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Identifying housing vacancy using data on registered addresses and domestic consumption

Abstract

Housing vacancy is a significant issue in developed countries' decaying and densely populated cities. Comparisons are made between the number of "vacant housing" and "homeless people" stressing the existence of inequalities in access to housing. The reasons for addressing vacancy are manifold, ranging from mitigating urban blight to mobilising latent resources in tight markets. Little attention is paid to vacancy in municipal housing strategies. Still, mapping vacant units appears to be complex and resource-demanding, likely discouraging municipalities from planning further operations against vacancy. Given the lack of methodological support in the literature, this paper discusses how to identify housing vacancy units. Through a case study in Wallonia (Belgium), this paper highlights the benefits of combining visual surveys and processing data provided by utilities and registered addresses. Our results suggest that housing vacancy is underestimated through official statistics and that data mining would help mitigate the administrative burden related to identification and help to prioritise operations designed to reduce housing vacancy.

Keywords: Vacant Housing Identification, Domestic consumption, Registered address, Household-level data, Wallonia

Introduction

The study of housing vacancy is a complex area of research due to variations in the phenomenon across countries and local scales (Huuhka, 2016). The context, both locally and nationally, underlies a variety of issues that require addressing vacancy, as well as a multitude of causes for this vacancy. Therefore, responses must be adapted to each situation. Vacancy can be illustrated through two extremes, reflecting the imbalance of the market, even though the reality of a number of cities lies between these two poles.

Shrinking cities that have experienced a population decline and impoverishment (Couch et al., 2013; Hartt, 2021) are also concerned about housing vacancy. These cities represent a context where the challenge is to mitigate urban blight. In such contexts, reducing the number of vacant housings helps to control adverse environmental effects such as the decreased value of nearby properties (Han, 2014; Lerbs & Teske, 2016), disinvestment by property owners, increased crime and vandalism, and financial losses for municipalities that need to condemn damaged infrastructure and provide security (Glock & Häussermann, 2004).

On the opposite side is the context of a tight market, where it is necessary to address a twofold urban challenge: *(i)* the creation of housing to meet the demand induced by the reduction in household size coupled with continued population growth (Hanin et al., 2012; Ivanova et al., 2021) and *(ii)* the gradual halt to the artificialisation of land and urban sprawl. Indeed, under increasing demand pressure, as in inner Paris, the rents and property values rise, compromising housing affordability (Dittgen, 2005). Concerned with preserving scarce urban green space from construction, Henderson (2015) discusses the potential of vacant housing as reserves for new housing construction within cities. Similarly, Godart et al. (2019) consider the fight against land and property retention as essential to meet urban renewal objectives and zero net land artificialization. In a tight market, property retention is seen as a waste of resources in the face of housing demand exceeding supply (Wyatt, 2008; Han, 2014) or the need for green space in urban areas (Henderson, 2015) and as a considerable potential land reserve for current and future needs (Kohler & Hassler, 2002).

Although there is a strong rationale for adopting local policies dedicated to reducing housing vacancy, municipalities usually lack the information and resources to do so (Priemus, 2011). Calibrating adequate operational strategies at the municipal level while dealing with individual vacancy situations is far from obvious. It first requires quantifying vacancy based on the available data and their quality. Such quantification is especially challenging when the territory does not have a single data set, allowing for reliable mapping of vacant units. The approximate share of vacant housing at the municipal level can easily be estimated through a housing census, but locating individual vacant housing appears to be much more complex from a methodological point of view. Locating individual vacant housing is required for implementing actions such as taxation to reduce vacancy and for monitoring vacancy as part of communities' urban policies. In both the United Kingdom and the United States, the inaccuracy of available data has been acknowledged by governments, relying on the work of local authorities to improve and correct data for their territory (Wyatt, 2008; United States Government Accountability Office, 2011). U.S. local officials confirm a real need for reliable data to identify individual vacant housing and then plan action strategies.

Faced with these observations, the present paper aims to develop an efficient method for identifying individual vacant housing based on disaggregated data at the household level. Through a Belgian case study located in Wallonia, a method based on combining visual surveys and processing data provided on registered addresses and low water and electricity consumption is calibrated and tested. We will evaluate the relevance of an identification method by considering three factors: *(i)* the ease of implementation of the procedure, *(ii)* the share of recorded dwellings found to be effectively unoccupied by the visual field survey, and *(iii)* the ratio of identified vacant housing to the total housing market.

The contribution to the scientific literature is methodological. The main objective is to highlight the benefits of a method which combines a visual survey and the processing of several databases. This approach aims to be transposable in regions with several household-level databases that may indicate vacancy. It is often the case that none of these databases is sufficiently precise on its own but that combining several databases delivers more robust results. For vacancy research, a sub-objective is to support a systematic and reliable evaluation of housing vacancy rates likely to provide high-quality data to robustly study the phenomenon of residential vacancy over time and space. In addition to monitoring vacancy, a practical sub-objective is to relieve the efforts of local authorities to implement operations against vacancy (contacting owners, taxation, etc.).

First, we provide an international overview of housing vacancy concerning the methodological issues related to its definition, its measurement and exploring the operational strategies for action. Secondly, we present the research methodology, and discuss its limitations considering the input data available for the case study and the field verification. Thirdly, the result section estimates vacancy rates in the study area and suggests a phased approach for reducing the burden related to the administrative duties to collect data required to confirm the actual vacancy.

An international overview of housing vacancy

Definition of a vacant dwelling

The literature usually distinguishes two main types of vacancy: structural and frictional. Frictional vacancy represents the short duration between two occupancies, necessary to ensure mobility within the rental stock (Loris et al., 2016) or the reasonable delay for refurbishment. The length of time at which vacancy is said to be structural varies among authors but is generally between six and twelve months (Couch et al., 2013; Huuhka, 2016). While a healthy rate of frictional vacancy is in the range of 3 – 5 % (Gabriel, 1999; Glock & Häussermann, 2004; Molloy, 2016), we note that the total vacancy rate can, in some countries or areas, greatly exceed this percentage and reflect a non-negligible structural vacancy.

