decision dates. However, on 9 December 2008, an issued decree extended the validity period of permits and decisions of non-opposition to declarations to three years for permits and decisions made on or before 31 December 2010. To develop a replicable methodology at the European scale, it is important to conduct a specific analysis of urban planning regulations.

- Building permits

Building permits are valid for three years once received. If the construction work has not started within the three-year period or has been interrupted for more than a year, the building permit becomes invalid and needs to be renewed. However, it is possible to obtain two one-year extensions by contacting the town hall's planning department two months prior to the deadline. The administration has two months to review the file for a detached house and three months for other projects, starting from the date of receipt of the building permit application. The town hall may extend the deadline for obtaining a building permit if further examination is required but must inform the applicant before the original deadline. The town hall's failure to respond within the normal instruction period is considered an acceptance of the building permit (French Town Planning Code, article R 424-17).

The application for a building permit is based on CERFA n°1340601 for the construction of a detached house or its annexes, with or without demolitions, or on CERFA n°1340901 for any other type of construction, with or without demolitions. A building permit is mandatory for any new construction with a gross floor area (SHOB) exceeding 20 m^2, regardless of its height. Additionally, a building permit is required for changing the purpose of a building and for any work that modifies the load-bearing structures or the façade [24].

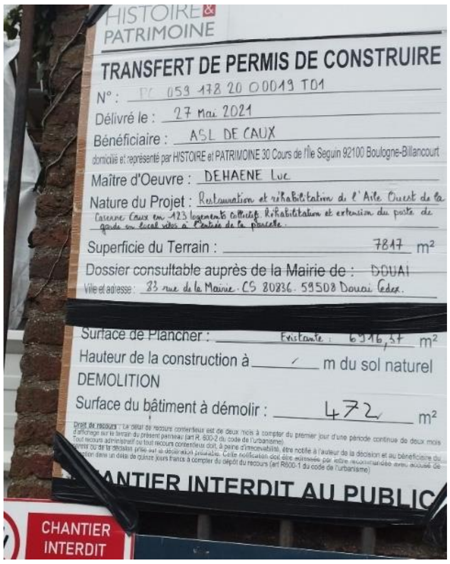
- Demolition permits

Demolition permits are valid for three years. The authorization expires if the demolition work is not commenced within three years or if the work is interrupted for more than a year. However, the validity period of the permit can be extended twice for one year each. The demolition permit must be obtained before starting the work on a building that either falls under special protection or is in an area where such a permit is mandatory [24].

When the demolition is associated with a construction or development project, the demolition request can be submitted along with the application for a building or development permit.

Figure 2a illustrates an example of a building permit for the restoration of housing without demolition, while Figure 2b represents a building permit that includes demolition. Notably, building permits often include information about the surfaces to be demolished, as seen in the case of Permit B, which specifies a surface area of 472 m^2 for the building to be demolished.

(**a**)



(**b**)

Figure 2. (**a**) Public posting of a building permit. (**b**) Public posting of a building permit requiring demolition.

2.1.2. Description of Demolition and Construction Permit Databases

- Demolition site database

The database for demolition sites is organized based on 30 attributes (Table 2). These attributes include crucial information such as the land area, permit number, municipality where the site is located, cadastral data, permit status, site status, year of authorization, and type of structure (Table 2). It is important to note that this database includes information on completely demolished structures only. However, it does not provide surface data for the demolished buildings. In summary, all the attributes included in the demolition database are presented in Table 2.

Table 2. Extract from demolition permit attribute dictionary.

Attribute Name	Attribute Description	Modalities
REG	Code of the region of the work place	Nomenclature of the Official Geographical Code (INSEE)
DEP	Code of the department of the work place	
COMM	Code of the municipality of the work place	Nomenclature of the Official Geographical Code (INSEE)
DP_Number	Number of demolition permit registrations	
DP_Status	Project progress	2 = Authorized 4 = Canceled 5 = Started 6 = Finished
REAL_DATE_AUTORIZATION	Real date of initial authorization	
DPC_AUT	Date (month) (DPC) of last data update	
DPC_DERN	Date (mois) (DPC) de last data update	
APPLICANT_APE	Establishment of a proven applicant as a legal person	Nomenclature NAF Rév2
APPLCANT_CJ	Legal category of a proven applicant as a legal person	Nomenclature of the Sirene directory
APPLICANT_NAME	Name of the applicant confirmed as a legal person	
APPLICANT_SIREN	SIREN number of the applicant confirmed as a legal person	
APPLICANT_SIRET	SIRET number of the applicant confirmed as a legal entity	
APPLICANT_ POSTCOD	Applicant postal code	
APPLICANT_LOCALITY	Applicant locality	
REC_ARCHI	Indicator of appeal to an architect	1 if yes, 0 if no
ADR_NUM_FIELD	Field number	
ADR_LABROADE_FIELD	Label of road	
ADR_LABWAY_TER	Label of the way of	
ADR_LAB_FIED	Label of place	
ADR_LOCALITY_FIED	Field locality	
ADR_CODPOST_FIELD	Fiel postal code	
SEC_CADASTRAL1	Cadastral Section 1	
NUM_CADASTRAL1	Number of cadastral plot 1	
SEC_CADASTRAL2	Cadastral Section 2	
NUM_CADASTRAL2	Number of cadastral Section 2	
SEC_CADASTRAL3	Cadastral Section 3	
NUM_CADATRAL3	Number of cadastral plot 3	
F_AREA	Field area	
OP_ZONE	"Operating zone" code	1 = Housing estate 2 = ZAC 3 = AFU 4 = Outside zones

Some pre-processing was made to the demolition database in Table 2. The attributes in green have been kept, while those in red were deleted because they are not useful for spatial analysis. On the other hand, the attributes in gray were concatenated.

- Construction site database

The construction site database comprises two main files, namely, building permits and prior declarations. It further differentiates between permits for creating non-residential premises and permits for creating residential dwellings. The data for residential and non-residential dwellings have several common fields but are stored in two separate attribute dictionaries. Additionally, unlike the demolition permits, the construction database includes rehabilitation sites, which are characterized by building permits preceded by demolition permits. The building permit databases have a higher number of attributes. The table describing the attributes for building permits creating premises contains over 91 attributes, while the table for building permits creating residential dwellings has 67 attributes. These two files are closely linked, which adds complexity to the understanding of the database. This complexity arises from the various changes in the building's purpose, such as the conversion from residential to non-residential (offices, shops) or from non-residential to residential. These databases, which are filled with rich information, include data on land areas, number of building floors, created building areas, demolished building areas, transformed areas, and rehabilitation. To streamline the files and simplify processing, non-essential attributes will be removed, and the tables will be formatted to ensure compatibility with GIS files.

Lastly, both the construction and demolition databases contain attributes that enable the identification of permits or prior declarations based on numerical codes. These codes indicate whether the projects or declarations were authorized (code 2), canceled (code 4), started (code 5), or completed (code 6) (Table 2). This information is crucial as it contributes to the historical analysis of worksite evolution.

- C&D permits data quality

The methodological document accompanying the town planning permit data presents a comprehensive overview and description of the data quality obtained from construction and demolition permits. To provide a concise and clearer understanding, the following subsection is presented according to the authors' terms:

"The disseminated information exhibits varying quality levels. The data with the highest quality for the town planning authorization forms relates to the following aspects:

- Destinations and floor areas created, and to a lesser extent, the existing areas before and after the works. This information proves highly valuable for investigating and establishing the basis for town planning taxes.
- The number of dwellings created: This information is fundamental and subject to close monitoring by the relevant departments responsible for Sitadel data collection.
- The location of the worksite: This aspect holds significant importance for permit evaluation and processing.
- The land area, even though it is absent in approximately 15% of building permits.
- The nature of the project (new construction or work on existing structures) is generally well-declared.
- Other information exhibits a more uneven quality: It is often missing, but when provided, it is typically filled in correctly".

By presenting these key aspects, the authors offer insights into the varying quality of data obtained from construction and demolition permits and highlight the significance of specific fields for a comprehensive understanding of town planning activities.

The quality of data from construction and demolition permits is presented and described in the methodological document https://www.statistiques.developpement-durable.gouv.fr/liste-des-permis-de-construire-et-autres-autorisations-durbanisme (accessed on 25 May 2023) accompanying the data from town planning permits. For better synthesis and r better understanding, this subsection is written using the authors' terms:

"The disseminated information varies in quality. The most reliable information from the forms of request for authorization of town planning pertains to the following:

- Destinations and floor areas created, and to a lesser extent, those existing before the works and those that have been removed. This information proves highly valuable for investigating and determining the base for town planning taxes.
- The number of dwellings created is not only fundamental but also closely monitored by the departments of the ministry responsible for Citadel collection.
- The place of work is another crucial factor in the approval process.
- The land area, though, is missing in about 15% of building permits.
- The nature of the project (whether it involves new construction or work on existing structures) is generally well-declared.

On the other hand, other pieces of information have more erratic quality: they are often missing, but when present, they are usually filled in correctly".

Additionally, several other biases exist in the data. The authors have observed the absence of essential metadata in a large number of demolition and construction permits, particularly regarding cadastral information and surfaces. Upon closer analysis, this missing information resulted from inadequately or partially filled forms submitted by the applicants. This impasse presents a significant inconvenience as it leads to a substantial loss of valuable data. One example of this is the lack of surface data for demolition permits. Unlike building permits, which contain such information, the database lacks any details on demolished surfaces. Furthermore, the Citadel services responsible for managing these forms only oversee construction data, leaving demolitions unchecked. Moreover, not all form fields are consistently filled in. However, a properly completed form serves as an important data source and significantly contributes to the approaches and methodology for quantifying building waste stocks.

- Choice of C&D permit data and future contribution of C&DW quantification

Obtaining data from construction and demolition sites has been challenging. Participants in the building sector continue to display significant reluctance when it comes to sharing site-related data. Furthermore, the authors have identified several stakeholders who lack sufficient data concerning the buildings earmarked for demolition, particularly with respect to quantities categorized by type of waste.

This deficiency in data arises from the fact that the law does not mandate a waste diagnosis for any building with a floor area greater than or equal to 1000 m^2. For structures falling below this threshold, a waste diagnosis is not required. During investigations, the authors encountered a deconstruction player who operated on an 18,000 m^2 site consisting of 360 housing units, each measuring less than 1000 m^2. Remarkably, this entity does not conduct a waste diagnosis because the social landlord demands that each building be treated as a separate construction site rather than considering the entire 18,000 m^2 area. Consequently, they evade the obligation to carry out a waste diagnosis.

The primary driver behind this practice is purely economic, as conducting a diagnosis incurs a cost, and waste management necessitates meticulous tracing and handling.

2.2. Spatial Reference Database for the Analysis of Demolition and Construction Sites

The previous sections were dedicated to the presentation of the types of data used, their respective content, and their quality. Emphasis was placed on the description of building and demolition permits and their contribution to the process of assisting in the quantification of construction waste. The following section describes the various pre-processing and processing operations performed on the different data types on text files (Excel format) and their matching with vector files (GIS). It is worth noting that the building and demolition permit data have no spatial references. They cannot be represented on a map or be associated with a GIS file. To do this, several operations processing are necessary to prepare a single GIS layer containing all the attribute data required by the spatial analysis. Thus, building data, building and demolition permits, and urban fabrics will be combined or merged to obtain a single working layer. This layer constitutes a database to help quantify waste from C&D activities.

