Spatial exploration of the refurbishment dynamics of urban housing stocks

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Abstract

This study investigates previous refurbishment activities linked to spatial distribution of individual buildings. The work identifies where larger changes has been made (or not), to what extent and in relation to type of ownership. A specific aim is to test selected parameters from the Swedish Property register to analyze refurbishments using the multi-family residential building stock of the city of Gothenburg, 7172 buildings, as an example. The stock has been divided into six age-classes: before 1931, 1931-1945, 1946-1960, 1961-1975, 1976-1990, and 1991-2005. Extensive refurbishment activities were carried out in the stock constructed before 1946. Almost half of the stock has not been refurbished to a larger extent. There is no clear relation between type of ownership and larger refurbishments for the total stock, however the tenant owned stock is less refurbished for the periods covering 1931-1975. The property register is a valuable source for studying major refurbishment activities in lager stocks. Further studies are needed to obtain a more nuanced picture of the refurbishment activities.

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Background

Urban building stocks must be transformed in order to reduce energy and resource use so that climate change mitigation targets can be met as well as to adapt to possible changes in climate. In Europe, building stocks have a low rate of renewal, about 0.5-1.5% per year (BPIE 2011), and a large part of the building stock of today will still exist in 2050. The renewal rate of the Swedish residential stock is among the lowest in Europe with 0.6% (Boverket, 2014). Thus, cost efficient and timely transformation of the existing building stock whilst taking consideration to architectural conditions is a key to reduce energy demand and carbon emissions from the European building stocks and it is therefore important to identify trajectories for the development of existing stocks.

In the last decades improvement of the overall structures of buildings, adaptation for elderly and disabled, social inclusion and energy efficiency measures are partly reasons for initiating a refurbishment. Still, the main reason for refurbishments in Europe are improved housing quality (Baek & Park, 2012). In order to evaluate transformation of the building stock on a urban level to understand the challenges and possibilities associated with refurbishment, incorporating not only general building properties on a national level but also the building in its setting, a local approach is needed. A first step is to learn from previous rates of refurbishment across a range of different buildings considering its spatial distribution.

During the last decades, research on spatial urban building stock has increasingly addressed individual buildings with focus on different aspects, such as general descriptions of stocks (Thuvander 2002), energy use in buildings (e.g. Aksoezen et al 2015; Caputo, et al 2013; Dall'O' et al, 2012, Heiple & Sailor 2008; Mastrucci et al 2014), material stock analysis (Tanikawa, H., Hashimoto, S. 2009), or sustainability assessment (Xu & Coors 2012). Less attentions has been paid to the condition of the stock from a refurbishment perspective, which is an important aspect for the development of building stock transformation strategies.

In Sweden, there are several registers available with attribute data on properties, among others, for buildings a so-called 'value year' is recorded for property taxation. A 'value year' is a calculated age of a building based on 'year of construction' and 'year of refurbishment' (Skatteverket, 2014). It is weighted to the economic extent of refurbishment activities, improvement of standard, and related to the expected remaining life time of a building. These data has been used to study migration patterns in Swedish rental housing connected to refurbishments carried out year 2008-2011 (Boverket 2014). However, these kind of data has not yet been explored as a source to

understand the overall dynamics of building stocks and in relation to larger refurbishment activities on the building level. The aim of the present work is to provide a first step in such analysis, using the multi-family residential building (MF) building stock of the City of Gothenburg as a case.

The work investigates and characterizes previous refurbishment activities linked to the spatial distribution of individual buildings in order to facilitate the understanding, where changes has been made (or not) and to what extent. A more specific aim is to test the suitability of selected parameters from the Swedish Property register to describe and analyze refurbishment activities. The MF building stock and the city of Gothenburg, Sweden, is used for testing. Gothenburg, founded in 1621, is situated in South-Western Sweden and with its about 550 000 inhabitants the second largest city, with about 150 800 buildings.

Method

In this paper the rate and grade/extent of refurbishment activities are calculated for the whole MF building stock in the city of Gothenburg in relation to the age of buildings and type of ownership. The type of ownership and extent of refurbishment is also investigated through spatial analysis. By that, it is possible to identify where to expect buildings with original architecture and from what construction period. This has significance for development of future transformation trajectories. The spatial analysis is carried out in Esri ArcGIS 10.2.