Depending on the authors, besides the length of time after which vacancy is structural, the notion of vacancy also varies and there is little explicit agreement on how to define vacancy precisely (Caramaschi and Chiodelli, 2022). According to the latter authors, the academic literature on residential vacancy is composed of three phases which underlie different types of vacancy: *(i)* housing abandonment in declining inner cities of the U.S (Sternlieb et al., 1974), *(ii)* housing vacancy and abandonment in shrinking cities (Keenan et al., 1999; Couch et al., 2013), and *(iii)* vacancy and under-occupancy in neoliberal times (O'Callaghan, 2018). The first phases relate to unfit or unattractive housing in an urban blight context. The last phase captures the excess of a private market run amok escalating in the aftermath of the 2007-2008 Global Financial Crisis (Aalbers, 2008). This phase refers to new forms of vacancy ranging from foreclosed houses (U.S. Government Accountability Office, 2011), unfinished projects (Kitchin et al., 2014), or temporary occupancy (Gentili et al., 2019) to the retention of empty dwellings voluntarily kept away through speculation (Fernandez et al., 2016).

Housing vacancy can thus be declined in a multitude of forms according to the duration (frictional or structural), the state (ruined, abandoned, unfit for habitation, unfinished, etc.) or even according to the frequency of occupation (e.g., second home as under-occupancy). Depending on the context of the territory and the motivations for addressing the vacancy, it is necessary to be aware of these different forms. The definition to be retained depends intrinsically on the objectives pursued. As an example, according to Pagano and Bowman (2000), abandoned dwellings are those that pose a threat in terms of safety or hygiene, whereas the U.S. Government Accountability Office (2011) excludes dwellings in a state of ruin for operational purposes. The inclusion of second homes is relevant when the aim is to mitigate the pressure on the demand (Fitzgerald, 2005).

Identification methods

The methods for identifying vacant housing are varied and not adapted to each country since they strongly depend on available data, its quality, and the survey's main objective, i.e., the quantification or localisation of vacant units.

The first basic method for locating vacant units is visual identification (U.S. Government Accountability Office, 2011), which does not require any database manipulation and is easily implemented by local authorities. However, several major constraints are perceptible: it is a time-consuming method when a large territory must be covered, a method that is difficult to apply to dwellings that are not visible from the public space, such as apartments on upper floors, and a method that contains a certain amount of subjectivity since the exterior appearance of the property influences it. It is also easy for owners to mask the unoccupied appearance of the property by placing curtains and decorations on windows. Similarly, the surveyors may have difficulty judging when few criteria are verifiable, particularly when shutters are down (Lelubre and al., 2015).

An effective method of maintaining residential vacancy rate statistics is through webmail, postal mail or telephone surveys of homeowners (U.S. Government Accountability Office, 2011). For example, in the United States, the American Housing Survey, the Housing Vacancy Survey, and the Decennial Census are three distinct surveys that address housing vacancy (Molloy, 2016). Those surveys are generally much more costly and more concerned with the topic of housing in general. Consequently, they often do not collect data on vacancy duration and they occult strong local variations (Smith et al., 1984; Molloy, 2016).

Administrative data are interesting because they are immediately available to public authorities. In several countries, such as Belgium, Denmark and Finland, registered addresses are the main source of administrative data consulted (Jensen, 2017; Huuhka, 2016). A unit in the building register is considered occupied when at least one person is registered at that address. For this data source to be reliable, it is still necessary to have a strict policy of registration at an address, as in Finland (Huuhka, 2016). These data allow for the analysis of vacancy duration. However, exceptions such as second homes or student accommodation could be counted as vacant.

Similarly, in the United Kingdom, the residential property tax, known as the Council Tax, is a source of administrative data that provides a great deal of information on property occupancy (Wyatt, 2008). This tax, based on the value of the dwelling, is applied to all dwellings. In the specific case of empty units and depending on the situation, there are several classes of reduction or exemption, often limited in time. After a certain period of vacancy, local authorities can double the tax applied to that property to prevent long-term vacancy, introducing the notions of operational strategies that we will develop later. In addition to extracting long-term vacancy, these data allow spatially representing the proportion of vacancy within the housing stock.

As an alternative to administrative data, it is possible to solicit data collected by para-public companies. In the United States, using data from the Postal Services makes it possible to isolate vacancy for more than 90 days, follow the duration of vacancy, and carry out spatial and local analysis (Molloy, 2016). The analysis of domestic water and/or electricity consumption animates research in the United States, in China for rural areas, in Japan, in Ireland, and in Belgium (U.S. Government Accountability Office, 2011; Li et al., 2019; Kumagai et al., 2016; Fitzgerald, 2005; Lemaire et al., 2016). Specifically, a sensitive issue is to define the threshold below which consumption is considered too low to allow occupancy. In Belgium, it is suggested to cross data on water and electricity consumption since the combination of a double low consumption of water and electricity reinforces the suspicion of unoccupancy. In addition to the difficulties of cross-referencing such data, given the discrepancies in addresses between the data from two different service operators, the method proves not to be sufficient on its own, as the proportion of false positives is significant, even in the case of double low consumption (Lemaire, 2015; Lemaire et al., 2016). The identification of some occupied dwellings with a simple low consumption can be explained by the presence of a water tank or photovoltaic panels, by low-consumption lifestyles, by a punctual presence of the inhabitant, or by the temporal delay between the year of registration of low consumption and the year of the data collection (Lemaire, 2015). We also add the hypothesis of precarious housing situations explaining low consumption. Finally, the results obtained will be highly sensitive to the consumption threshold chosen, which must be specific to the local realities of a region (Lemaire et al., 2016).

At last, new families of approaches are the exploitation of open-source social media data of essential facilities (Williams, 2019) and the use of satellite nighttime lighting data coupled with land use information (Wang et al., 2019; Tan et al., 2020; Pan et al., 2020). These approaches are relevant in the face of mass vacancy, as in China, where the vacancy phenomenon reaches rates of an order of magnitude of 20% in the major cities (Tan et al., 2020) and entire neighbourhoods under-occupied. This phenomenon is known as ghost cities and results from high population growth that requires rapid urbanization, but where this urbanisation outpaces demand (Williams et al., 2019). Studying rapidly changing vacancy rates through census and socio-economic statistics is laborious in this context (Wang et al., 2019). The satellite data analysis is relatively accurate compared to pre-existing statistics (Wang et al., 2019), but it has important limitations. While it can identify areas of vacancy and can be implemented regularly, it cannot determine addresses or duration (Pan et al., 2020). The approach is suitable for major cities but not for smaller cities, as the intensity of light radiation is too low (Wang et al., 2019). The low resolution of the satellite data, about 100 m, coupled with spurious light sources such as urban park lighting and road traffic induce inaccuracies that prevent analysis of the vacancy phenomenon at a more precise scale (Tan et al., 2020; Pan et al., 2020). The method of open-source social media data of essential facilities assumes that residents need essential facilities such as shops and schools. Measuring access to these amenities makes it possible to determine whether a neighbourhood is conducive to residential activity or is more likely to be under-occupied (Williams, 2019).