2.2.1. Data Pre-processing Method

- Tools and Methods

Data processing was carried out using mainly QGIS version 3.10 software because of its stability. The data preparation is divided into two essential phases, namely, the pre-processing carried out on the databases (Excel) and the processing carried out on the GIS files. The pre-processing phase includes all the operations carried out on the database, from extraction to cleaning and consolidation to clean the data and make it usable. This necessary step reorganizes the data, which may be directly usable, such as in the case of building and demolition permits. The processing phase includes the operations of combining and transforming the data with a view to their interrogation and analysis. While the pre-processing and data structuring operations were carried out using database management software (mainly Excel-version 2020), the processing itself uses geographic information system technologies. GIS is used to answer problems in a multitude of fields. The use of these tools has considerably increased in view of the mass circulation of data (open data). Today, GIS is recognized as a knowledge and decision-support tool. Its use for the management of construction and demolition waste is increasingly observed. In the building waste management sector, one of the particularities of GIS tools is to allow several spatial analyses [25].

For data processing, several operations were carried out on the files containing building and demolition permits and GIS files. The main conceptual lines of the processing method are presented in Figure 3.

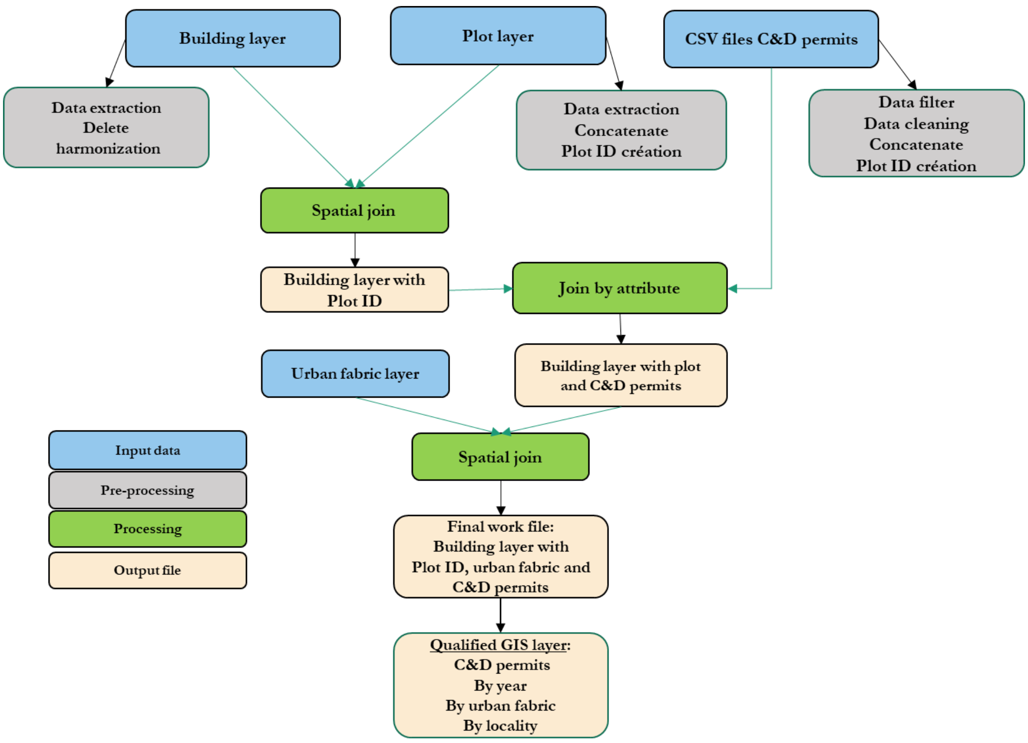


Figure 3. Sequence of the main functional steps allowing the crossing of data sets. Cedric Mpié Simba.

This model illustrates the creation of a final working layer containing attribute data needed for spatial analysis. The attributes of these deals are added by performing spatial joints. Figure 3 presents all the processing carried out on the database files. The input data consists of the building layer of the MEL, the plots layer, the CD permit database, and the urban fabric layer. The datasets were first consolidated. This step requires the following operations:

- Extraction of data from the study area according to its geometric shape via the “cut” module,
- Filter data in CSV files based on attributes,
- Deletion of non-essential attributes (to lighten the files),
- Harmonization of authors GIS tables and attribute data, cleaning, concatenation, and creation of common table identifiers,
- Association or intersections (joining by location),
- Association or crosses by attributes from a field common to two tables,
- Enrichment of files by adding other information from another table (by spatial intersection or attribute join).

The carried-out pre-processing consists of data extraction operations according to the geographical limits of the study area and the deletion of incomplete and non-essential attributes (to lighten the files in the GIS). These operations were carried out both on the vector files (urban fabrics, buildings, and plots) and the building and demolition permits. Additionally, some vectors had geometric errors and lacked spatial indexes. To overcome these problems, pre-processing was carried out in the QGIS interface, geometric repair, and the creation of spatial indexes. These were essential to ensure the combination or association of files, which in turn allows the creation of derived spatial relationships. The complexity of this work lies in the type of data to be processed and especially in the organization of the source (or base) files. The construction and demolition permit databases are not organized in such a way as to facilitate their processing by GIS. Indeed, the latter do not have explicit spatial references (neither geographical coordinate nor vector). Therefore, they cannot be directly supported by GIS software (version 2023). Moreover, there is no link between the C&D permit files and the other vector files. However, this condition is mandatory to be able to cross-reference the data of the C&D permits and the buildings with a view to their location (spatialization) and/or their identification by type.

2.2.2. Spatialization Method for Demolition and Building Permits

The objective is to identify or locate the buildings that correspond to each type of C&D permit. This action involves spatial crossing operations and attribute joins. Geospatial crossing consists of grouping the attributes of two or more layers (GIS) into a single base layer. However, these attributes must be hooked from a common object or field. However, for all our data, there is no field or attributes common to vector files (GIS) and C&D permits. To be able to carry out these operations (joins), a unique parcel identifier was created for each building and each permit from the cadastral information contained in the two files. Note that the buildings layer is not attached to the plots layer, and the plot vectors do not have information on the buildings. This is also the case for text files (C&D), which do not have common attributes to GIS files. However, the latter contains, with the plots layer, common information on land, but organized differently (Figures 4 and 5. This is the section number, the cadastral number, and the communal and departmental code. To have a common layer, these two sets of data (GIS layer of buildings and CSV file of permits) must be harmonized. They allow the creation of a unique identifier for each plot. Figures 4 and 5 shows the data organization of the two layers. Although their attributes are of the same nature, they are presented in different ways. The column of cadastral numbers, for example, has four digits in the plots layer (Figure 4), while certain columns of the permit file have 3 (Figure 5). This last file must be organized according to the plots layer.

	NUMERO	SECTION	NOM_COM	CODE_COM
1	1643	0A	Bauvin	052
2	1644	0A	Bauvin	052
3	1101	0C	Sainghin-en-Weppes	524
4	1216	0C	Sainghin-en-Weppes	524
5	1104	0C	Sainghin-en-Weppes	524
6	1103	0C	Sainghin-en-Weppes	524
7	1102	0C	Sainghin-en-Weppes	524
8	0132	AA	Annœullin	011
9	0139	AA	Annœullin	011
10	0133	AA	Annœullin	011
11	0137	AA	Annœullin	011
12	0138	AA	Annœullin	011
13	0131	AA	Annœullin	011
14	1930	0C	Sainghin-en-Weppes	524
15	1612	0C	Sainghin-en-Weppes	524

Figure 4. Plots layer attribute data (GIS).

ADR_LOCALITE_TER	ADR_CODPOST_TER	Sec_cadastre1	Num_cadastre1
Allennes-les-Marais	59251	B	3608
Anhiers	59194	A	166
Aniche	59580	AI	19
ANICHE	59580	AH	152
Aniche	59580	AD	879
ANICHE	59580	AM	268
ANICHE	59580	AD	879
ANICHE	59580	AB	477
Aniche	59580	AE	480
Aniche	59580	AD	385
Aniche	59580	AM	230
ANICHE	59580	AD	05
ANICHE	59580	AD	367
ANICHE	59580	AB	9

Figure 5. Attribute data from PC and PD files (CSV).

The creation of a unique identifier for each plot is the combination of the commune code (the last three digits), the cadastral section (usually letters), and the cadastral number (composed of four digits). This is obtained by concatenation of these three columns. Thus, the results are presented below.

Example line 1: 052A1634 (Figure 4); 251B3608 (Figure 5)

Example line 8: 011AA0132 (Figure 4); 580AB0477 (Figure 5)

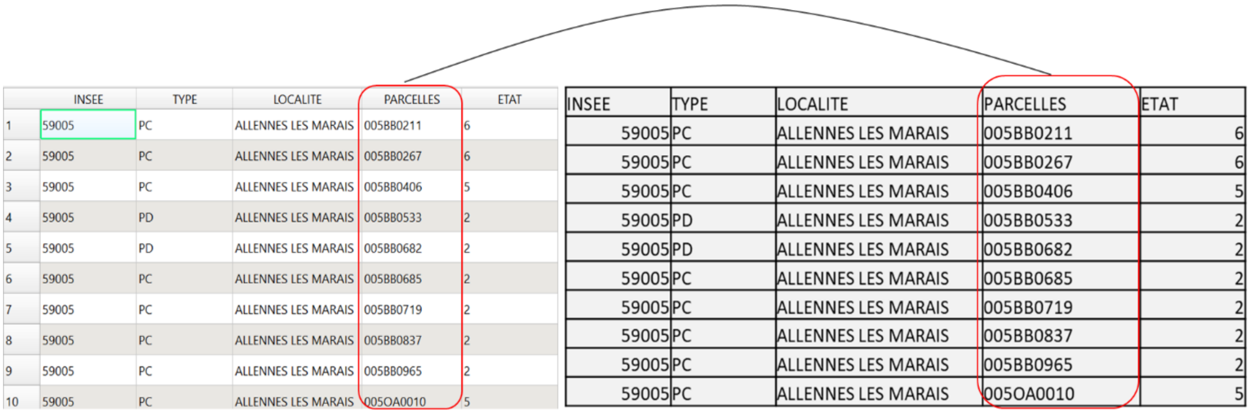
However, it happens that certain cadastral numbers are composed of one, two, or three digits instead of four. In that case, any cadastral number that does not have four digits must be completed (preceded) by 0. Thus, a number cadastral, composed of a number, will be completed by 000, while the one composed of two digits will be preceded by 00. The goal is to replace the number of missing digits with 0s to reach four digits.

Example line 13: 580AB0009 (Figure 4)

Example line 11: 580AD0005 (Figure 5)

Creating the plot identifier is a laborious step, given the large number of entities to be processed (more than 500,000). It requires the application of processes or techniques that allow automatic execution of tasks. The processing was performed in Excel. Several functions (*Replace*; Substitute) have made it possible to automatically delete or insert characters or digits. These functions were used, for example, for deleting the first two digits

(59350) from municipality codes and for inserting missing values of cadastral numbers in building and demolition permit files. Figure 6 shows an overview of the final rendering of the two datasets after harmonization.



