



This is a repository copy of *The potential of vertical extension at the city scale*.

White Rose Research Online URL for this paper:

<https://eprints.whiterose.ac.uk/191177/>

Version: Published Version

Proceedings Paper:

Gillott, C. orcid.org/0000-0001-5706-7909, Davison, J. orcid.org/0000-0002-6191-7301 and Densley Tingley, D. orcid.org/0000-0002-2477-7629 (2022) The potential of vertical extension at the city scale. In: Lützkendorf, T., Roswag-Klinge, E., Gundlach, K., Schlez, S., Passer, A. and Habert, G., (eds.) IOP Conference Series : Earth and Environmental Science. sbe22 Berlin, 20-23 Sep 2022, Berlin, Germany. IOP Publishing .

<https://doi.org/10.1088/1755-1315/1078/1/012079>

Reuse

This article is distributed under the terms of the Creative Commons Attribution (CC BY) licence. This licence allows you to distribute, remix, tweak, and build upon the work, even commercially, as long as you credit the authors for the original work. More information and the full terms of the licence here:

<https://creativecommons.org/licenses/>

Takedown

If you consider content in White Rose Research Online to be in breach of UK law, please notify us by emailing eprints@whiterose.ac.uk including the URL of the record and the reason for the withdrawal request.



eprints@whiterose.ac.uk
<https://eprints.whiterose.ac.uk/>

PAPER • OPEN ACCESS


The potential of vertical extension at the city scale

To cite this article: C Gillott *et al* 2022 *IOP Conf. Ser.: Earth Environ. Sci.* **1078** 012079

View the [article online](#) for updates and enhancements.

You may also like

- [Affordable Housing for Low-Income Communities: Between Residential and Investment](#)
S Sunarti, N Yuliasuti, W Prananingtyas et al.
- [Sustainable affordable Housing Delivery System \(HDS\): A comparative study of Indonesia and United Kingdom best practices](#)
M P Monika, A Suraji, J Hardi et al.
- [Interior Living Space Preferences in the Early Housing Career of Low-Income People in DKI Jakarta, Indonesia](#)
Antony Sihombing, Coriesta Dian Sulistiani, Rossa Turpuk Gabe et al.



The banner features the ECS logo on the left, a central portrait of M. Stanley Whittingham with a Nobel Prize medal, and a 'Register now!' button with a checkmark icon on the right. The background includes a photo of a lecture hall and a person interacting with a futuristic interface.

ECS The Electrochemical Society
Advancing solid state & electrochemical science & technology

242nd ECS Meeting
Oct 9 – 13, 2022 • Atlanta, GA, US
Presenting more than 2,400 technical abstracts in 50 symposia

ECS Plenary Lecture featuring M. Stanley Whittingham,
Binghamton University
Nobel Laureate – 2019 Nobel Prize in Chemistry

Register now!

The potential of vertical extension at the city scale

C Gillott¹, J B Davison¹ and D Densley Tingley¹

¹Department of Civil and Structural Engineering, The University of Sheffield, Mappin Street, Sheffield, S1 3JD

cgillott1@sheffield.ac.uk

Abstract. The UK construction sector is central to the climate and housing crises and must now deliver vast amounts of residential accommodation whilst reaching net zero emissions by 2050. Housing provision through the vertical extension of existing buildings offers opportunity to achieve this, reducing embodied carbon emissions and creating more efficient high-density settlements. In England, permitted development (PD) rights allow for residential vertical extensions without the requirement for conventional planning permission. Despite this, and due to limited uptake of PD rights and a lack of existing studies, the potential for housing provision through widespread extension is unknown. This paper develops a framework to assess the ability of vertical extensions in providing housing at different scales and applies this to Sheffield, England. The generation of new dwellings through PD vertical extension could house up to 175,000 in Sheffield, with detached buildings and those in residential use being most suited to extension. PD rights favour the enlargement of existing dwellings over the generation of new residential units, potentially limiting their effectiveness in tackling the housing crisis.

Keywords: housing, geographic information system (GIS), building reuse, vertical extension, permitted development.

1. Introduction

The UK ‘housing crisis’ describes a shortage of residential accommodation [1], the decreasing affordability of housing [2] and near-record levels of homelessness [3]. In England, the Chartered Institute of Housing (CIH) estimate this shortage to be around 4 million homes and recommend that 340,000 be generated each year for 15 years in order to clear this deficit and meet growing demand [1]. Despite this, supply is still below the 300,000 homes a year pledged by the UK government [4] with only 240,000 and 216,000 net additions made in England in 2020 and 2021 respectively [5].

The challenge of increasing housing supply is compounded with the requirement for this to be done amidst a global climate crisis. In 2015, signatories of the Paris Agreement committed to limiting global average temperature increase to 2°C [6], leading the UK to introduce legislation mandating economy-wide greenhouse gas emissions be reduced to ‘net zero’ by 2050 [7]. This includes the built environment, which is currently responsible for 42% of total greenhouse gas emissions in the UK [8].



1.1. *Delivering low carbon housing*

Although building operational efficiency is legislated in the UK [9], embodied carbon (emissions from material extraction, manufacturing, transport, construction, deconstruction, and waste disposal) is not. Decarbonisation of the electricity grid and improving operational performance is increasing the proportion of whole-life emissions attributed to embodied carbon, which is estimated to grow from 19% in 2020 to 42% by 2030 [8]. One of the most effective approaches to reducing embodied carbon is the reuse of existing buildings. This is also consistent with the transition to a circular economy, which aims to retain resources at their most useful level for as long as possible. Building reuse offers embodied carbon benefits over the alternative of (demolition and) new-build construction through reductions in waste generation and resource extraction. These benefits are acknowledged by increasing advocacy for the adaptive reuse of existing buildings, both in the UK [8,10] and internationally [11].