Operational strategies for managing the vacant stock

As introduced earlier, maintaining a database of vacant housing enables both to study the functioning of local markets and apply policies to reduce this vacancy. Such policies may consist of taxation, incentives to real estate owners or even, in some cases, requisition orders. This section offers an overview of strategies and good practices encountered in different countries and discusses the efficiency of such strategies according to the quality of the database on vacant housing.

A first strategy for action, illustrated by the German Stadtumbau Ost program (Glock & Häussermann, 2004; Berndt, 2009), is subsidies provided to municipalities to demolish inadequate vacant housing. In Denmark, despite this subsidy policy, Jensen (2017) observes a lack of a framework for requisitioning properties for demolition and negotiating with owners. While Danish municipalities consider that the demolition of vacant properties has a favourable impact on the price of surrounding properties, this demolition policy remains quite controversial. According to Hacksworth (2016), a demolition policy is insufficient to stabilize the U.S. housing market.

Subsidies can also be granted to authorities to acquire and refurbish vacant housing. This strategy is notably framed by two programmes in Ireland to reinforce the supply of social housing in areas where demand is high (Government of Ireland. Department of Housing, Planning and Local Government, 2018). The Buy and Renew Scheme programme allows local authorities to acquire privately owned vacant dwellings. The Housing Acquisitions Fund is provided to the Housing Agency to target the vacant property portfolios of financial institutions and investment companies. However, this complex procedure is more resource-consuming for local authorities than social housing construction programmes. When the combined cost of purchasing and remediating exceeds the cost of acquiring a good quality property, the procedure can still be relevant by meeting the urban renewal objectives of a neighbourhood.

Other strategies rely on financial incentives to lead owners to address housing vacancy. While the Council Tax in England – which sanctions vacancy after a certain period – is the first form of incentive, both Belgium and France have implemented a tax policy that targets vacant housing. However, it is difficult to fine-tune a single tax system against a phenomenon whose drivers and characteristics vary greatly. When a structural vacancy is due to insufficient demand or the need for heavy work is observed, the taxation of vacant dwellings contributes to limiting the attractiveness of the dwellings for investors, whereas the main issue is to put these properties back on the market. Faced with these observations, Boquet et al. (2016) recommend the introduction of taxation in territories with a tight market, for which the existence of structural vacancies is more often a choice of the owners (rental management tiredness, keeping for a relative, speculation, etc.) than a consequence of a lack of attractiveness. It should also be noted that such a policy requires massive identification of vacant dwellings, monitoring vacancy duration and contact with owners.

Another form of non-repressive incentive is landlord subsidy. These policies are used in Belgium and France, where granting a subsidy is associated with a rent ceiling for a few years to increase the supply of public housing (Lefebvre, 2019; Boquet et al., 2016).

The requisition of vacant housing is another alternative. In Wallonia, the procedure is too cumbersome and, therefore, never initiated. In the United Kingdom, local authorities' management of vacant housing has been encouraged by the Empty Dwelling management orders program. This strategy has several limitations. According to Henderson (2015), it presupposes a lack of interest on the part of landlords, and, because of its interventionist nature, the strategy is usually perceived as a punishment. If it is an alternative to costly acquisitions, the local authority will have to carry out works that will have to be reimbursed by the rent collected over a limited number of years. This strategy does not seem viable when the building has severely deteriorated.

Finally, it is important to recall the benefits of informing and raising awareness among citizens who are sometimes unaware of subsidies or assistance in rental management opportunities (Halleux & Lambotte, 2004). The citizen initiatives described in Denmark by Jensen (2017) reveal that citizens, because they are neutral actors, can play a role as a link between owners and public authorities during acquisition negotiations.

For the acquisition or requisition of property by municipalities, a database of vacant dwellings, coupled with various other socio-economic indicators, would enable municipal authorities to target priority intervention areas as effectively as possible. For a mass strategy such as taxation to be successful, it must be applied systematically to as many vacant dwellings as possible. However, one needs to ensure that this taxation is applied correctly to areas where vacancy is not mainly the result of insufficient demand or the need for heavy work to avoid further reduction of the attractiveness of the dwellings in these areas. A strategy such as an owner subsidy has the advantage of not requiring contact with each owner of vacant units – and thus address-by-address identification of the properties – although such contact is advisable to inform the owners of the existence of subsidies. In any case, knowing the vacancy rates within these territories is necessary.

Materials and Methods

In Wallonia, within which our case study is located, mainly two kinds of databases are available to identify potential vacant housing: the registered address or the domestic consumption of water and electricity. The proposed method relies on field surveys aiming to consolidate vacancy suspicion or reject it. Although this is not very effective for verifying upper floors of multi-family buildings, a visual verification on the field allows a first estimate of vacancy rates. Unlike a survey of owners by mail, visual verification is not biased by the fear of being taxed if they declare the dwelling is not occupied. In this way, for each database, we evaluated the share of dwellings identified for which vacancy seems to be verified (true positives). In parallel, we examined a sample of dwellings taken randomly from the entire housing stock to identify vacant housing that would not have been recorded by any of our databases (false negative). Based on the Walloon legal definition of vacant dwellings, we will consider in this paper vacant dwellings that have been obviously vacant for more than 12 months and have not been used for any activity. The 12-month threshold is intended to capture mainly structural vacancy. It includes, among others, dilapidated housing but rejects second homes. This definition from the legislation is retained as it is relevant to the issues in the area, i.e. mitigating the urban blight and ensuring urban renewal. We first present the case study and the data. Then we detail the visual field verification protocol before discussing the method.

The case study: the municipality of Herstal

The municipality of Herstal is a municipality of the Liège agglomeration with a high level of urbanisation, a high level of facilities, and a standard of living below the average of Walloon municipalities (Statbel, 2018). It has a population of 40,190 inhabitants for a population density of 1,720.6 inhabitants per square kilometre (2021). The housing stock includes 17,704 dwellings. The most represented housing categories are terraced houses, semi-detached houses, and apartments (Statbel, 2020). The percentage of owner-occupied dwellings in Herstal is very close to the Walloon average: 65.4% in Herstal *versus* 65.6% in Wallonia (Census 2011).