	INSEE	TYPE	LOCALITE	PARCELLES	ETAT
1	59005	PC	ALLENNES LES MARAIS	005BB0211	6
2	59005	PC	ALLENNES LES MARAIS	005BB0267	6
3	59005	PC	ALLENNES LES MARAIS	005BB0406	5
4	59005	PD	ALLENNES LES MARAIS	005BB0533	2
5	59005	PD	ALLENNES LES MARAIS	005BB0682	2
6	59005	PC	ALLENNES LES MARAIS	005BB0685	2
7	59005	PC	ALLENNES LES MARAIS	005BB0719	2
8	59005	PC	ALLENNES LES MARAIS	005BB0837	2
9	59005	PC	ALLENNES LES MARAIS	005BB0965	2
10	59005	PC	ALLENNES LES MARAIS	005OA0010	5

INSEE	TYPE	LOCALITE	PARCELLES	ETAT
59005	PC	ALLENNES LES MARAIS	005BB0211	6
59005	PC	ALLENNES LES MARAIS	005BB0267	6
59005	PC	ALLENNES LES MARAIS	005BB0406	5
59005	PD	ALLENNES LES MARAIS	005BB0533	2
59005	PD	ALLENNES LES MARAIS	005BB0682	2
59005	PC	ALLENNES LES MARAIS	005BB0685	2
59005	PC	ALLENNES LES MARAIS	005BB0719	2
59005	PC	ALLENNES LES MARAIS	005BB0837	2
59005	PC	ALLENNES LES MARAIS	005BB0965	2
59005	PC	ALLENNES LES MARAIS	005OA0010	5

Figure 6. Attribute data final rendering of the two files after harmonization and creation of an attribute column common for the two tables.

It is now possible to use this created field (the plot identifier) to operate the data cross-referencing and carry out the spatial analysis. The spatial crossings are carried out after harmonizing the files.

- Crossing of data sets

Geospatial crosses are made between the different datasets. First, the vector files of buildings, plots, and urban fabrics were combined to obtain a single layer. Each building was attached to the plot and to the urban fabric to which it belongs via a spatial join (or by location). This join does not require attributes common to the files. The spatial intersection is performed by an algorithm (in the Qgis interface) that takes an input vector layer and creates a new one, which is an extended version with additional attributes. Additional attributes and values are extracted from a second vector layer. A spatial criterion (intersection, overlap, crossing, interior, content, etc.) is applied to select the values of the second layer, which are added to each element of the first layer to obtain a new resulting layer. At the end of this process, a new enriched GIS layer is obtained, in which each building is attached to a plot and an urban fabric. Since several tasks are repetitive, a Builder model (the processing chain modeler) is created. It allows to automatically perform a chain of processing (tasks) on GIS layers. This saves time on repetitive tasks. The Builder pattern helps us automate tasks by series of operations so that the authors can perform them in one step. This allows the creation of workflows that are reproducible for data processing. The Processing Modeler GUI does not require any coding knowledge to implement the functions. It allowed us to perform the following tasks: fix the geometry, cut/merge/intersection or symmetric difference, and join.

A second type of data crossing is carried out between the GIS layer obtained and the text files containing the demolition and building permit data. This is the join by attribute, which requires having attributes common to two layers. This crossing consists of joining the attributes according to the values of the fields. The algorithm takes an input vector layer and creates a new layer with additional attributes. The additional attributes and their values are extracted from a second layer (file) from a field common to both layers. The purpose of joining attributes is to identify which buildings and/or urban fabrics each demolition and construction permit belongs to. Thus, the C&D data are attached to the GIS layer of plots and fabrics by a column of attributes common to the two layers, in this case, the plot identifier. At the end of this process, authors obtain an enriched final GIS layer, which makes it possible to geolocate or identify C&D permits according to urban fabrics, by year, and by municipality.

3. Results and Analysis

3.1. Understand the Organization of C&D Databases

The Figure 7 shows in detail the organization of the construction and demolition databases. It is characterized by the simplicity and complexity of demolition and construction comics, respectively. The building permit database can be confusing due to its data complexity and organization. To understand the data organization, there is a need to analyze the dictionaries of attributes for each database and contact Sitadel's technical department in charge of setting up the C&D databases.

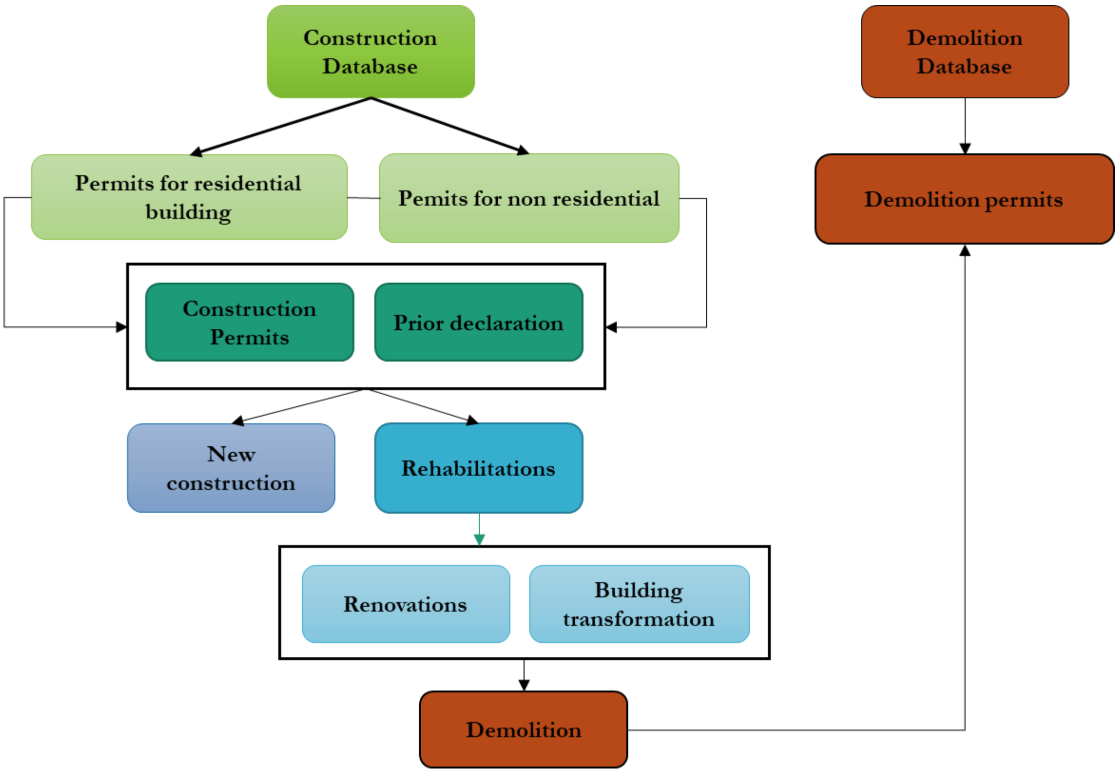


Figure 7. Organization of C&D databases, Cédric Mpié Simba, 2022.

It is worth noting that the building permits contain a major part of the demolition data, which includes the construction projects requiring prior demolition (rehabilitation). This assertion is validated by the remarks gathered during the interview with the agents of the Sitadel service. The interview provided the following three main information pieces that allow us to understand the organization and quality of the data:

1. "You should know that the majority of demolitions occur in building permits (also worth demolition permits) and that Sitadel's collection services check building rather than demolition permits".
2. "The number of housing units and the surface area demolished appear in the open data building permit files. The number of demolished dwellings does not appear in the demolition permit files currently available online but could possibly be added to it, even if it is rarely filled out".
3. "The demolition permit forms do not contain the area demolished, only the mention "total demolition" or "partial demolition" and the number of dwellings possibly demolished. Sitadel only asks town halls for the number of homes demolished".

It is, therefore, understandable that construction data is of better quality and much more complete than demolition data. However, not all demolition data is included in the construction DB. Not all data in the demolition DB contains surface data. All these parameters must be considered for the determination of the actual workforce of each database.

3.1.1. Overview of the Number of Building and Demolition Permits Granted from 2013 to 2022

The monitoring of the allocation of permits was performed on a metropolitan (or regional) scale for monitoring the dynamics as a whole and on a fine scale (municipal or local) to compare the dynamics between the different territories that make up the MEL. From January 2013 to April 2022, 21,261 C&D permits (19,073 buildings and 2188 demolition permits) have been recorded in all metropolitan areas of France. Unlike the demolition permits, the construction database includes the building permits and prior declarations, which contain the underlying information on new constructions and rehabilitations. The 19,073 permits included 9670, 7192, and 2210 new construction, renovation, and prior declaration sites, respectively (Figure 8a). The data shows a large gap between the number of permits granted to construction and demolition sites. Therefore, the data does not reflect the real weight of demolition sites in the MEL.

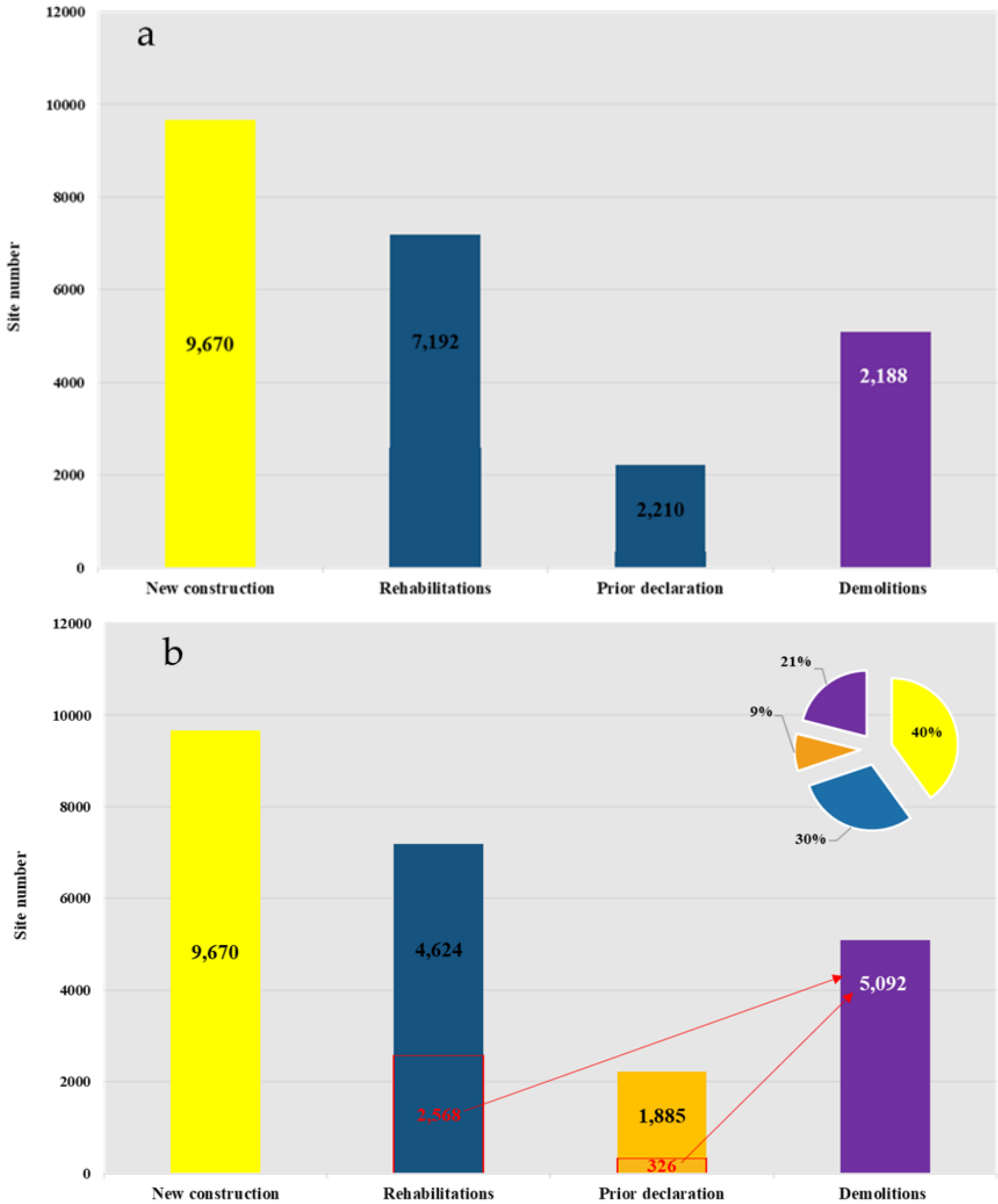


Figure 8. C&D permits numbers by type of worksite. (**a**) worksite number before extraction of demolition data; (**b**) number of demolition permits after treatment. In red are the demolitions identified in the sub-categories. The total number of demolitions takes into account demolition sites resulting from rehabilitation and prior declarations.