The MF building stock is divided into six age-classes based on the 'year of construction' defined in the following periods: before 1931, 1931-1945, 1946-1960, 1961-1975, 1976-1990, and 1991-2005. The periods represent typical eras in Swedish history from an architectural, technical but also political point of view. For example the period 1946-1960, called 'Folkhemmet' (Peoples home), is the result of a combination of political will and functionalist and modernistic ideals for architecture. This period is also considered the golden era of twentieth-century Swedish architecture with buildings designed to form cohesive neighborhoods, with great care for the quality of the home and a high level of craftsmanship. Similar to that, the period 1961-1975 is part of a period of economic growth, the so-called ´Rekordåren' (record years), and includes a period of extensive construction of residential buildings, one million apartments during a ten year period. At the end of the 1950s and in the beginning of the 1960s construction methods based on craftsmanship were replaced by industrial pre-fabrication. Buildings constructed later than 2006 are excluded as those buildings fall within

the decennial warranty period after construction, i.e. all potential defects after construction must be fixed by the construction company without extra cost for the owner. Thus, it is anticipated that no larger ordinary refurbishments have been carried out in these buildings up to date. As most of the MF buildings in Gothenburg are connected to district heating, we assume no larger changes in the heating systems have been taken place.

The primary attribute input data for the study were 'year of construction', 'value year', and 'year of refurbishment' of the buildings. The 'year of refurbishment' is the year a building has been refurbished to a larger extend or extended.[i]

These data are linked to the building co-ordinates in a georeferenced co-ordinate system. The type of ownership (privately owned, municipally owned, tenant owned) is linked to the administrative districts, which in turn are linked to shape files, i.e. geospatial vector data format for geographic information system (GIS) software, for building footprints.

In order to identify if refurbishment activities have taken place or not, the attribute data 'year of construction' was subtracted from the attribute data 'value year'. The extent of refurbishment was calculated as follow:

(value year – year of construction) / (2014 – year of construction). (1)

The type of ownership data were provided on the district level, i.e. administrative districts in the city on the lowest level of aggregation, called 'basområde' (low level aggregation area). If a district had a dominating ownership type, for example more than 50% was 'tenant owned', the district and all MF building in the district were coded as 'tenant owned' (majority principle). The average figure for the largest group of type of ownership is 94%. For administrative districts where none of the three types of ownerships were more than 50%, all buildings in this district have been coded as 'mixed ownership'.

Data sources and data

Data sources are the

- National Property register from the Swedish mapping, cadastral and land registration authority, Lantmäteriet (National mapping agency),
- Energy Performance Certificates (EPC) stored in a national register managed by the National Board of Housing, Building and Planning (Boverket), and
- Geodata and statistics department of the City of Gothenburg.

From the geodata department GIS shape files were provided and from the statistics department the attribute data for administrative districts and ownership. In turn, Statistics Sweden is the source for Gothenburg city.

From the Property register the part with building information (transfer table 50A REGBYG) is of our interest and specifically the following fields: ID number for the building[ii], property ID, x and y coordinates for the midpoint in the buildings in the local reference system SWEREF99 12 00, type of building (43 different codes available for detailed purpose of use of the building such as single-family or multi-family residential, university, chemical industry, etc.), year of construction, year of refurbishment, and value year. For our purpose, all buildings belonging to the building type "multi-family residential building" (code 33) have been selected for further investigation.

The attribute data 'year of construction' and 'value year' originates for most of the cases from the property taxation. According to the taxation law, a 'value year' cannot be set before year 1929. Initially, the 'year of construction' and 'value year' are the same for a building. Only invested costs for larger refurbishments or extensions of a building can result in a change of the 'value year' (Skatteverket, 2012). The data from the property taxation is determined annually by the Swedish Tax Agency and is made available by Lantmäteriet in the beginning of the following year. For example, year 2013 the taxation results from the 2012 are presented.

For the whole city of Gothenburg, in the Property register a total of 150 804 buildings are recorded (all buildings[iii] with an area about 15 sqm/ 10.8 sqft and more). Out of these, 7 527 buildings are defined as MF buildings, with the newest records dated 28th of February 2014. When removing buildings with 'year of construction' later than 2005, the population of MF buildings is 7 192. Out of this, 1 002 buildings did not have a 'year of construction'. In order to minimize the missing data for 'year of construction', the data set from the Property register was matched with data from the EPC. The matching was based on the property ID and only for properties[iv] with a single building. After matching, the 'year of construction' was modified, i.e. if there was a missing 'year of construction' in the property data but a 'year of construction' in the EPC, the EPC data has been assumed to be the same and added to the property data set. The matching resulted in 20 buildings with a 'year of construction' later than 2005. These buildings were removed from the data set. After the correction, the final population of MF residential buildings was 7 172, of which 410 buildings had a missing value for 'year of construction', figure 1.