The average annual net taxable income per inhabitant is well below the regional average. Poverty is also expressed by the high demand for social housing despite the existing supply. The housing stock includes 1,683 social rental dwellings, i.e., 9.3% of rented social housing in relation to the total housing market (IWEPS, 2020). This percentage is significantly higher than the estimated regional average of 5.3 per cent (Anfrie & Gobert, 2016). However, it is not enough to meet the demand as there are 777 valid applications for social housing at the municipal level. This situation reflects the concentration of impoverished people in centrally located and post-industrial neighbourhoods in Belgium (Lejeune et al., 2016).

Data and sampling

The data are provided at the household level and cover all the addresses of dwellings identified by a lack of registered address or low water consumption, or low electricity consumption in the municipality of Herstal. Cross-referencing the addresses from the lists of the Population Register, the electricity network operator, and the water network operator was a delicate step because it requires an exact match between the addresses identifiers (street name or code, street number and box number) of each list. Incorrectly encoded addresses must be corrected, sometimes manually. For each address processed, we have various additional information: on the one hand, the occurrence of an absence of a registered address and, on the other hand, the occurrence of low consumption of water or electricity, the date of the last recorded domicile, the values of the consumption, and the occurrence of various indicators intrinsic to the lists kept by the municipalities such as the orders of insalubrity, the properties already taxed for vacancy, etc.

Addresses identified by no registered address are those for which no resident was registered by the end of November 2019. It is compulsory for everyone to be registered with an address to control the household's composition and correspondingly calculate a series of tax reductions and access to social security.

The addresses identified by low consumption are those for which water consumption of less than 5 m³ per year or electricity consumption of less than 100 kWh for the year 2019 is recorded. The threshold for electricity is relatively low since gas and oil cover 64% of the energy consumption of Walloon households (Prevedello et al., 2015). The thresholds were defined according to two complementary Walloon studies (Lemaire, 2015; Lemaire et al., 2016). The first study tested the relevance of consumption in identifying unoccupied dwellings. It arbitrarily sets consumption thresholds at 5 m³ for water and 10 kWh for electricity. The second study analysed the relevance of thresholds. The study concluded that beyond a limit of 15 m³ for water and 100 kWh for electricity, the amount of vacancy detected no longer increased significantly, and the number of false positives became too high. Given the high proportion of false positives when it is impossible to exclude dwellings with a water tank, we keep the limit of 5 m³ for water and increase it to 100 kWh for electricity. In doing so, the thresholds correspond to the average consumption of a single person for 30 to 45 days. Since the thresholds are relatively low, this choice is a relevant compromise to exclude second homes while taking into account low consumption related to water leaks or electrical appliances that are kept on.

The data were recorded during 2019, implying that the verification work could, in theory, start in January 2020. However, a time lag, extended due to the conditions of the COVID-19 crisis, was necessary to obtain the data with confidentiality agreements and to cross-reference them. We conducted the visual vacancy verification on the field in March 2021, implying that some vacancy was resolved during the 14 months between data collection and field verification.

We have at our disposal the population of all the housing units identified by a lack of registered address or, at least, water or electricity consumption. The starting population includes 5,199 addresses, representing 29.4% of the housing stock in the municipality. This rate of potentially vacant housing is overestimated since we observe that a significant part of these addresses no longer exists, mainly due to demolitions or mergers of dwellings into one, but which persist in the databases for years.

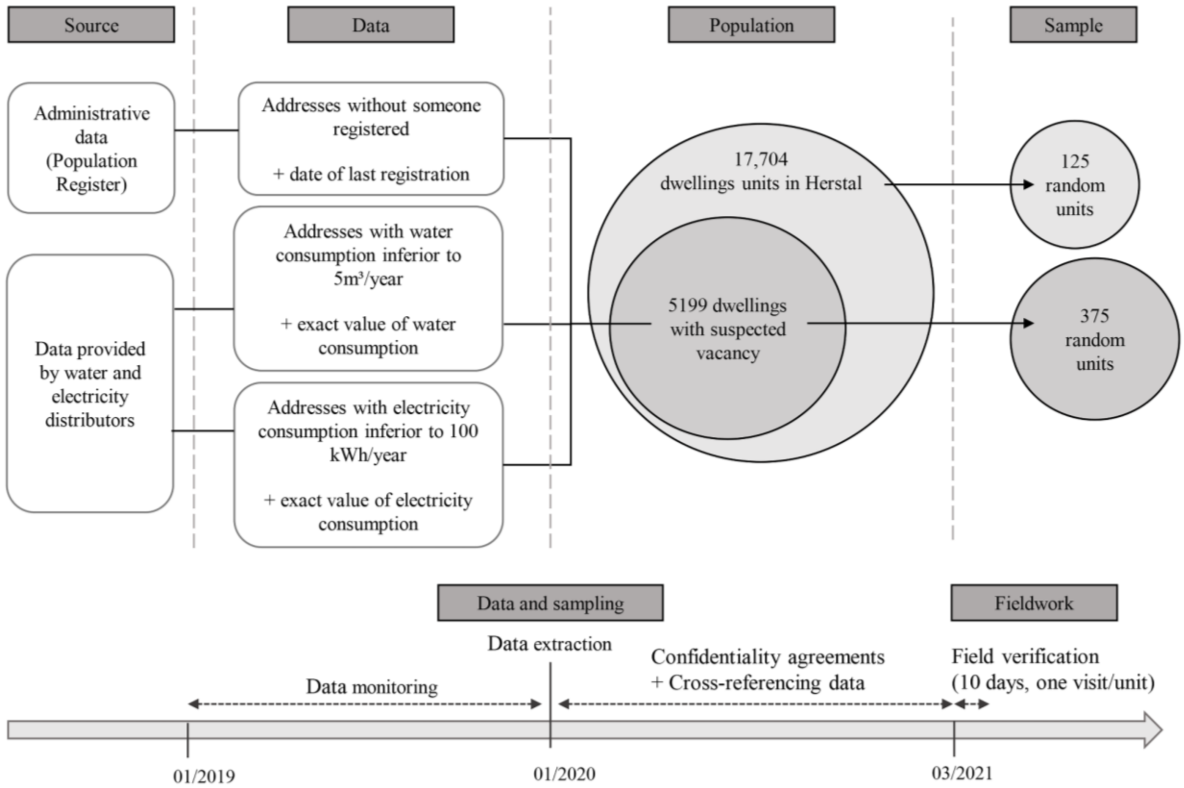

Figure 1. Data, sampling and timeline of the steps

As shown in Figure 1, we used a first sample to analyse the presence of "false positives", i.e., dwellings whose suspected vacancy is not consolidated following visual verification. We determined the sample size *n* using the sample size determination for finite populations formula:

$$n = \frac{N\,Z^2 P(1-P)}{d^2(N-1) + Z^2 P(1-P)}$$

where N = Population Size; Z = Z Statistics for a level of confidence; P = expected proportion; and d = precision.