An in-depth analysis of the construction database highlighted the undervaluation of the number of demolition permits. However, it is possible to extract the demolition information contained in the construction database. In other words, the construction database also contains demolition data. Three scenarios arise, namely, new constructions (no demolition), construction renovations (demolition or deconstruction), and building transformations (change of destination). Apart from new construction scenarios, all other built surfaces have previously been totally or partially demolished or deconstructed. However, for sites prior to construction demolition, the application is registered and granted as a building permit only, but not as a demolition permit. Only the demolished surfaces are declared in the form (cerfa). This explains the significant difference between the numbers of permits in the two databases. To be exhaustive, it is necessary to consider the demolition workforce contained in the construction database. Therefore, the two subtypes of building permits are differentiated as with and without demolition to record demolished surface data. Figure 8b shows demolition permits with 2568 rehabilitations and 4624 transformations and prior declarations with 326 demolition sites. In the construction database, 2904 construction sites were identified as requiring prior demolition. These are added to the demolition comic, which brings the total number of demolition sites to 5092 (2188 +2904) (Figure 8b).

The building permit database defines a complex set of relationships. To understand this complexity and identify construction sites with prior demolition, the attribute data of the building permit database is analyzed. Four indicators (attributes) in this database make it possible to carry out this analysis, namely, living area or premises before the works, living area or premise created, living area or the premises resulting from the transformation, and living area or the premises demolished. This analysis shows that the permit is intended for the construction of a new building or premises (example line 2 Table 3) when the living space or premises before the work are nil (=0). Moreover, the permit is granted for the transformation of an existing building and requires prior deconstruction (Example: line 6, Table 3) when the living area or premises before the work are positive (290 m^2). The transformation designates the functionality change of the building, which is the modification of a residential surface into a local business office and vice versa. Under these conditions, the permit will have a positive surface area value before works (e.g., m^2 line 1 Table 3) and a living area before zero work (=0). In other words, 213 m^2 of premises have been transformed into living space. This analysis allowed us to retrace the history or trajectories of each building. It also allowed the identification of sub-categories or construction sites (new construction, rehabilitation, etc.).

Table 3. Overview of the attributes used to identify the different worksites in the construction database.

	SURF_HAB_AVANT	SURF_HAB_CREEE	SURF_HAB_ISSUE_TRANSFO	SURF_HAB_DEMOLIE	SURF_HAB_TRANSFORMEE	SURF_LOC_AVANT	SURF_LOC_CREEE	SURF_LOC_ISSUE_TRANSFO	SURF_LOC_DEMOLIE	SURF_LOC_TRANSFORMEE
1	0	0	213	0	0	213	0	0	0	213
2	0	169	0	0	0	0	0	0	0	0
3	0	404	0	0	0	0	0	0	0	0
4	0	124	0	0	0	0	0	0	0	0
5	0	115	0	0	0	0	0	0	0	0
6	290	70	82	0	0	170	0	0	18	82
7	84	132	0	84	0	0	0	0	0	0
8	0	158	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	102,750	0	0	0
10	0	172	0	0	0	0	0	0	0	0
11	0	3519	0	0	0	515	0	0	0	0
12	0	164	0	0	0	0	0	0	0	0
13	70	0	70	0	70	0	0	0	0	0
14	143	18	143	0	143	0	0	0	0	0
15	0	0	145	0	0	145	0	0	0	145
16	0	120	0	0	0	0	0	0	0	0

Notes: In orange, the transformation or change of use sites; in blue, new constructions (on empty plots); in green, renovations.

This introductory sub-section aimed to provide an overall analysis of the number of town planning authorizations by type and to understand the content of the databases of demolition and building permits. It reveals a complex construction data organization. This complexity has a direct influence on the completeness of the actual number of demolition permits. A large part of the demolitions contained in the building permits, which are not identified or listed in the database of demolition sites, was considered and integrated into the overall analysis.

After defining and specifying the number of building and demolition permits, their dynamics in space and time are analyzed. The objective is to highlight the interregional dynamics by analyzing the distribution of the various projects by type, locality, and year. To identify the material deposits, the territories that register the most demolition and construction requests are assumed to have potentially a greater quantity of secondary raw material (stock of reusable materials). The assumption represents the analysis of the first step of MEL territories' geopotential because it helps in the census or the identification of the territories with a high potential of deposits resulting from building deconstruction.

3.1.2. Spatiotemporal Dynamics of Building and Demolition Permits between 2013 and 2022

The overall allocation of C&D permits is currently 21,261 sites based on Sitadel extracted data from January 2013 to April 2022. The new constructions, rehabilitations, and prior declarations represent 70% of authorizations. On the other hand, the demolition sites represent 30% of authorizations, including sites resulting from the construction of comic strips. The analysis of the dynamics of C&D projects involves their spatialization and their identification by urban fabric type. The spatialization purpose is to observe the permit allocation rates by locality while their urban fabric identification provides information on those with strong demolition and construction demands. This analysis is also performed by locality and year. It enables us to trace in time and space the number of authorization disputes by fabric type. This analysis constitutes the basic element for estimating available MEL waste quantity. This estimate involves establishing a link between the building type and its materials. Thus, to quantify waste, the analysis must determine for each permit type the corresponding surfaces and their percentage with respect to MEL building stock. The analysis of the spatial distribution of C&D permits was carried out by cross-referencing building data with building and demolition permit files. Each C&D permit has thus been assigned to the municipality, building, and urban fabric to which it belongs. The table below shows the different numbers of permits by municipality and site type.

Subsequently, a spatialization of the results was carried out to support the analysis of territorial dynamics (Figure 9a,b), which makes it possible to spatially represent the various workforces by site type and locality, as shown on the map below. It puts into perspective the localities of interest, which hold the workforce by type of the most important site. This information can be used to fine-tune construction site waste management policies in the building sector and can be combined with urban density analysis. These localities can be considered as having most of the mineral waste.

Several observations can be made here. For most municipalities, the number of building permits is significantly higher than demolition permits (Figure 9a and Table 4). Urbanized localities recorded most of the allocations. The main urban centers of the metropolis (Lille, Roubaix, Tourcoing, Villeneuve-d'Ascq, etc.) are also the most dynamic in terms of demolition, new construction, and rehabilitation. The city of Lille is by far the one with the most sites in all categories, with 1051 new constructions, 860 rehabilitation sites, 532 prior work declarations, and 353 demolition sites. Table 4 presents the details for the other localities. The analysis of demolition and building permits by locality reveals the following major facts:

- There is a correlation between the locality type and the dynamics of requests or permit allocation. In fact, the number of C&D permits decreases with increasing distance away from major urban city centers (Table 4). Peri-urban and/or rural areas are naturally less dynamic than urban areas.

- The territories that have the largest number of building permits also have most of the demolition permits. Many building permits are issued for the transformation of existing premises, which involves deconstruction and demolition. Building permits include new construction and existing building transformation or modification (renovation, extension, etc.).
- New building construction permits are often located in areas with abundant land resources such as peri-urban or under urban sprawl influence, rural with predominantly agricultural character, newly developed neighbourhoods, etc. Moreover, building permits requiring prior demolition are mostly granted in urban areas, where the built environment is very dense.
- There is a correlation between building abundance or stock importance and demolition request numbers. In other words, demolition permit requests are larger in areas with an extensive number of buildings.

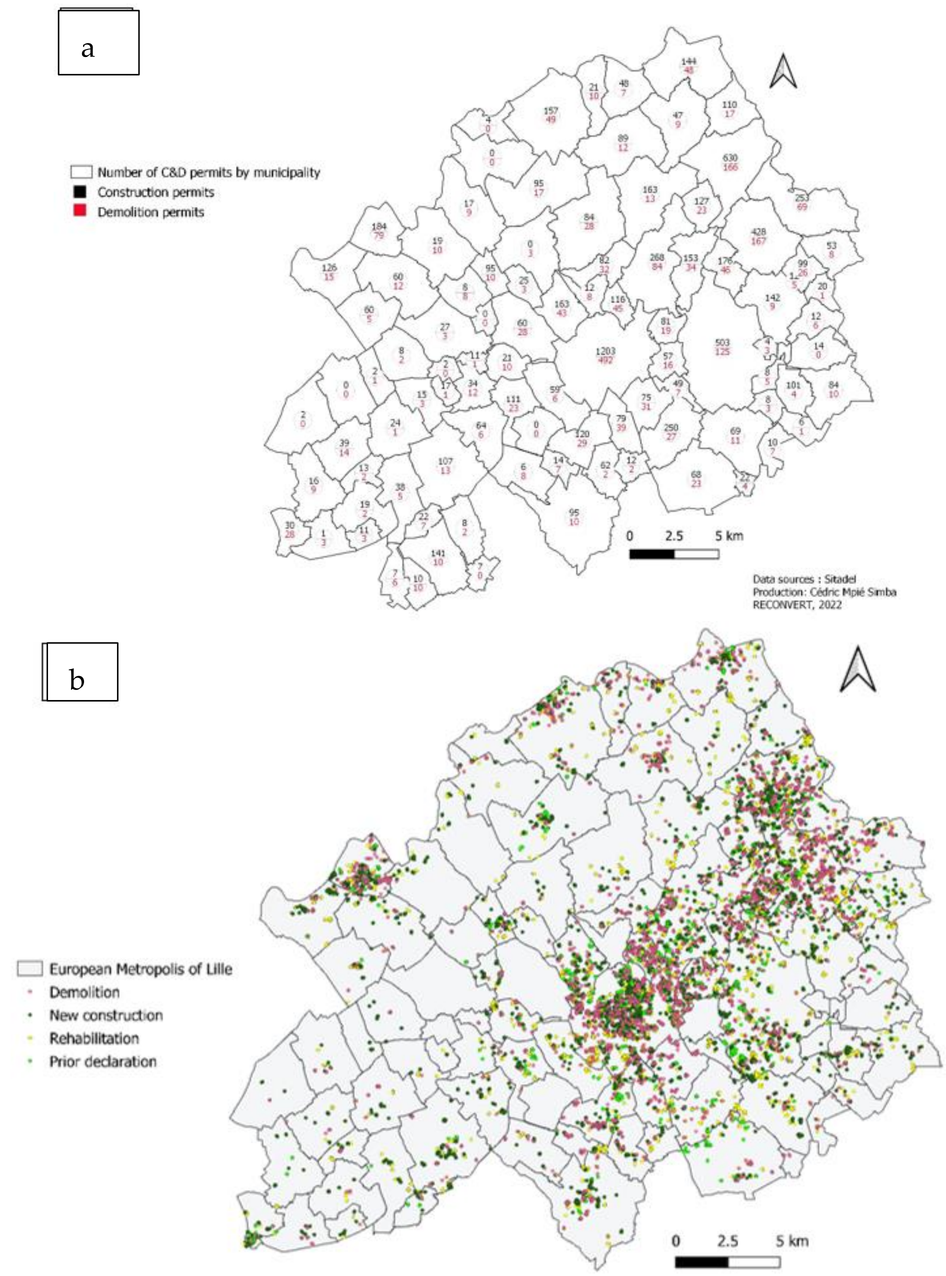


Figure 9. (**a**) C&D permits allocation per municipality; (**b**) Spatial distribution of C&D types.