In Sweden, there is no other statistics available on the building level. For example, for the housing stock, Statistics Sweden only provides number of apartments or square meters but not number of buildings.

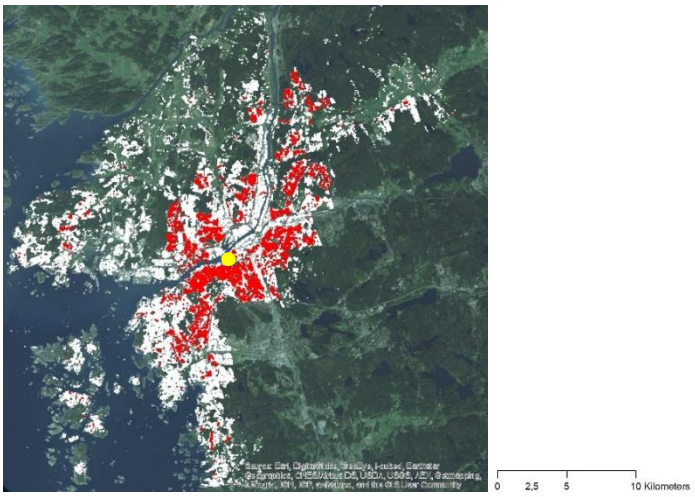

Fig. 1. The spatial distribution of the total multi-family residential building stock in Gothenburg (red dots). The yellow dot marks the city center and the white areas show the total buildings stock in 2014.

Results

The distribution of the MF building stock in different age-classes is rather uniform for the stock constructed before 1976, with around 20% in each period. More than 80% of buildings of the MF residential building stock was constructed before 1975 (table 1).

Table 1. Distribution of multi-family residential building stocks 'year of construction' in age-classes.

Age-class (year of construction)	Number of buildings	% of stock
-1930	1 313	18
1931-1945	1 453	20
1946-1960	1 559	22
1961-1975	1 596	22
1976-1990	330	5
1991-2005	511	7
Missing 'year of construction'	410	6
All	7 172	100

The obtained spatial distribution of the MF building stock per age-class, figure 2, shows that the stock has expanded from the city center outwards up to 1975. After 1975, the MF buildings have been constructed all over the

city, with a certain focus on densification in the city center. Buildings with missing values for 'year of construction', a result of incomplete data registration in the Property register and the EPC, can be found all over the city.