For the population of 5,199 addresses with a 95 percent confidence level and a 5 per cent margin of error, the random sample must include at least 358 addresses. To be on the safe side, we increased the sample to 375 addresses.

We used a second sample to check for the presence of dwellings that were not identified as potentially vacant but were found to be unoccupied during the visual check; we refer to these as "false negatives". To compose the sample of any dwellings, assuming a population of 17,704 dwellings (Statbel, 2020), we estimated that the probability of observing the factor of interest – namely vacancy – is less than 9%, given the rates suggested by the literature for other Western European countries (Huuhka, 2016). Therefore, again with a 95% confidence interval and a 5% margin of error, we made a random sample of 125 units.

Visual verification protocol

During the field verification, we only consult the address of the dwellings to be verified so as not to be influenced by the different vacancy indicators related to these addresses, such as low consumption or lack of registered addresses. The first step of the protocol is to identify the residential building based on its address. If the address of the building cannot be found, we consider the dwelling neither occupied nor unoccupied; we create a "not applicable" category. When the building is found, we check that it is a building with residential functions. If it is not, the non-residential buildingis again discarded and placed in the "not applicable" category.

When the housing unit is identified, we check for occupancy and vacancy criteria during a single visit. If we meet only one occupancy criteria, the unit is automatically classified as "occupied". The 2021 COVID-19 crisis conditions were favourable to us as more people were in their homes, which increased our chances of observing a sign of occupancy during the few minutes we spent in front of the property. These criteria are a human or animal presence, a car parked in a space reserved for the dwelling, a light on or an open window.

Next, we check the vacancy criteria and consider that at least two of them must be verified to classify the unit as "vacant". These criteria are the absence of names on the doorbell, the absence of a mailbox, the accumulation of mail, the lack of maintenance of the building, the presence of condemned or broken windows or door on the front facade, the absence of furniture inside, the absence of curtains on the windows, and a derelict front yard. If two criteria are not met, we conclude in favour of occupied housing.

In some cases, we could not verify the criteria because of a lack of visibility or because the housing unit is not identified within a building. When two or more criteria cannot be verified, we consider the visual verification method to be inconclusive. In this case, we classify the dwelling as “non-conclusive”.

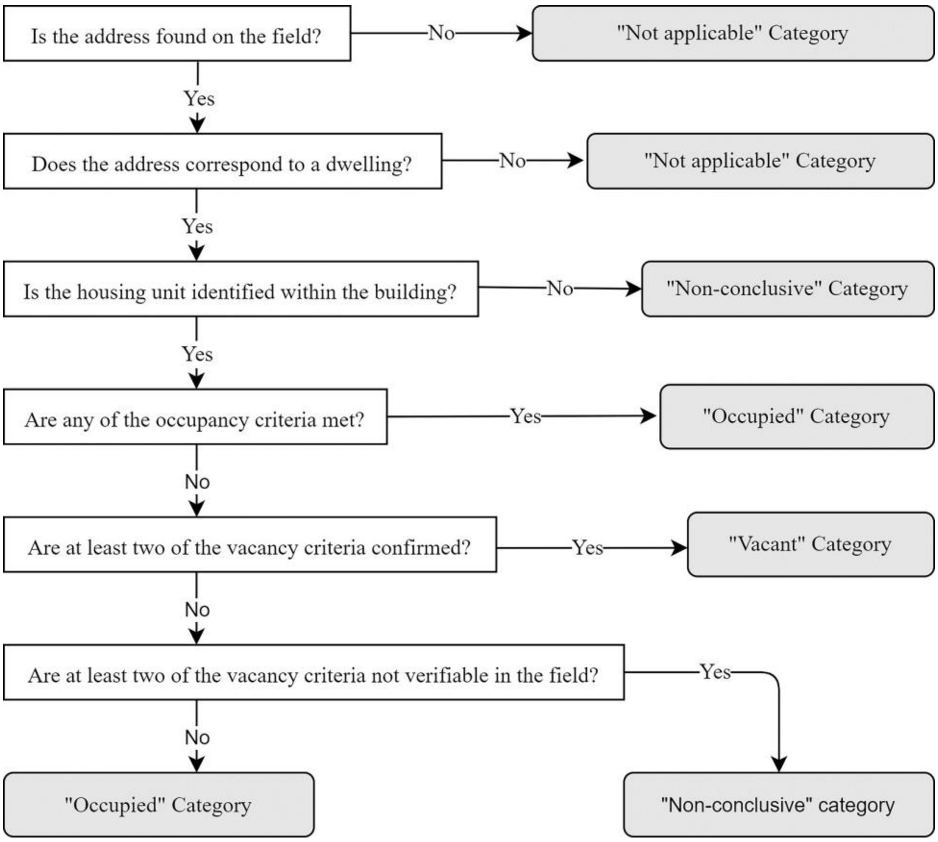

Figure 2. Visual verification protocol

Discussion of the methodology

The main limitation of the study is the vacancy verification protocol. Indeed, the visual identification method does not allow establishing the occupancy or vacancy status with certainty since some criteria are easily disputable and do not automatically imply a vacancy. In particular, the method is not very efficient in verifying apartment dwellings. Field verification remains an approach presented in the literature, particularly as a method of verifying an identification based on water meter data (Kumagai et al., 2016). An alternative is to verify vacancy by contacting homeowners by mail (Lemaire et al., 2016). Due to the topic’s sensitivity, however, biased results are likely to be obtained as owners of occupied units are more motivated to respond, while owners of unoccupied buildings may tend to cover up the status of the building to avoid taxation. The visual method is not optimal for distinguishing between frictional and structural vacancy. Nevertheless, most of the frictional vacancy is avoided by checking dwellings presumed to be unoccupied for more than 12 months. For the municipalities, the visual method has the advantage of allowing to collect new information on the field as the condition or the type of building. We have also taken note of any signs of frictional vacancy - such as signs of renovation or sale - although these are not part of the protocol criteria. Indeed, a dwelling may have been occupied at the time of the data collection and now be subject to frictional vacancy. Still, it may have been finally put back on the market after a structural vacancy.