Table 4. Number of permits by worksite type and municipality.

Communes	New Construction	Rehabilitations	Prior Declaration	Demolitions
Lille	1051	860	523	353
Tourcoing	582	450	178	7
Villeneuve-d'Ascq	445	258	136	17
Roubaix	350	335	107	102
Wattrelos	281	177	62	70
Marcq- En-Baroeul	232	209	93	102
Croix	203	125	50	53
Annœullin	201	113	13	40
Armentières	193	126	100	51
Bondues	175	128	0	60
Lambersart	164	103	50	43
Wasquehal	161	106	29	34
Baisieux	159	91	8	32
Comines	157	107	51	45
Hem	154	95	11	22
La Chapelle d'Armentières	153	111	15	54
Erquinghem-Lys	152	104	15	53
Roncq	143	155	11	58
Wambrechies	143	113	23	142
Houplines	141	67	7	20
Chéreng	135	71	3	20
Halluin	135	121	28	40
Allennes-Les-Marais	131	77	2	39
Wattignies	129	131	30	50
Ronchin	122	45	14	20
Seclin	119	111	26	9
Aubers	118	93	7	57
Faches-Thumesnil	118	92	37	41
Neuville-en-Ferrain	118	43	4	18
Fromelles	114	56	5	28
Mouvaux	113	97	30	49
Wavrin	110	107	16	41
Pérenchies	107	54	11	13
Bois-Grenier	84	40	17	11
Carnin	84	53	3	18
Mons-En-Barœul	84	51	20	26
Deulemont	83	42	4	25
Provin	83	73	10	38
Quesnoy-sur-Deûle	83	65	19	17

Table 4. *Cont.*

Communes	New Construction	Rehabilitations	Prior Declaration	Demolitions
Radinghem-en-Weppes	81	26	2	9
Eringhem	6	7		1
Englos	4	19		9
Prémesques	4	4	7	3
Péronne-En-Mélantois	0	1	0	0
Total	9669	7192	2211	5092

NB: The data in the table have been classified in descending order. Due to the length of the table, it has been truncated. It is presented here for illustrative purposes.

Between 2013 and 2022, the average annual number of building permits (all categories combined) was around 1900. The average annual numbers of the permits for new construction, rehabilitation, preliminary declaration, and demolition were around 1000, 700, 200, and 500, respectively (Figure 10). Whether PCs or PDs, the annual allocation trend remains relatively stable over the entire period except for the year 2018, which recorded a peak in all categories. Moreover, there is a downward trend in the various workforces in 2020, followed by a recovery in 2021. This variation may be linked to the effect of COVID-19, which particularly affected the construction sector. Additionally, the year 2022 data is incomplete. Indeed, the permit data collected covers the 12 months of the year, except 2022, whose data only covers 4 months (January–April). The data from May to December 2022 has not yet been integrated into the Sitadel database. The interannual evolution of the workforce by site type is illustrated in Figure 10 below.

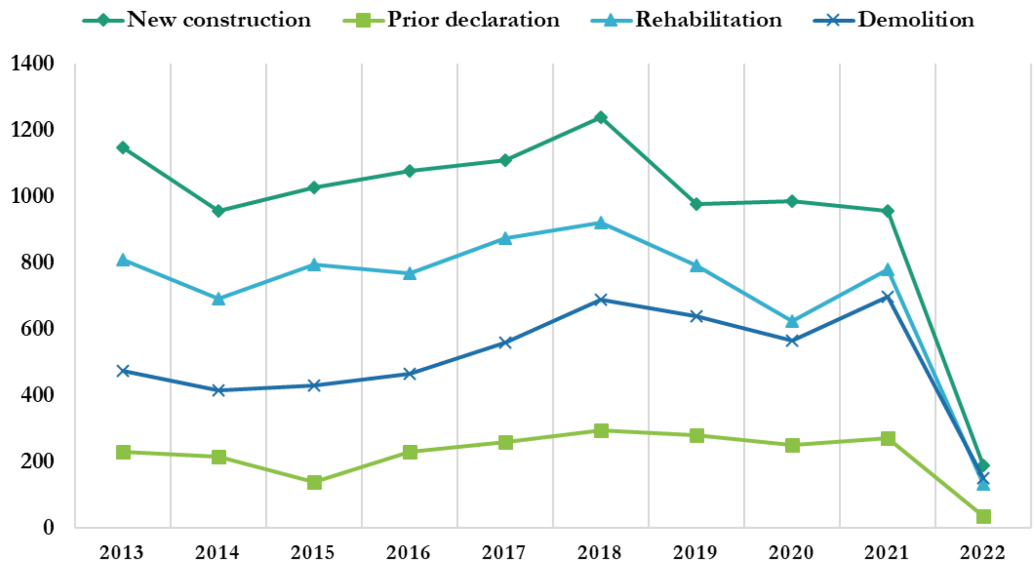


Figure 10. Annual demolition and construction permit numbers.

The data configuration allows for the analysis of the various construction sites according to the building's main use. The analysis is useful if a material typology according to building uses is available. The analysis purpose of the analysis is to highlight the surfaces by site type for residential housing or non-residential premises in the C&D databases. The obtained data is shown in Figure 11.

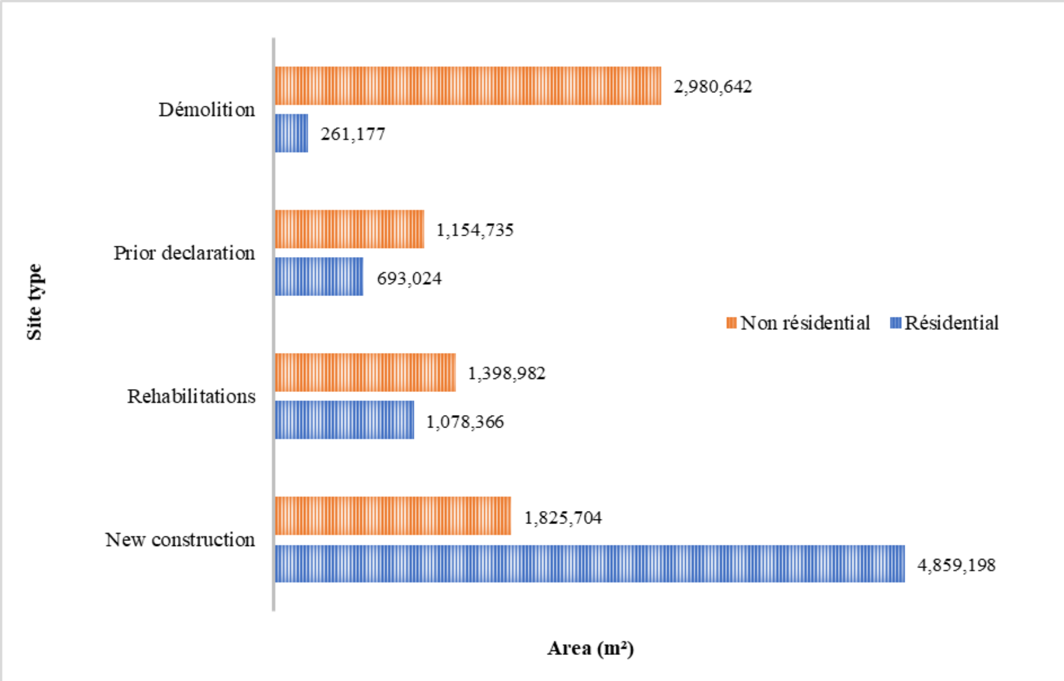


Figure 11. Building total surfaces based on construction site main use type.

The construction and demolition sites occupy an area of 14,251,828 m^2, broken down into 6,891,765 m^2 and 7,360,063 m^2 for residential and non-residential construction sites, respectively. The surfaces of residential and non-residential premises vary according to building site type. For all construction sites, the surfaces of non-residential premises are larger except for new constructions. Residential building demolitions are about 10 times less important than those of non-residential premises. The demolished surfaces for residential and non-residential premises were 261,177 m^2 and 2,980,642 m^2, respectively. The rehabilitation projects have a total surface area of 2,477,348 m^2, broken down into 1,078,366 m^2 and 1,398,982 m^2 for residential and non-residential buildings, respectively. The same is true for the prior declarations, which occupy a total area of 1,847,759 m^2, with 1,154,735 m^2 and 693,024 m^2 for non-residential and residential building sites, respectively. In addition, there is a significant gap between residential and non-residential buildings. The total area of 6,684,902 m^2 with those of non-residential and residential premises are 1,825,704 m^2 and 4,859,198 m^2, respectively. Thus, more new residential buildings are more than non-residential premises on the metropolis scale.

An analysis of the distribution of the various construction sites is carried out by urban fabric type. This approach allows a better understanding of the territorial dynamics and statistics of the work sites. It provides analysis data on the territories' dependence on building products and materials needs and available resources. It is based on the determination of surfaces demolished or built by fabric, municipality, and year. The territories and urban fabrics which have the most demolished or built surface areas are assumed to have significant resources or materials. The typological knowledge of most demolished urban and fabric areas constitutes a first step towards estimating available waste quantity.

3.2. Analysis of the Distribution of Permits by Urban Fabric

The spatial and statistical analysis of C&D permit distribution based on urban fabrics is a groundbreaking endeavor within the European metropolis of Lille («MEL»). To date, there has been a lack of access to specific bibliographical references pertaining to this approach. The primary objective of this analysis is to identify urban fabrics with high demolition demand and those that constitute a significant portion of MEL's built environment (Figure 12).