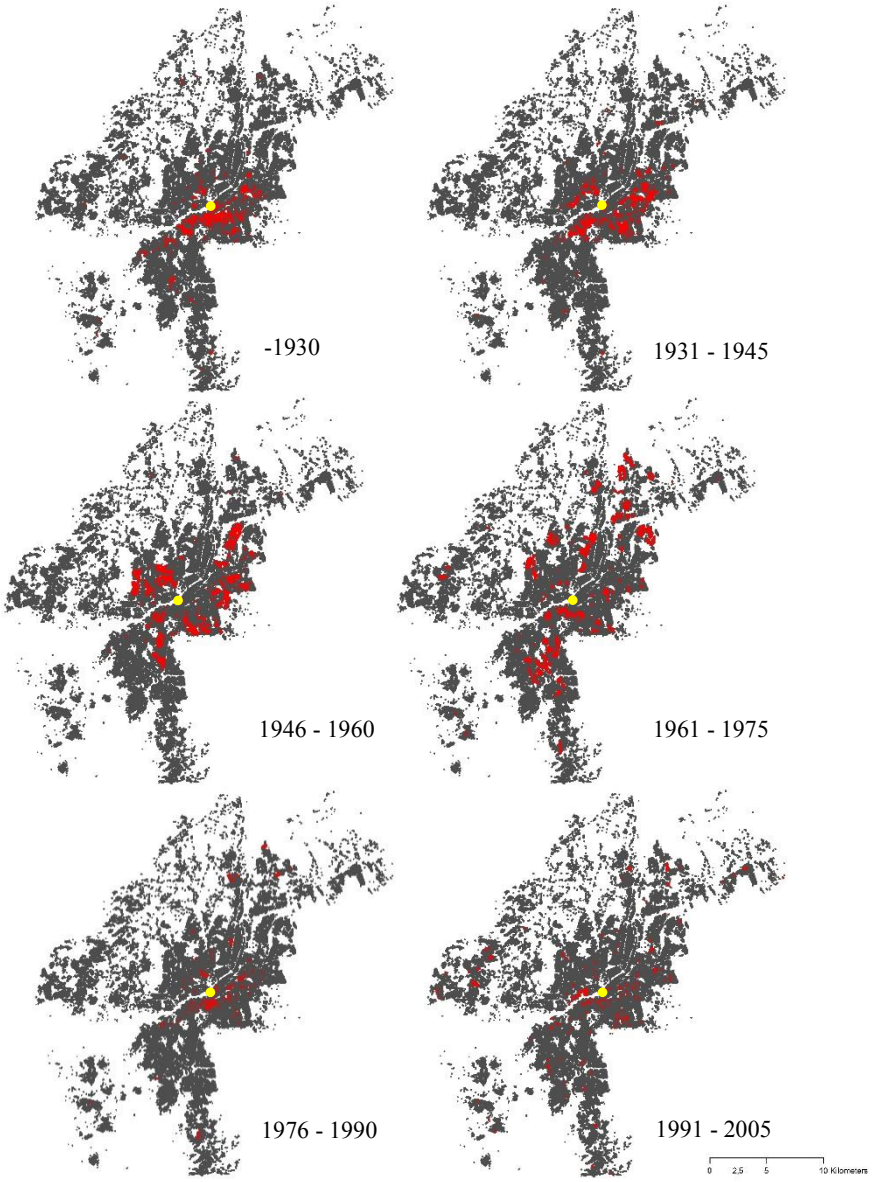

Fig. 2. Spatial distribution of the multi-family residential building stock divided into age classes for 'year of new construction'. The yellow dot marks the city center.

A point density map of the buildings shows that the highest density of multi-family buildings can be found south of the city center and in the eastern part of the city, figure 3.

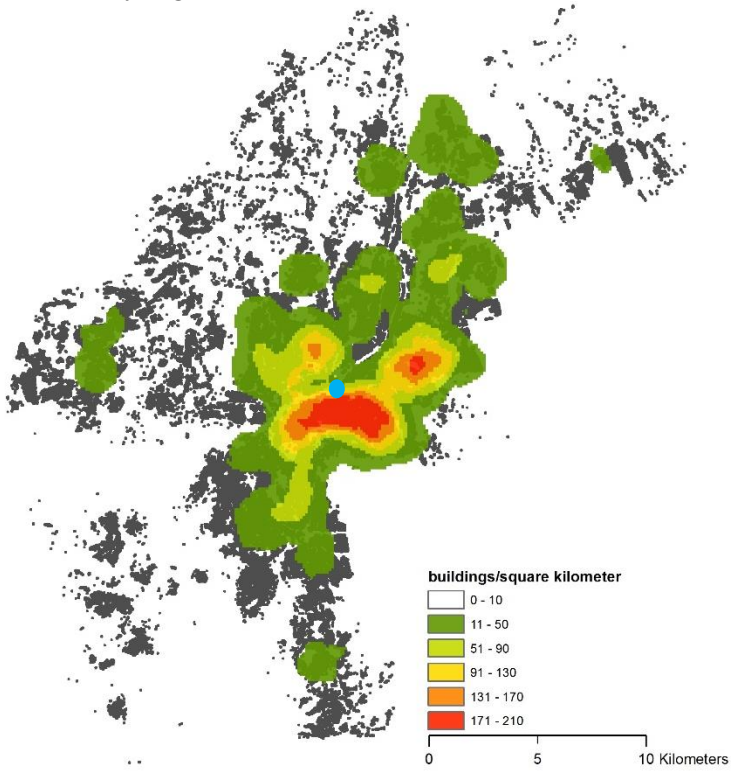

Fig. 3. Point density map (grid based) for the total multi-family residential building stock. The light-blue dot marks the city center.

While 38 % of the buildings were built prior to 1946, only 11% of the buildings have a 'value year' corresponding to this period, which shows that extensive refurbishment activities have been carried out in the oldest part of the MF residential building stock.