As for the study on low consumption, a second limitation is the 14-month time lag observed between the year of observation of low consumption or lack of registered address and the year of verification on the field. Due to the time lag, we assume that the number of dwellings for which we have consolidated the suspicion of structural vacancy (true positives) is underestimated, given the number of dwellings that may have been effectively unoccupied for a significant period of at least 12 months but whose vacancy has ceased at the time of the field survey. However, exceeding the 12-month threshold of structural vacancy reinforces the hypothesis of a structural and not frictional vacancy. On the contrary, within the sample composed of addresses not presumed unoccupied, the share of false negatives increases. In addition to frictional vacancy mixed with structural vacancy not detected by the data (false negatives), there is a share of vacancy that has become structural during this time gap and which might have been detected by the data if it had been more recent.

Finally, although time-consuming, an identification of larger samples would have allowed us to maintain a precision margin of error of less than 5 % for a confidence interval of 95 %. However, because of the presence of dwellings not found for which our research method is not applicable, we had to increase the margin of error of the results obtained when we excluded the dwellings not found from the object of analysis.

Results

Vacancy consolidation and projection to the study area

We refer to "potentially vacant dwellings" when the address is suspected of being vacant because of a lack of a registered address or because of low consumption. Where 3,480 of the 5,199 potentially vacant addresses are identified solely by a lack of address, 1,166 are identified by low consumption and only 553 by combining these two criteria. We call the vacancy "consolidated" when field observations have confirmed the suspicion.

A first finding is the presence of eleven units suspected of being vacant among the 125 units randomly taken from the total housing stock. Six of these units are not included in the list of the 5199 potentially vacant units. We can explain three of these cases by the time lag between the data collection and the fieldwork: they show signs of frictional and recent vacancy such as works, sale, or rental panels. For the three other cases, no sign allows us to validate either the hypothesis of a frictional vacancy or, on the contrary, the hypothesis of a structural vacancy not detected by our data. An alternative explanation could be that a part of the dwellings declared vacant based on visual criteria are, in fact, occupied. Thus, the vacancy would be slightly overestimated by the visual verification method.

	Sample without non-conclusive addresses (n=291)		Projection to the study population (p=5199)		Percentage of municipal housing stock (17,704 units)
	Size	Frequency	Size	Frequency	Frequency
Occupied	101	34.7 %	[1513; 2096]	[29.1 %; 40.3 %]	/
Vacant	66	22.7 %	[888; 1470]	[17.1%; 28.3 %]	[5 %; 8.3 %]
Non-applicable	124	42.6 %	[1924; 2507]	[37.0 %; 48.2 %]	/

Table 1. Projecting occupancy status across the study population and estimating the consolidated vacancy percentage of the housing stock

Considering only the sample from the population of potentially vacant housing in Table 1, we have projected the results to the entire study population. As a reminder, the “non-applicable” category includes addresses that cannot be found and non-residential buildings. We use the “non-conclusive” category, related to the visual verification protocol when it is impossible to verify occupancy and vacancy criteria. It mainly concerns apartments. The 84 “non-conclusive” addresses are akin to non-response in the survey and are excluded from Table 1. With just over one-fifth of the cases being non-conclusive, reducing the sample to 291 units, we decrease the precision of the observations by a factor of interest from 5 to 5.6 %, while maintaining a confidence level of 95 %.

Table 1 presents the rate of consolidated vacancy, mainly structural, in the municipality’s housing stock, which ranges from 5.0 to 8.3 %. The average rate of 6.7 % seems realistic considering international statistics shared by Huuhka (2016). We observe, for example, that on a national level, the frictional and structural vacancy rates in France amount to 6.8 %. Obviously, Herstal does not represent an average Walloon municipality since it is part of a former industrial agglomeration, which is related to a more intense residential vacancy problem (Halleux and Lambotte, 2004). This explains why the structural vacancy rate is particularly high. Moreover, the rate obtained represents a consolidated vacancy, not the actual vacancy. On the one hand, the actual vacancy might appear to be underestimated because of the unaccounted-for vacant addresses due to the time lag. On the other hand, the consolidated vacancy is probably overestimated by the uncertainties of the visual verification protocol. If we consider the lower limit of our estimate for security reasons, there would be 888 structural vacant housing in the municipality of Herstal. This figure is striking given the current difficulty in setting up projects to create significant amounts of dwellings: the housing stock in Herstal has only grown by about 90 units per year since 2015 (Statbel, 2020).

Discussion of registered address and consumption-based methods

The objective is to test the contribution of the use of consumption data compared to the use of registered addresses. We have considered three scenarios: *(i)* one that concerns dwellings with only no household registered at this address, *(ii)* one that concerns dwellings with only low electricity or water consumption and *(iii)* a mixed inventory that includes all dwellings concerned simultaneously by an absence of registered addresses and low consumption of water or electricity. While the results of the previous subsection should sometimes be interpreted with caution given the uncertainties associated with the visual verification method, we can assume here that the bias induced by this verification applies uniformly to each sub-sample and therefore does not interfere with a comparative analysis.

The last column of Table 2 presents that out of the 375 addresses we checked, 101 were occupied addresses compared to 66 vacant addresses. This difference is particularly marked when there is no household registered at the address or a low consumption is registered. In contrast, the trend reverses when we consider both criteria simultaneously: we find 10 occupied addresses against 20 vacant.

	No household registered at this address only		Low consumption only		No registered address and low consumption		Total	
	Size	Frequency	Size	Frequency	Size	Frequency	Size	Frequency
Occupied	69	26.4 %	22	30.1 %	10	24.4 %	101	26.9 %
Vacancy	32	12.3 %	14	19.2 %	20	48.8 %	66	17.6 %
Non-applicable	100	38.3 %	16	21.9 %	8	19.5 %	124	33.1 %
Non-conclusive	60	23.0 %	21	28.8 %	3	7.3 %	84	22.4 %
Total	261	100 %	73	100 %	41	100 %	375	100%

Table 2. Distribution of tenure status by identification mode

To verify these observations, we performed a $\chi 2$ test between a binary variable of observation of vacancy consolidation and a variable representing the mode of identification. We can then consider these dependent variables with a risk of error of less than 0.1 %. The combination of a lack of registered addresses and low consumption reinforces the probability of vacancy. However, an identification based solely on these two criteria would be too restrictive: only 20 of the 66 dwellings for which we have consolidated the suspicion of vacancy have been identified in this way. We also note in Table 2 that almost a quarter of the dwellings identified simultaneously by an absence of registered address and a low consumption turn out to be occupied. The delay between obtaining the consumption data or the registered address data and the observation in the field is insufficient to explain the large proportion of occupied dwellings. To the hypotheses already mentioned, as a reminder, the presence of photovoltaic panels or water tanks and a low presence in the dwelling (Lemaire, 2015), we may add the hypothesis of a sometimes very precarious occupation of the dwellings associated with low consumption.