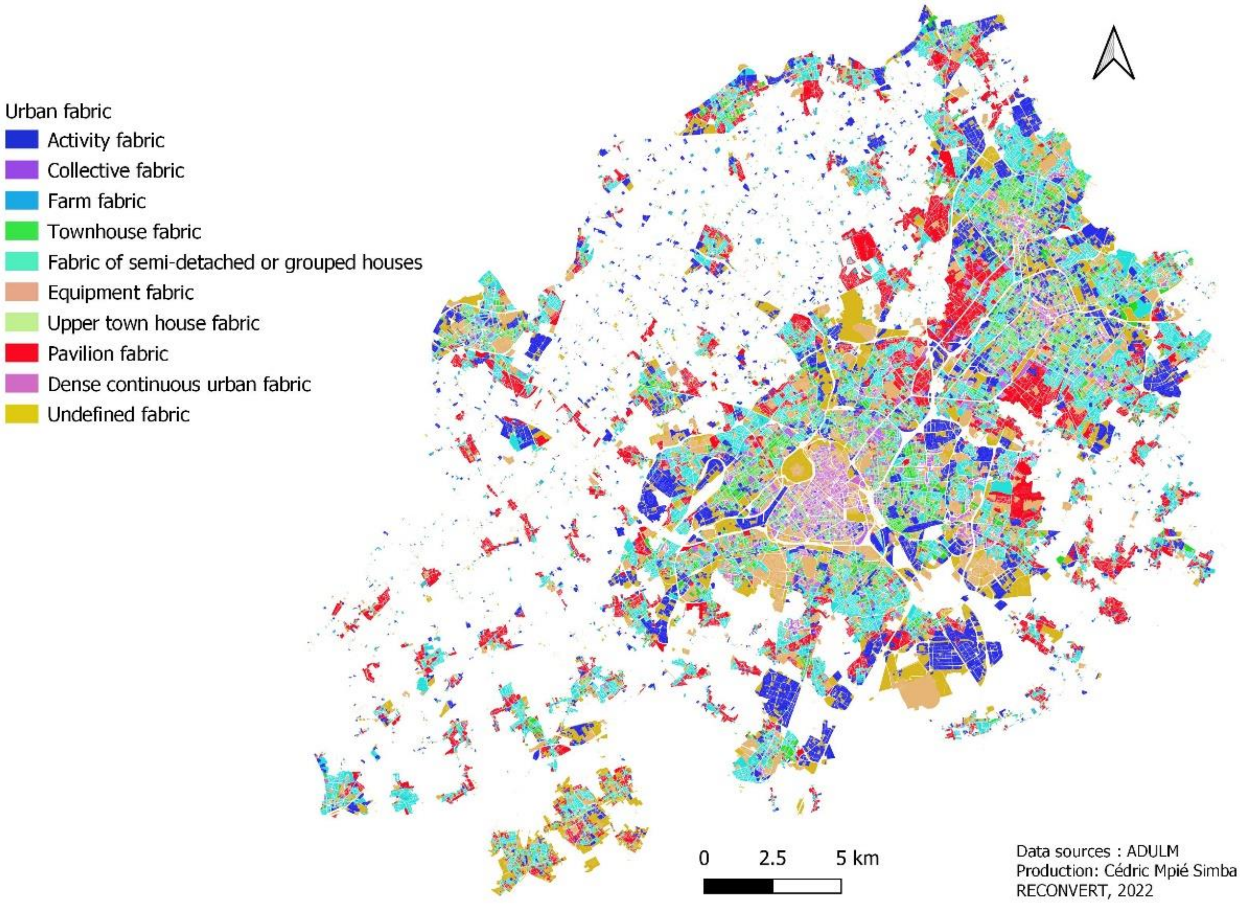


Figure 12. Urban fabrics distribution in the European Metropolis of Lille.

This comprehensive analysis was conducted by locality and year to trace the authorization dispute numbers across different fabric types, both spatially and temporally. It serves as a fundamental tool in estimating the quantity of waste available within the MEL region. Moreover, this estimation process involves establishing a crucial link between the type of building (fabric) and the materials that compose it.

Our analysis successfully identifies nine distinct urban fabrics in MEL, presenting a comprehensive overview of the distribution of C&D permits across the metropolis. These findings contribute significant insights into the spatial trends of demolition demand and the composition of MEL's built environment. However, it is important to note that the incompleteness of the available data limits the scope of our results, particularly concerning territories that remain undefined or inapplicable.

Despite the challenges posed by incomplete data, our analysis marks a critical milestone in understanding the dynamics of C&D permit distribution and its connection to urban fabrics in the MEL. This pioneering effort not only sheds light on previously unexplored aspects but also paves the way for further research and informed decision-making in urban planning and waste management.

Moving forward, the authors aspire to enhance the accuracy and scope of our analysis by incorporating additional data sources and refining our methodologies. By doing so, the authors can continue to contribute valuable insights to the field and support sustainable development practices in the MEL and beyond.

3.2.1. Analysis of the Distribution of Worksites by Urban Fabric

This section is dedicated to the identification of the number of worksites based on urban fabrics within the MEL. This identification process involves a spatial analysis that overlays the urban fabric layer with the layer containing the Construction and Demolition (C&D) permits. Consequently, the authors will present, for each fabric type, the number of construction worksites allocated between the years 2013 and 2022. The primary aim of this analysis is to characterize the distribution of worksites according to the types of buildings present.

In addition to the sheer number of C&D permits per fabric, our focus extends to the area encompassed by each worksite within these fabrics. It is essential to recognize that the number of demolition permits alone does not suffice as an indicator to determine the most impacted fabrics (i.e., those with the highest demolition rates). For a more comprehensive assessment, it becomes necessary to ascertain the extent of demolished areas for each urban fabric and their percentage relative to the entire territory.

Determining the surface areas of each construction site was achieved using information contained within the construction database. However, it is crucial to note that the demolition permits do not include any surface-related data. To address this limitation, the authors calculated the corresponding surface area for each demolition permit. The outcomes of this analysis are presented in Table 5 below, providing valuable insights into the spatial distribution and magnitudes of demolition activities across the various urban fabrics within MEL. The percentages in Table 5 are calculated according to the 50,517,395 m^2 of MEL building surface area.

Table 5. Number of construction site types and their surfaces according to urban fabric.

TISSU	Rehab Nbr	Rehab Area (m^2)	%	NC Nbr	NC Area (m^2)	%	PD Nbr	PD Area (m^2)	%	Demol Nbr	Demol Area (m^2)	%
Farm fabric	186	45,514	0.090	227	130,811	0.259	21	6613	0.013	138	48,614,65	0.096
Pavilion fabric	544	110,471	0.219	1042	767,731	1.520	81	56,857	0.113	323	148,933,59	0.295
Fabric of semi-detached or grouped houses	1594	290,710	0.575	2325	1,823,756	3.610	430	356,530	0.706	1104	566,205,13	1.121
Townhouse fabric	874	162,669	0.322	1604	1,324,486	2.622	335	281,441	0.557	981	340,607,52	0.674
Upper townhouse fabric	163	31,505	0.062	172	156,292	0.309	100	53,130	0.105	145	48,631,21	0.096
Collective fabric	163	27,980	0.055	165	113,743	0.225	273	339,973	0.673	148	121,819,30	0.241
Dense, continuous urban fabric	814	151,683	0.300	396	180,580	0.357	456	350,921	0.695	299	176,423,08	0.349
Equipment fabric	1264	256,649	0.508	1237	710,538	1.407	227	231,363	0.458	730	418,504,84	0.828
Activity fabric	1048	353,548	0.700	1448	921,413	1.824	165	186,084	0.368	685	689,828,44	1.366
Undefined fabric	542	258,485	0.512	1053	559,902	1.108	122	109,514	0.217	539	225,944,69	0.447
TOTAL	7192	1,689,214	3.344	9669	6,689,252	13,241	2210	1,972,426	3.904	5092	2,785,512	5.514

Notes: Rehab: rehabilitations; NC: new constructions; PD: prior declaration; Demol: Demolitions.

Statistical data pertaining to various types of worksites was extracted based on the different urban fabrics. Over the period from 2013 to 2022, the cumulative allocation of all Construction and Demolition (C&D) sites accounted for 1.95% of the total metropolitan area, equivalent to 13,136,404.45 m^2. Further granularity reveals that new constructions comprised approximately 0.99% of the total surface area of MEL, while rehabilitations and prior declarations accounted for 0.25% and 0.29%, respectively. Demolition sites constituted 0.41% of the overall MEL area.

The analysis of worksite distribution according to urban fabrics, along with the determination of their surfaces and spatial locations, holds particular significance in comprehending the underlying dynamics. This detailed examination, to be presented in subsequent sections, offers valuable insights into the diverse types of sites and their respective impacts within the metropolitan area.

- Demolition sites

Throughout the entirety of the study period, a total of 2,785,512.45 m^2, corresponding to 5082 construction sites, underwent demolition in the MEL. This equates to approximately 5.51% of the building stock and a mere 0.41% of the expansive metropolitan territory, which covers an area of 671,900,000 m^2. Analyzing the respective significance of each demolished urban fabric reveals notable disparities when considering the number of construction sites versus their surface area.

Figure 13 and Table 5 offer illustrative examples, indicating that the fabric of semi-detached or grouped houses (with 1104 worksites) and townhouses (with 981 worksites) witnessed the highest number of demolitions. However, in terms of surface area, the fabric of activity (comprising 685 worksites) and equipment (with 730 worksites) covered substantially larger areas. These two fabrics accounted for 24.76% and 15.02%, respectively, in comparison to 20.33% and 12.23% for the former two fabrics, concerning their contribution to the total demolished surface. This pattern holds true across all urban fabrics analyzed.

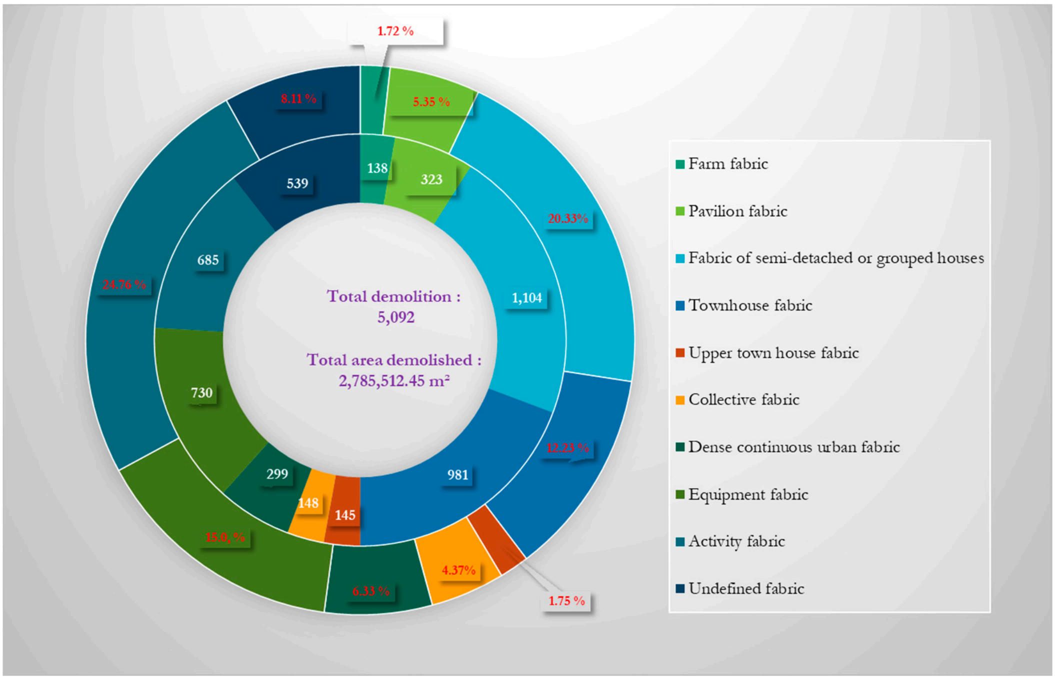


Figure 13. Demolition work site shared by urban fabric.

Notably, the absence of a systematic relationship between the number of demolition permits and the total surface area demolished underscores the critical necessity for precise surface information. While the number of construction sites bears significance, their equivalent in terms of surface area carries decisive importance, particularly for accurate quantification of the deposits resulting from building demolitions. The data on the number of demolition permits categorized by fabric, along with the corresponding surface areas and percentages, is presented in Figure 13 below. The figure presents the distribution of demolition permits by urban fabric, depicted as numbers within the white circle. Additionally, the red circle displays the percentages representing the corresponding areas that have been demolished for each fabric. These percentages are calculated in relation to the total surface area encompassed by the building stock within the MEL.

- Construction Worksites

It is important to note that the building permit database contains three distinct sub-categories. The statistical data within these sub-categories were meticulously analyzed based on their corresponding urban fabrics. In total, these construction worksites cover an area of 10,350,892 m^2, constituting over 20% of all buildings within the MEL. Further comprehensive data for each specific category is presented in the subsequent subsections.