When comparing 'year of construction' and 'value year', it should be noted that for more than 50% of the MF building stock the 'year of construction' is the same as the 'value year' which indicates that those buildings have not been refurbished to any larger extent (or not at all). Table 3 shows for each age-class the number of buildings that have a changed 'value year', i.e. buildings with different 'year of construction' and 'value year'. The highest share of refurbished buildings, 81% (1070 buildings), can be found in the age-class before 1931 followed by buildings from the period 1931-1945 with 71% refurbished buildings. Only 45% of the buildings from the

period 1946-1960 have been refurbished, thus more than half of the stock is in need of larger refurbishment. Even less buildings have been refurbished in the period 1961-1975 namely 17%.

The mean value for all MF buildings for 'year of construction´ is year 1952 and 1970 for the 'value year', table 3, a difference of 18 years. This means that the existing stock has been refurbished to such an extent that the expected remaining life-time of the stock is equivalent with a stock constructed 1970. The average for extent of refurbishment for the overall stock is 0.23 and the estimated extent of the refurbishment in the refurbished stock is 0.36, table 3. Interesting to note is that the youngest stock from the period 1991-2005 has a slightly larger extent of refurbishment than the stock from 1976-1990, i.e. 0.10 with 5% of the stock refurbished compared to 0.08 and 2% of the stock refurbished.

The estimated extent of refurbishment of the refurbished stock, shown in table 3, is lower for the buildings from the period 1961-1975 than for the older buildings' periods.

For 777 buildings the 'year of construction' and 'value year' is the same but a 'year of refurbishment' exists, which means that a minor refurbishment has taken place but with no impact on the 'value year'.

Table 3. Mean value for 'year of new construction' and 'value year' and the extent of refurbishment as estimated from this work

Age-class (year of construction)	Nr of buildings	Mean year of construction	Mean value year*	Year of refurbishment exists	Nr of buildings with changed value year	Estimated extent of refurbishment of the stock	Estimated extent of refurbishment of the refurbished stock
Missing year	410	0	1967	8	40	-	-
-1930	1313	1922	1963	522	1070	0.45	0.48
1931-1945	1453	1938	1966	513	1035	0.36	0.49
1946-1960	1559	1952	1966	720	697	0.23	0.47
1961-1975	1596	1968	1972	519	278	0.07	0.36
1976-1990	330	1982	1982	44	6	0.00	0.08
1991-2005	511	1999	1998	22	27	0.00	0.10
Average		1952	1970			0.23	0.36
Total	7172			2348	3153		

Note: The values in the column "estimated extent of refurbishment of the stock" are calculated according to Equation 1, (mean value year – mean year of construction) / (2014 – mean year of construction). *For 410 buildings have a missing 'year of construction' and 888 buildings a missing 'value year' and may explain the lower 'value year' for the stock from 1991-2005.

Table 4 lists the different types of ownership for the buildings investigated related to age-classes. The aggregated percentage of the distribution of ownership, excluding the buildings with missing data for ownership, is rather homogenous, 34% of the MF building stock is privately owned, 32% municipally owned, and 28% tenant owned. However, differences can be seen within the age-classes. Private owners are dominating owners of the stock from the period 1931-1945 and newer stocks from 1991, and tenant ownership is slightly dominating for the oldest stock constructed before 1930. Municipal ownership dominates the periods from 1946-1990, which can be linked to political decisions (subsidies) and the Swedish welfare regime.

Table 4. Type of ownership of the multi-family residential buildings related to age-classes (number of buildings). 20% of the buildings have missing data for ownership.

Age-class (year of construction)	Tenant owned	Municipally owned	Privately owned	Mixed ownership	Missing data for ownership
- 1930	374	203	286	126	324
1931-1945	191	222	590	97	353
1946-1960	393	544	315	75	232
1961-1975	444	601	448	0	103
1976-1990	97	113	87	9	24
1991-2005	90	91	188	11	131
Missing year	30	45	69	12	254
Total	1619	1819	1983	330	1421

Figure 4 shows the spatial distribution of the stock with refurbishment needs. There are no larger differences between the types of ownership. The non-refurbished tenant owned stock is slightly more concentrated to the city center than the private and municipally owned buildings. The private owned stock is slightly more concentrated to the eastern part of the city.