Table 3 suggests that the use of low consumption is interesting because the rate of consolidation of vacancy (29.8 %) is greater than that of absences from registered addresses (17.2 %). However, its application alone allows us to identify only 34 of the 66 vacant housing we identified, where the registered addresses method identifies 52 vacant housing.

	No household registered at this address (including the one with low consumption)	Low consumption (including the one with a lack of registered addresses)
Vacancy consolidation	52	34
No vacancy consolidation	250	80
Total	302	114
Consolidation rate	17.2 %	29.8 %

Table 3. Comparison of registered addresses and low consumption methods

The method of the absence of registered address proves to be the least effective in terms of the vacancy rate detected (Table 2). We can explain it for two reasons: firstly, because a registered address is not compulsory to occupy a dwelling and, secondly, because of the presence of many inconsistent addresses. However, it allows us to identify the largest number of dwellings with consolidated vacancies. Our analysis tends to show that updating addresses from the Population Register is particularly problematic since Table 4 shows that 84 of the 99 non-existent addresses are included in the category “no household registered at this address only” and in the category “no registered address and low consumption”. One hypothesis could be that demolitions or address changes occurred between the data collection and the fieldwork, but no evidence gathered during the field verification confirms this. Instead, we explain this result by the functioning of the Population Register: it keeps all addresses where someone has once been registered, even if the address has changed or if the building has been destroyed later on. A systematic cross-referencing with the Building Register, as in Finland (Huuhka, 2016), should improve the situation.

We can assert through the $\chi 2$ test conducted on contingency Table 4 that the identification mode has an influence on the share of non-existent addresses with a risk of error of 0.01 %. We can also assume that the low rate of non-existent addresses when we encounter both an absence of a registered address and a low consumption is because a non-existent address is less likely to be included in both data sources.

	No household registered at this address only	Low consumption only	No registered address and low consumption	Total
Non-existent address	84	12	3	99
Address found	177	61	38	276
Total	261	73	41	375
Non-existent address rate	32.2 %	16.4 %	7.3 %	26.4 %

Table 4. Contingency table between the mode of identification and non-existent addresses

All the elements discussed lead us to believe that the existing methods do not allow, in their current state, efficient identification of vacant housing.

Towards a multi-criteria identification method

We will now discuss ways to improve a more comprehensive multi-criteria method that crosses National Register and consumption data. The objective is to build a phased approach that can be easily implemented in municipalities. We will base this approach on logistic regression. We have various possible explanatory variables of the vacancy:

- No registered address (binary variable, success = 1) ;
- Low water consumption (binary variable, success = 1) ;
- Low electricity consumption (binary variable, success = 1) ;
- Number of years without registered address, grouped into seven classes (discrete variable, numbered from 1 to 7) ;

— Value of water consumption (continuous variable) ;

— Value of electricity consumption (continuous variable) ;

— Additional filters: list of insalubrity order, addresses to be discarded, notarial list of transactions, list of empty commercial cells (binary variable, success = 1).

We select the variables with a stepwise selection method, which tests the combination of variables minimising the Bayesian information criterion to obtain a parsimonious model including only the most relevant variables. The result obtained suggests that we should retain the following variables: no registered address and the number of years without a registered address. The last two steps of the selection discarded variables inherent to the model, low water and electricity consumption, which we need to retain as these are variables from which the sample is built.

We can examine the contribution of each variable through the odds ratios, their confidence intervals, and the associated p-value in Table 5. The following formula then expresses the logit model:

$$logit\ p_\beta = \log \frac{p_\beta(x)}{1-p_\beta(x)} = \beta_0 + \beta_1 x_1 + \cdots + \beta_p x_p.$$

The β coefficients are the logarithms of the associated odds ratios. The probability of vacancy p_β for each item is presented in Table 7. The number of years without a registered address has an odd ratio lower than one, which indicates a negative causal relationship between the number of years without a residence and the probability of vacancy. We can explain this negative causal relationship by the presence of inconsistent addresses that have been present for many years. In fact, we observe that these addresses – non-residential or non-existent – stand out because of their very high number of years without a registered address. The interpretation of the odds ratios suggests that the lack of a registered address is the most important factor, subject to a small number of years without a household registered.

Variable	N	Odds ratio		p
No registered address	291		5.18 (2.04, 13.78)	<0.001
Low water consumption	291		1.84 (0.86, 3.93)	0.11
Low electricity consumption	291		2.62 (1.12, 6.25)	0.03
Years without registered address	291		0.65 (0.53, 0.78)	<0.001
		1 2 5 10		

Table 5. Odd ratio for each variable

We calculate the point-biserial correlation coefficient to describe the possible relationship between a continuous and a binary variable (Leblanc & Cox, 2017; Makowski et al., 2020). The coefficient of point-biserial correlation between the prediction of vacancy by the model and the consolidation of vacancy on the ground, which amounts to 0.39 with a p-value lower than 0.001, indicates a strong correlation. More concretely, Figure 3 and Table 6 provide the number of owner contacts required for municipalities to detect a certain share of the consolidated vacancy to meet our efficiency target. As a reminder, out of the 17 704 dwellings in Herstal's housing stock, we isolated 5199 addresses suspected of being vacant due to a lack of registered address or low consumption. Since it is very costly for municipalities to contact as many owners of suspected vacant units, we recommend using this model to target owners of units most likely to be vacant. Figure 3 shows that below a vacancy probability of 0.28, the number of contacts increases sharply relative to the total share of identified vacant units. Table 6 shows that in order to identify half of the vacant units in the municipality, it is necessary to contact only 1,233 owners instead of half of the owners of all the suspected vacant units, i.e. 2,600 owners, which reduces the number of contacts required by 47.4%.