- New Constructions

On a metropolitan scale, new constructions undertaken between 2013 and 2022 represent approximately 13.24% of the building stock. This percentage corresponds to 9669 worksites, covering an extensive area of 6,689,252 m^2. Unlike demolition worksites, there exists a clear correlation between the number of construction permits and the generated surface areas. Urban fabrics with a higher concentration of construction worksites also encompass larger areas. This is notably observed in the grouped house fabric, the townhouse fabric, and the activity fabric, which account for 2325, 1604, and 1448 worksites, respectively. Remarkably, these three categories collectively account for over 50% of the total surface area of new constructions, with proportions of 3.61%, 2.62%, and 1.82%, respectively. Following these are the equipment fabrics and suburban fabrics, covering 1.52% and 1.41% of the constructions within MEL (Figure 14a).

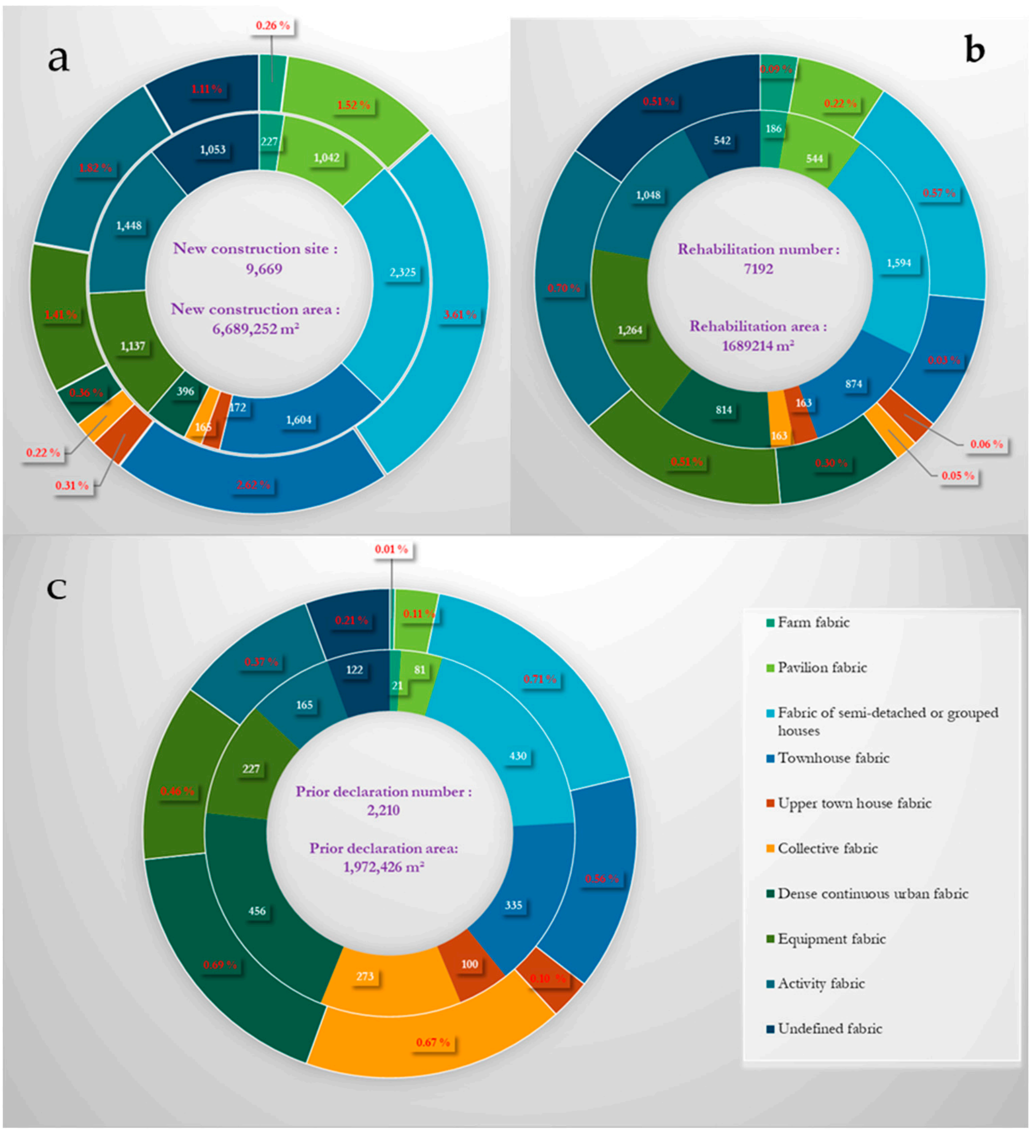


Figure 14. Distribution of Various Construction Worksites by Urban Fabric. (**a**) New construction; (**b**) Rehabilitation; (**c**) Prior declaration.

- Rehabilitation

The second sub-category within the construction database pertains to rehabilitation worksites, which comprise 7192 worksites distributed across nine urban fabrics (or ten if considering undefined fabrics). The distribution of rehabilitation permits based on urban fabric follows a similar pattern observed in demolition sites. Notably, the number of sites per fabric does not consistently correlate with their respective surface areas, resulting in fabrics with high representation not necessarily covering larger areas. Overall, rehabilitations cover nearly three times less space compared to new constructions. The identified 7192 sites occupy an area of 1,689,214 m^2, constituting approximately 3.34% of the buildings in MEL. Among these, the fabrics of semi-detached or grouped houses (1594), equipment (1264), and activity (1048) dominate in terms of the number of permits. Regarding the surface areas, the fabric of activity leads, followed by the fabric of semi-detached houses and equipment (Figure 14b).

- Prior Declaration

Amongst the worksites, prior declarations exhibit the lowest representation in both number and surface area over the 2013–2022 period. They only account for 3.9% of the MEL's building stock. The 2210 listed worksites collectively span an area of nearly 1,972,426 m^2. Three fabrics stand out in terms of the number of permits, namely the dense continuous urban fabric, the grouped house fabric, and the townhouse fabric, with 456, 430, and 335 permits, respectively. Interestingly, these fabrics also cover the largest surfaces, except for the collective fabric. In other cases, the trends align with those observed for new constructions (Figure 14c). In the figure, the distribution of different construction worksites according to their respective urban fabrics is presented. The numbers displayed in white, positioned within the circle, represent the count of worksites or permits categorized by each type of urban fabric. Furthermore, the red circle illustrates the percentages calculated in relation to the total area of buildings within the MEL. These percentages provide valuable insights into the relative spatial coverage of construction activities across various urban fabrics within the study area.

An analysis conducted at a finer scale, specifically by the municipality, has enabled us to unveil the distribution of demolition permits based on urban fabrics. This analysis reveals a significant heterogeneity in the number of permits granted across different urban fabrics in the localities (see Table 6). Overall, the spatial distribution of demolition permits delineates the territory into two distinct segments, each characterized by contrasting dynamics. On the one hand, the authors observe urban territories that record a noteworthy number of demolition requests, and on the other hand, peri-urban territories, predominantly agricultural, where the number of requests remains exceedingly low or even nonexistent, with certain urban fabrics having zero permits. In some localities, merely one or two requests have been filed over the course of a decade (Table 6). Notably, more than half of the localities have witnessed less than 50 demolition permits throughout the entire study period (Table 6).

Table 6. Number of demolition permits by urban fabric according to locality.

	Urban Fabric										
Municipality	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**T9**	**Nd**	**Total**
Lille	-	10	142	92	54	22	189	205	36	21	771
Tourcoing	12	10	82	84	2	3	3	56	61	26	339
Roubaix	-	23	66	78	2	15	3	90	23	24	324
Villeneuve d'Ascq	3	10	91	27	-	-	-	36	59	32	258
Wattrelos	19	-	43	-	-	6	3	12	24	92	200
Marcq-en-Baroeul	7	27	34	45	2	6	1	13	6	19	160

Table 6. *Cont.*

	Urban Fabric										
Municipality	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**T9**	**Nd**	**Total**
Lomme	-	-	14	59	21	16	-	4	33	11	158
La Madeleine	2	9	23	15	-	-	-	24	65	5	143
Armentieres	-	15	20	30	10	-	-	20	37	10	142
Croix	4	22	41	23	5	-	4	-	24	13	136
Halluin	2	10	21	33	2	2	-	16	27	8	121
Comines	11	9	39	8	-	-	-	11	18	2	98
Wasquehal	3	6	16	9	3	-	8	18	11	14	88
Faches-Thumesnil	0	8	22	8	1	-	3	10	15	5	72
Lambersart	1	-	28	14	5	12	-	11	-	-	71
Marquette-Lez-Lille	14	12	28	4	-	-	-	10	3	-	71
Hellemmes	3	5	17	11	-	-	3	19	7	5	70
Wattignies	4	10	13	-	-	-	-	2	24	17	70
Bondues	-	4	5	15	-	14	-	17	5	8	68
Linselles	-	-	5	11	2	1	16	11	6	13	65
Seclin	-	6	5	9	2	3	3	12	23	2	65
Mouvaux	-	-	39	14	-	6	-	1	1	3	64
La Chapelle d'Armentieres	4	15	10	20	2	2	-	-	4	2	59
Erquinghem-Lys	3	-	8	24	3	2	5	-	7	6	58
Roncq	-	13	17	19	-	-	-	-	3	6	58
Wambrechies	-	-	17	15	-	-	6	5	11	4	58
Aubers	-	5	5	13	-	-	-	-	23	11	57
Lys-Lez-Lannoy	-	6	19	15	-	5	-	3	1	1	50
Ronchin	-	3	10	11	-	3	5	2	5	11	50
Sainghin-En-Melantois	-	-	8	7	-	-	-	7	9	18	49
Wervicq-Sud	-	-	-	-	-	4	2	3	15	19	43
Wavrin	9	5	8	-	-	-	-	1	7	11	41
Allennes-les-Marais	-	4	10	9	-	-	-	7	1	9	40
Annoeullin	-	-	3	10	1	7	12	3	-	4	40
Provin	-	-	12	20	2	-	-	-	-	4	38
Fretin	-	2	4	-	-	4	-	6	12	7	35
Baisieux	5	12	-	-	-	-	-	-	10	7	34
Lesquin	-	-	6	19	-	4	-	-	1	4	34
Carnin	-	-	0	3	2	2	5	3	1	2	18
Toufflers	-	-	3	6	-	-	-	-	-	-	9
Le Maisnil	-	-	-	-	-	-	-	8	-	-	8
Beaucamps-Ligny	-	7	-	-	-	-	-	-	-	-	7
Erquinghem-Le-Sec	-	-	-	4	-	-	-	3	-	-	7
Lezennes	-	-	-	-	-	-	2	-	-	5	7
Marquillies	-	-	2	-	-	-	2	-	3	-	7

Table 6. *Cont.*

	Urban Fabric										
Municipality	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**T9**	**Nd**	**Total**
Hantay	-	1		1	4	-	-	-	-	-	6
Pernne-En-Melantois	-	-	-	-	-	-	-	-	1	3	4
Premesques	-	-	2	-	-	-	-	-	-	1	3
Vendeville	-	-	-	3	-	-	-	-	-	-	3
Bouvines	-	-	-	1	-	-	-	-	1	-	2
Ferin	-	-	2	-	-	-	-	-	-	-	2
Hellesmes	-	-	-	1	-	-	-	-	-	-	2
Lannoy	-	-	-	-	1	-	-	1	-	-	2
Tressin	-	-	-	2	-	-	-	-	-	-	2
Eringhem	-	-	-	-	-	-	-	1	-	-	1
Total	138	323	1104	981	145	148	299	730	685	538	5092

Regarding the various municipalities within the metropolis, the urban fabric least affected by demolition and reconstruction is the farm fabric (T1). Between 2013 and 2022, this fabric recorded the lowest number of allocations, primarily observed in predominantly agricultural areas. Conversely, the most demolished and rebuilt urban fabric varies from one locality to another. For instance, in Lille, the number of demolition permits granted by fabric follows, with a few exceptions, a similar pattern observed at the scale of the entire MEL. While each municipality exhibits distinct profiles, fabrics T3, T4, T7, and T8 consistently remain associated with a substantial number of demolition requests across all territories. For a comprehensive overview of the number of demolition permits by fabric in all areas of MEL, refer to Table 6. Due to its length, Table 6 has been truncated for presentation purposes. The values in the table are arranged in descending order, with the highest values appearing at the beginning and the lowest values at the bottom.