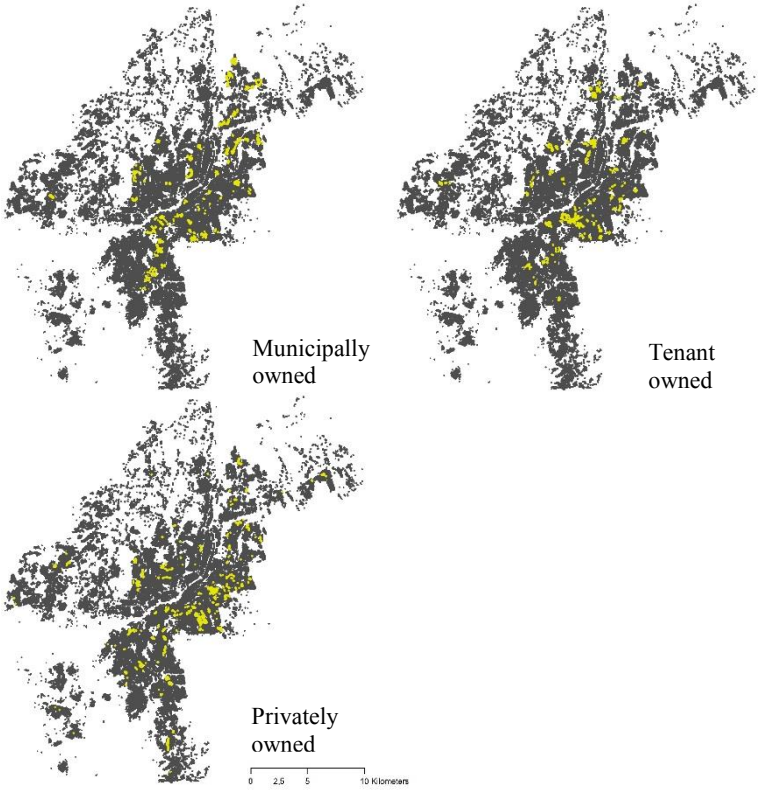

Fig. 4. Spatial distribution of the buildings for different type of ownership for the non-refurbished stock.

Table 5 illustrates the different type of ownership of the buildings with the same 'year of construction' and 'value year', i.e. non-refurbished buildings or buildings with only minor refurbishments. It can be seen that the type of ownership at first glance has not influenced the degree of refurbishment when considering the whole stock. For both the tenant owned and the privately owned stock about 50% have not gone through a larger refurbishment and for the municipally owned stock it is 53%.

A closer look at the type of ownership in relation to the age-classes in table 5, nevertheless shows some interesting differences. To start with, the tenant owned stock is the stock with the highest percentage of non-refurbished buildings for three age-classes covering the years 1931-1975 and especially for the period 1931-1945 with 35% compared to 26% of the private owned stock and 18% for municipally owned buildings. At the same time, a remarkable 54% of the tenant owned stock from the youngest period 1991-

2005 has already been refurbished compared to less than 20% for the municipally and privately owned buildings. Thus, it could be of interest to have an even closer look at this stock.

There is no mixed ownership for the stock constructed in the period of 1961-1975, which mirrors the construction tradition at that period, i.e. large scale housing.

Table 5. Non-refurbished stock/stock with minor refurbishments in relation to type of ownership (number of buildings). Included are buildings where the 'year of construction' and 'value year' are the same. In brackets the percentage of non-refurbished stock/stock with minor refurbishments.

Year of construction	Tenant owned	Municipally owned	Privately owned	Mixed ownership	Missing value
- 1930	17 (5%)	18 (9%)	28 (10%)	14 (11%)	58 (18%)
1931-1945	67 (35%)	41 (18%)	153 (26%)	24 (25%)	79 (22%)
1946-1960	203 (52%)	274 (50%)	140 (44%)	28 (37%)	107 (46%)
1961-1975	366 (82%)	400 (67%)	370 (83%)	0	63 (61%)
1976-1990	93 (96%)	108 (96%)	82 (94%)	7 (78%)	16 (67%)
1991-2005	41 (46%)	80 (88%)	156 (83%)	8 (73%)	81 (62%)
Missing	30	44	63	0	233
Total	817 (50%)	965 (53%)	992 (50%)	81 (25%)	637 (45%)

Figure 5 shows the density of the non-refurbished MF building for the different age-classes. Most of the periods have one to tthree hot spots. The stock from the period 1946-1960 the non-refurbished stock has several hot spots for different locations in the city.