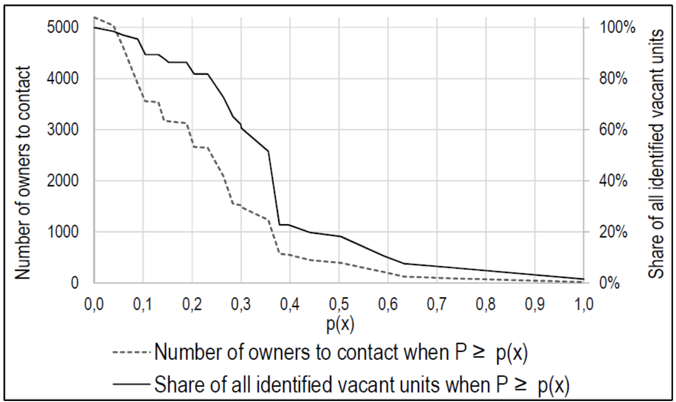

Figure 3. Evolution of the number of contacts and the rate of identified units according to the probability P from which the model predicts a vacancy

$P \geq p(x)$ = 0.356	No vacancy	Vacancy
No vacancy prediction	190	32
Vacancy prediction	35	34
Share of all identified vacant units	51.5 % (± 5.6%)	
Number of owners to contact	1233 ([942; 1524])	

Table 6. Number of contacts and rate of identified units according to the probability P from which the model predicts a vacancy

We can propose a phased approach based on the vacancy probabilities extracted from the logistic regression model (Table 7). Let us recall that the suggested phases are built from observations of a specific municipality, within which a significant presence of non-existent addresses complicates the identification. Therefore, the methodology must be adapted in other territories to determine the appropriate phases.

Phase	Identification criteria		Probability of vacancy
	Years without registered address	Low consumption	
1	≤ 5	water & electricity	0.727
	6 - 10	water & electricity	0.633
2	≤ 5	electricity	0.591
	≤ 5	water	0.504
3	6 - 10	electricity	0.483
	none	water & electricity	0.441
	6 - 10	water	0.397
4	≤ 5	none	0.356
	none	electricity	0.301
	6 - 10	none	0.264
	none	water	0.232
5	≥ 10	none	≤ 0.189

Table 7. Composition of the identification phases using vacancy probabilities from the logistic regression model

We suggest that municipalities proceed in five phases (Table 8), with the first phases being the ones for which they can expect higher vacancy probabilities (Table 7). In this way, municipalities will be able to identify as many vacant units as possible while minimising the number of verifications and contacts with owners, provided that the development of an appropriate tool facilitates the cross-referencing of data. Once the phases are determined following the field verification of a random sample, the field verification may be substituted by direct contact with the owners of the dwellings most likely to be vacant. The field approach remains an important source of information in order to verify the occurrence of works or the willingness to sell or rent.

Phase	Identification criteria
1	Building with no registered address since less than 10 years with double low water and electricity consumption
2	Building with no registered address since less than 5 years with single low water or electricity consumption
3	Building with double low water and electricity consumption Building with no registered address for 6 to 10 years with single low water or electricity consumption
4	Building with single low water or electricity consumption Building with no registered address since less than 10 years
5	Building with no registered address since more than 10 years

Table 8. Composition of the identification phases

Discussion

The multi-criteria method we implemented is relevant when there is no single set of data that can reliably identify vacant addresses. By using automated data cross-referencing, e.g. by introducing a unique identifier for each dwelling, the method is relatively resource-efficient, as fieldwork is only needed occasionally for a small sample of dwellings. The phased approach allows municipalities to adjust resources allocated to owner contact according to their annual objectives.

For the sake of replicability of the method, the data on registered addresses and consumption can be adjusted according to their availability and relevance to the context and issues relating to vacancy in each territory. The use of registered addresses is replicable in several countries since, according to Poulain et al. (2013), 13 European countries have a population register that includes the residential address. In the absence of such data, other data sources related to occupancy, such as whether an annual household waste collection fee is paid, could be used. Alternatively, if the amount of waste produced is recorded by weight, volume, or frequency of collection (Welivita et al., 2015), such data can complement or replace water and electricity consumption data. In the context of a tight market, where it might be relevant to include under-occupancy and second homes, it is advisable to define a minimum occupancy duration and to adjust the consumption thresholds accordingly. It would be relevant – subject to further studies – to investigate whether these thresholds can be adjusted according to the size of the dwelling.

The multi-criteria method helps to define likely vacancy. The confirmation of vacancy still requires contacting the owners. As with housing census, the method allows for the projection of statistics and the comparison of territories. This is why Boquet et al. (2016) suggest keeping an inventory of vacant housing to improve local markets' functioning and adequate territorialisation of housing policies. In our case, we show that vacant housing constitutes a real resource when figures are put into perspective with the applications for access to social housing and the construction of new housing at the municipal level.

Where the housing census method fails to provide the location of vacancy and obscures local variations (Smith et al., 1984; Molloy, 2016), the advantage of the multi-criteria method is that it provides a list of addresses where to implement operations to tackle vacancy. In our case, this inventory is used to inform owners of the possible alternatives to put their property back on the market and, if vacancy persists, to apply a tax on vacant housing. In addition to the main motivation of reducing vacancy, a more exhaustive inventory is likely to increase the revenue from the tax. We could consider – subject to further studies – a model of self-remuneration of the identification effort and allocation of the remaining budget to subsidise operations for the acquisition of degraded real estate.

Conclusion

While some countries are able to identify and locate vacant dwellings from a single database, e.g. the United Kingdom and France using council tax data (Wyatt, 2008; Bouquet et al., 2016), several countries generally use an estimate of vacancy through housing census (Norris, 2004), which do not allow for individual identification of these dwellings.

To address this issue, this paper developed a methodology to optimise the identification of vacant housing using a phased approach based on cross-referencing registered addresses and domestic consumption of water and electricity at the household level. This cross-referencing proves to be relevant since it leads to a more complete identification than the one obtained from only one of these databases. Indeed, by analysing separately the methods based on low consumption and on registered addresses, we demonstrate that neither of these methods allows an exhaustive and reliable identification due to a significant presence of dwellings identified as vacant but nevertheless turn out to be occupied.

Quantifying housing vacancy remains methodologically complex and requires crossing approaches to construct an inventory of vacant housing that is as precise as possible. While it is possible to target dwellings with a higher probability of vacancy through cross-referencing data, obtaining a complete inventory of vacancies remains a sensitive issue. The lack of methodological support may explain why there are still too few municipal policies dedicated to curb vacancy, even though the reasons for addressing vacancy are manifold, ranging from mitigating urban blight to mobilising latent resources in tight markets.

Coolos and Vorms (2013) noted that it is still difficult to say how much of this resource can be easily mobilised, especially given the condition and health of these dwellings. This paper reinforces this last statement, demonstrating that beyond knowing the state of vacant housing, their individual identification and mapping raise methodological problems that must be tackled as a priority.

Disclosure statement

No potential conflict of interest was reported by the authors.

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