The purpose of this comprehensive analysis is to demonstrate the significance of surface data from construction and demolition worksites in comparison to the number of permits issued. Relying solely on the number of permits in a given territory is insufficient for effectively analyzing urban dynamics. Surface data, on the other hand, provides valuable insights into the evolution of urban areas, which are influenced by the dynamics of urbanization resulting from population growth. This growth leads to a substantial consumption of space via construction activities. However, it also offers valuable information on the intensity and consumption patterns of the resulting materials (Babi Almenar et al., 2021).

The statistical data obtained by municipality and urban fabric contributes to spatial analysis and the study of construction and demolition dynamics. This data highlights territories with both weak and strong dynamics and provides essential information on the potential stock of building materials or waste. Construction and demolition activities generate waste, and it is observed that territories with low levels of construction and demolition (hence fewer C&D permits) produce less waste than those with robust dynamics. For example, Table 6 illustrates that the most dynamic urban municipalities in the metropolis (e.g., Lille, Roubaix, Tourcoing, Villeneuve d'Ascq, and Armentières) also have the highest number of C&D permits. Conversely, rural municipalities characterized by low population and building density, such as Eringhem, Tressin, Marquillies, and Pernne-En-Melantois (Table 6), have significantly fewer permit allocations.

This data serves as a knowledge base for understanding the spatial and temporal evolution of construction and demolition sites based on the type of urban fabric and worksite. By utilizing this information, it becomes possible to estimate the degree of constructability and deconstructability for each municipality. Consequently, the data produced can be used to develop methods for quantifying C&D waste. The classification of permits into different types of construction (new construction, rehabilitation, prior declarations, and demolitions) allows for typological monitoring and better consideration and estimation of potential waste deposits. Notably, the production of waste differs depending on the type of site, where rehabilitation and new construction will not generate the same quantities of waste as demolition activities.

3.2.2. Discussion and Perspectives

The primary objective of this article was to generate data for analyzing potential building waste deposits. To achieve this, the authors utilized data from demolition and construction permits. The authors posited that the dynamics of construction and demolition permits serve as an indicator of the waste potential in different territories.

This study serves as an introduction to evaluating the urban mining potential of a territory using the analysis of historical construction and demolition dynamics. The data collected provides a significant wealth of information for this type of analysis, particularly in contexts where data is limited. Importantly, our focus was not on studying waste from buildings but rather on analyzing and preparing the source data necessary to quantify it. Consequently, the expected results here encompass comprehensive knowledge of the content of the C&D databases, the quantification of building and demolition permits by worksite type, their distribution by urban fabric and municipality, and the corresponding surface areas. To achieve this, the authors conducted a spatial and multi-date analysis of construction, rehabilitation, and demolition sites, along with their respective contributions to the entire metropolitan territory.

Initially, the authors undertook an analysis of C&D databases, which enabled us to explain their contents and analyze them based on worksite types (new construction, rehabilitation, prior declarations, and demolitions) and municipalities. It was crucial to integrate data from rehabilitation sites to account for the actual number of demolitions. Subsequently, the authors spatialized the results to represent the different constructions according to their respective localities. However, this analysis encountered a notable loss of C&D data. Some construction and demolition permits could not be spatialized due to the absence of plot identifiers. As a reminder, creating a plot identifier was only feasible for C&D permits with complete cadastral information (municipality code, cadastral number, section number). Unfortunately, several permits lacked this information, making it impossible to link them to specific localities and urban fabric. Moreover, an "undefined" class in the urban fabric layer contained a number of permits, leading to further information loss. Overall, approximately 10% of the total number of construction sites (across all sub-categories) and more than 1500 demolition permits (15% of the total) could not be spatialized, amounting to around 2000 sites in total.

Moreover, extracting data from C&D permits proved to be a challenging task. The plots layer used for overlaying or snapping with the C&D permits file lacked a unique value for each plot, resulting in some plot identifiers appearing more than 20 times, while in our C&D permit files, they appeared only once. As a consequence, cross-referencing these two files led to the multiplication of C&D permits by the number of occurrences of each plot identifier in the join layer. To avoid the issue of duplicate plots, authors first removed duplicates within the QGIS interface and then in Excel. By employing a combination of GIS and Excel, the authors identified and extracted the unique values, refining the results and mitigating the duplication of certain values. The duplication of statistical values is a concern as it has the potential to significantly influence the final results of this analysis, particularly concerning surface areas. To address this, the solution lies in ensuring the quality of the basic data, which necessitates extensive processing before utilization. Nevertheless, despite these data quality challenges, their impact on the overall dynamics and analysis of urban fabric is minimal.

Moving forward, each type of site was analyzed based on the urban fabric and the typology (use) of the buildings. This categorization will be later used to quantify waste by site type. Our hypothesis is that territories exhibiting strong dynamics in demolition, construction, and rehabilitation (in terms of workforce and surface area) are likely to possess greater material stocks and needs, and their distribution by fabric provides insights into the available typology of deposits. Thus, having data on the dynamics of construction, demolition, and building rehabilitation enables an analysis of regional or local production of disposal waste.

The analysis of worksite distribution across various urban fabric types, alongside their corresponding surface area equivalence, provides valuable insights into the typology of deposits available at the territorial scale. By examining this relationship, the authors can infer a connection between the type of urban fabric and the materials comprising them. This analysis sheds light on the localities affected in terms of available resources, contributing to a better understanding of circular economy policies and/or strategies concerning urban metabolism. It also facilitates an initial assessment of urban mining potential by identifying territories with the highest surface areas impacted by demolition and construction activities. These data are crucial for analyzing the territory's dependence on Primary Construction and Building Materials (PMCB) by measuring the gap between construction material needs and resources derived from deconstruction.

To effectively implement national policies aimed at recovering, preventing, and managing waste from the building sector, comprehensive and high-quality data on resources are essential. Therefore, the methodology and treatments outlined in this article represent one of the solutions to this challenge. The processing carried out successfully produced the necessary data, which can be utilized for managing Construction and Demolition (C&D) waste or gaining deeper insights into the waste potential of each territory within the study area.

Undoubtedly, the pre-processing and processing efforts were complex and laborious, but they enabled the extraction and spatial representation of construction and demolition data. Notably, the authors developed a unique plot identifier approach, allowing for the spatial identification of various C&D sites. While this method facilitated the location of different sites, calculating the actual demolished surfaces presented difficulties. Discrepancies arose when comparing surfaces calculated from buildings extracted with plot identifiers to those observed in the field. This disparity was attributed, in part, to the inclusion of new buildings in the database and the ground surface-only consideration of GIS buildings, disregarding the number of floors.

Furthermore, calculating the surfaces of buildings in demolition permits posed challenges as such permits did not contain any surface variable. In contrast to construction permits, which provided actual surface data, authors could only estimate the total area for each demolished building. This estimation considered the floor area and the number of floors or heights, assuming the complete demolition of the entire structure. In an effort to correct potential errors arising from overestimating demolished areas, authors cross-referenced the two site files (constructions and demolition) to identify permits where construction and demolition overlapped. For such cases, authors adopted the construction site values for demolition sites, reducing the margin of error in calculating demolition permit surfaces. Approximately 80% of the real data used in the study are based on real measurements, while the remaining 20% are calculated values".

- Perspective

The data generated presents a novel and authentic knowledge base for analyzing Construction and Demolition (C&D) waste in a significant region of France known as the MEL. This data has the potential to be utilized in various ways, such as quantifying the existing and potential waste stock at different scales. Notably, the Generation Rate Calculation (GRC) method is frequently employed to estimate quantities of C&D waste based on factors like surface areas, building and demolition permits, and population numbers.

The GRC method can be effectively deployed for construction, renovation, and demolition projects spanning multiple scales. Its fundamental principle involves determining the waste production rate for a specific unit area, denoted in units like kg/m^2 or m^3/m^2. This methodology relies on three key parameters:

(a) The multiplier per inhabitant: Calculated based on the average waste production per person (tonnes/year) to estimate the waste stock within a territory.
(b) Financial value extrapolation: Utilizes the financial value of buildings from construction and demolition permits to infer the waste generation rate.
(c) Area-based calculation: Utilizes the total construction or demolition area, gathered from project schedules or government statistical services, to estimate the overall C&D waste generated by multiplying the generation rate with the total area.
(d) In essence, the quantity of demolition waste can be determined by defining the volume generated per unit area of the building and the mass of material per unit volume, drawing insights from previous studies [13,17,20,26].

Consequently, with the aid of these methodologies and others, authors can achieve the following objectives using the previously generated data:

1. Quantify and analyze the urban mining potential of the MEL.
2. Examine the territory's dependency on building products and materials (Stocks, needs, and resources).
3. Analyze the geopotential of each territory by establishing a territorial network of recovery points tailored to individual territories.
4. Enhance the precision of circular economy policies.

Overall, by leveraging the insights obtained from the data, authors can make significant advancements in understanding and managing C&D waste in the MEL region, thereby contributing to sustainable practices and resource optimization.

4. Conclusions

The data from construction and demolition permits represent an untapped potential in both research and waste management policies for buildings in the European Metropolis of Lille. In the global context, where qualified data may be lacking or not disclosed due to various reasons, these open and accessible datasets offer a valuable opportunity to analyze the "waste potential" within a territory, particularly in the absence of PMCD (Post-Material Construction Diagnostics) or waste diagnostics.

Understanding the dynamics of construction and demolition of buildings provides crucial insights into the level of constructability and deconstructibility of territories. These indicators enable a quantitative and spatial analysis of areas with high waste potential. Therefore, monitoring the yearly changes in construction and demolition rates and their spatial distribution yields valuable information about the waste potential of each territory (municipality). Notably, territories such as Lille, Roubaix, Villeneuve d'Ascq, Armentières, Marcq-en Baroeul, etc., characterized by significant construction and demolition activity, are likely to generate higher amounts of waste and vice versa.

Recognizing the importance of quantifying building waste generation as a prerequisite for effective waste management, the data presented in this article can contribute to achieving two primary objectives: firstly, supporting the overall goals of eco-organizations and coordinating entities responsible for the producer's extended responsibility in the building sector (PMCB); and secondly, aligning with the objectives of national policies concerning recovery, prevention, and management of waste from the building sector.

The article demonstrates how data from construction and demolition permits can be effectively utilized to analyze urbanization dynamics and quantify waste arising from demolition and construction activities. By leveraging this valuable information, policymakers and waste management authorities can make informed decisions to foster sustainable waste practices and better address the challenges posed by the building-related waste in the MEL.

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