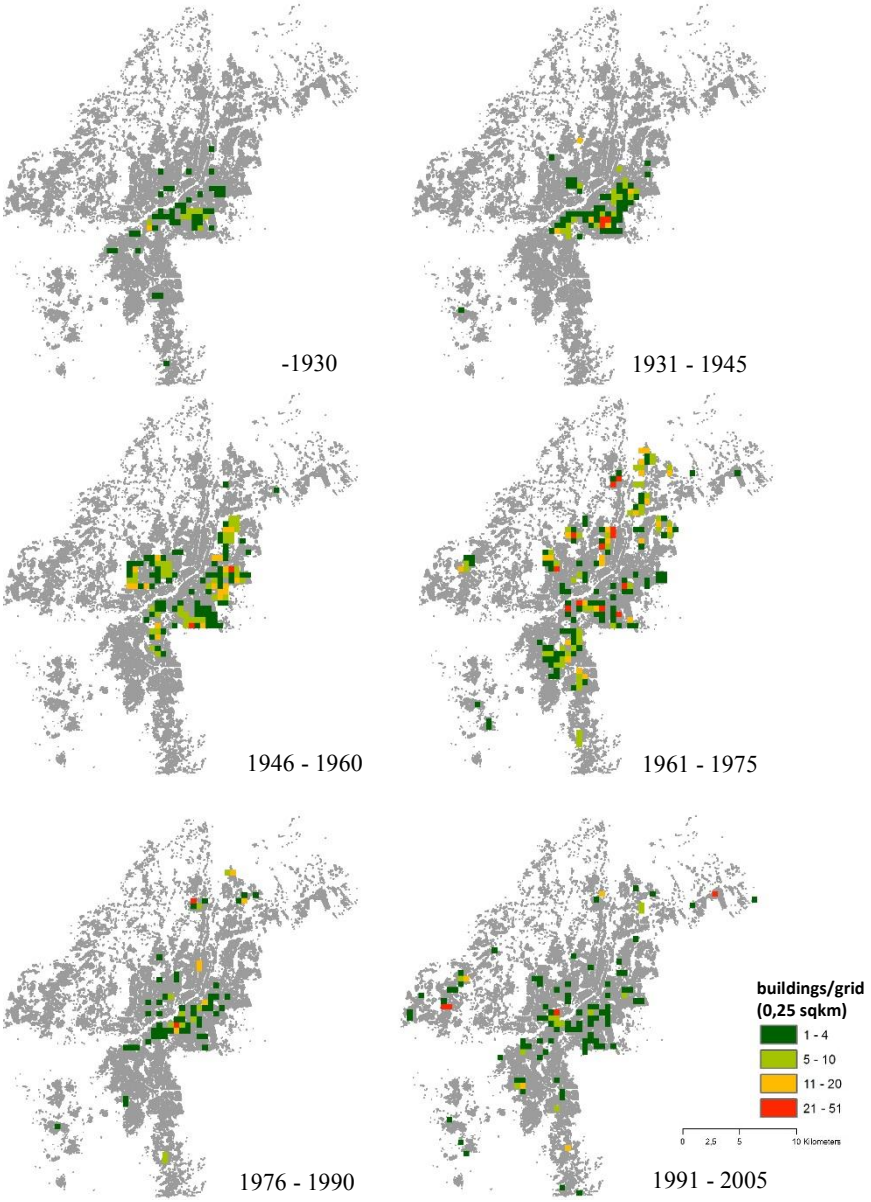

Fig. 5. Density map for the non-refurbished buildings/buildings with minor refurbishments for different age classes. Number of buildings per grid (500m x 500m).

Concluding discussion

In this study the extent of refurbishment activities of the MF building stock of the city of Gothenburg have been assessed divided into six age-classes and related to type of ownership and spatial distributions of the stock. Attribute data have been used such as 'year of construction' and 'value year' from the Swedish Property register, 'type of ownership' from the statistics department of the city of Gothenburg, and spatial data provided by the city of Gothenburg. Data from the EPC has been used for adjustment of the 'year of construction'.

It has been found that the MF building stock of the city of Gothenburg has clearly grown from the center outwards until 1975 whereas buildings from later periods where constructed all over the city leading to a densification of the stock. More than 50% of the MF residential building stock has not been refurbished to any larger extent. The extent of refurbishment is not equally distributed among the different age classes. As expected, the extent is highest for the oldest stock with a decreasing extent the younger the stock. Interesting to note is the very low extent of refurbishment of the stock from the period 1961-1975, a stock which is most frequent addressed in the contemporary refurbishment discussion. We also found that the extent of refurbishment in the already refurbished stock is equally distributed among the age-classes up to 1960 but lower for the buildings from the period 1961-1975. Further, we observed that the type of ownership is equally distributed for the total MF stock, considering both number of owned buildings and spatial distribution, but it is not equally distributed among the different age-classes. Ownership has not much influence on the refurbishment activities when considering the total stock, but differences can be found studying the age classes. Particularly, the tenant owned stock stands out as the less refurbished stock for three age-classes (1931-1975) and paradoxically as the most refurbished stock for the latest period, a period where the refurbishment need should be very low.

Our work can only address the latest type of ownership. However, ownership changes over time and previous refurbishment activities might be carried out by another type of owner. For example, in the last decades municipally owned buildings have been converted into tenant owned buildings. In those cases, our results show refurbishment activities for tenant owned building. Another example is municipally owned housing did not exist before 1945. Having said this, our work gives an overview of the existing situation and is a decent starting point for the development of refurbishment strategies and trajectories for the transformation of building stocks.

The Swedish building regulations have been sharpened during the last years. For example, for major refurbishment activities and altering of buildings that demand a building permit, the same standard as for new construction should be achieved. So far there is no clear definition of what a major refurbishment is and in reality the sharpened regulations are seldom applied or imposed. Thus, in the future we might expect an increased grade/extent of refurbishment.

For buildings constructed before 1930, a frequent 'year of construction' is 1929 which in not always according to reality. Important to note is also that buildings cannot have a 'value year' before 1929. This means, that most of the buildings of the age-class -1930 per se have a different 'year of construction' and 'value year'. This result in a larger extent of refurbishment activities in our data set than it probably is in reality.

Taxation data linked to the Swedish Property register is a valuable source for studying refurbishment activities in lager stock: if larger refurbishment activities have taken place and to what extent. Major refurbishments lead to a changed 'value year' and the presence of a 'refurbishment year' also indicates changes. For future research it is of interest to study what kind of measures can be carried out (what economic dimension) for obtaining a year of refurbishment but still have the same 'value year' and what measures lead the differentiated changes in 'value year'.

In this work, the data for 'type of ownership' with an aggregation on the lowest administrative district level has been allocated to individual building. For most of the cases, the results are in line with reality. Further sensitivity studies are needed to obtain more robust results for the districts with mixed use.

Upcoming refurbishment needs are not only linked to number and age of the buildings but also to the size of the buildings, the number of apartments, the number of people living in the apartments, and the energy use in the buildings. Future work on refurbishment should expand the parameters to describe the composition and state of the stock.

Another topic for further research is if executed refurbishments can be linked to the introduction of policy and subsidies, to type of ownership and to the spatial distribution of the stock. Finally, it would be interesting to study the extent of refurbishments of other cities in general and related to the spatial distribution of buildings and in the same way as in this work in order to get a better overall picture of the refurbishment needs and coming refurbishment activities in the country.

Our results show that more than 80% the MF building stock was constructed before 1975. Considering the low exchange rate of building stock, this means that if 80% of the MF building stock of 2050 already exists today,

about 60% of the future stock 2050 will be composed of buildings constructed before 1975. Since 50% of the MF building stock has not been refurbished yet to a larger extent, we can expect to find original architecture in a large part of the stock. Thus, there are substantial needs for refurbishment but also great potentials to find optimal refurbishment solutions that are advantageous from an energy saving and carbon mitigation perspective and at the same time preserve architectural and cultural historical values.

The research addresses urban planners and urban managers, but also housing mangers benefit. The spatial visualization of the refurbishment activities related to individual buildings support the communication with practitioners in the planning processes and facilitates identification of coming refurbishment needs in an urban context. Our study provides a differentiated picture of past refurbishment activities as a factor that have impact on the urban dynamics of the stock and contributes to methodological development within the field of spatial building stock modeling.

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[i] The Property register only records the year for the latest refurbishment. It is not possible to determine if the building has gone through one or several larger refurbishments.

[ii] In the Property register the part with building information can be found in the transfer table 50A REGBYG. The standardized names for the parameters used in this study are: ID number for the building = RIKSNYCKELID;

REGISTERBYGGNAD, property ID = FASTIGHETSNYCKEL, type of building = BYGGTYP, type of use = TYPBEBYGG.

[iii] A building is defined as follow: Construction works with roof and commonly also walls containing spaces designed for people or animals to inhabit or for storage.

[iv] A property can contain one or more buildings.