How and where housing is generated also influences the carbon emissions of prospective inhabitants and the systems and services upon which they rely. For example, infrastructure requirements (e.g. roads and electricity cables) and resource consumption (e.g. fuel sales) have been shown to scale sublinearly with a city's population size [12], thus, doubling the population of a city requires only an 85% increase in the amount of supporting infrastructure. Further economies of scale associated with high residential density (150 dwellings/ha) have been observed, with per capita carbon emissions from building material production, building operation, and private and public transport being 1.5, 1.8 and 3.7 times larger than at low density (19 dwellings/ha) [13].

1.2. *Vertical extensions and permitted development rights*

Although efforts to increase residential density and reuse existing buildings appear to be conflicting, vertical extensions allow these requirements to be met simultaneously. Also known as rooftop or airspace development, this refers to the construction of new storeys above existing buildings and is most often completed as part of a wider retrofit, or specifically with minimal impact upon the existing structure [14].

There are several examples of the vertical extension of both residential and non-residential buildings in the UK [14]. In 2020, permitted development (PD) rights specific to vertical extension [15,16] were introduced. These outline six development types, termed PD classes, for which up to two storeys may be added to existing buildings without the requirement for full planning permission. An overview of these is given in Table 1.

Table 1. Overview of vertical extension permitted development classes, detailing the corresponding part of the General Permitted Development Order [17] in which they are introduced.

Part	Class	Name/Development Type
1	AA	Enlargement of a dwellinghouse by construction of additional storeys.
	A	New dwellinghouses on detached blocks of flats.
	AA	New dwellinghouses on detached buildings in commercial or mixed use
20	AB	New dwellinghouses on terrace buildings in commercial or mixed use
	AC	New dwellinghouses on terrace buildings in use as dwellinghouses.
	AD	New dwellinghouses on detached buildings in use as dwellinghouses.

1.2.1. Scope and restrictions. For each of the classes in Table 1, there are several cases where vertical extension PD rights are not applicable. This includes buildings within national parks and conservation areas, and those with listed status or built before 1948 [15,16]. The specific combination of conditions required to be met for each PD class are detailed in Section 2.3.

The number of storeys that can be added, the height of each extended storey, and the total height of the extended building are restricted based upon the number and height of existing storeys and the height

of adjoining properties [15,16]. A breakdown of the conditions required to be satisfied by each PD class is given in Section 2.5.

In place of the conventional planning application process, a fast-tracked prior-approval system is used for PD extensions. This sees the local planning authority consider the impact of the proposed development (e.g. on highways, neighbours, and natural vistas) and the suitability of the extension (e.g. external appearance, access to natural light and internal space provision) [15–17].

1.2.2. Reaction and initial uptake. The Ministry of Housing, Communities & Local Government hoped that the introduction of new PD rights would “give homeowners the freedom to grow their home”, “support development on brownfield land” and make “better use of our towns and cities”, estimating they would generate 8,600 new homes a year [18]. However, commentary surrounding the PD rights suggested that they may be somewhat less effective [19] as a result of their limiting restrictions [20], the onerous nature of the prior approval process [21,22] and a preference for the conventional planning system [19]. The impacts of PD rights on housing provision may also be limited by the fact that conditions for the enlargement of existing dwellings are less stringent than for the generation of new residential units [15,16].

Government statistics show that only 444 prior approval applications for vertical extensions were submitted in England between April and September 2021 [23]. Of these just 188 (42%) were granted, only 25% of which related to the generation of new residential units [23].

1.3. Potential for vertical extension at the city scale

Although existing work has identified general barriers to vertical extensions, including a general unawareness of PD rights [24], it is unclear how the specific restrictions imposed by PD rights limit their ability to generate housing. There is also a lack of studies considering vertical extension beyond the single building scale, meaning that the potential for widespread housing generation remains unknown. This is the case for both PD-delivered projects and vertical extension more generally.

A shift towards residential densification through vertical extension necessitates a multi-scale understanding of the quantity, location and type of housing that may be generated. To address this need, an assessment framework to evaluate the potential for housing provision through vertical extension at the city, regional, and national scales has been developed. This has been tested on a case study city in the UK, considering solely planning aspects in order to investigate the suitability of PD rights specifically. The developed framework forms the basis of a wider workflow considering non-planning aspects affecting individual extensions (e.g. reserve structural capacity and cost) as well as the impacts of extension at scale (e.g. on infrastructure and service provision).

2. Methodology

2.1. Data collection

The primary dataset on which the assessment framework was developed and tested is the “UKBuildings” GIS (geographic information system) package from GeomniUK (licence no. 5560) [25]. This comprises geospatial polygons and key attributes (e.g. use and height) for all buildings in Great Britain. A more rich set of attributes (e.g. age, building type and number of storeys) is provided for residential buildings, as well as non-residential buildings within “urban extents”, defined as towns and cities with populations over 10,000 [26]. UKBuildings contains polygons representing both buildings – “a continuous structure used for residential or non-residential purposes” and premises – “a whole or part of a building with a consistent use, owner or occupant” [26]. Disaggregation of building polygons into premises is seen for all residential buildings but is limited to urban extents for non-residential and mixed-use buildings. Beyond urban extents, non-residential and mixed-use premises are instead represented as geospatially located points to which the relevant attributes are assigned.

To model the location-based restriction of PD rights, GIS packages detailing the locations and extents of National Parks [27], Areas of Outstanding Natural Beauty (AONB) [28], Sites of Special Scientific

Interest (SSSI) [29], World Heritage Sites [30], Conservation Areas [30], and Scheduled Monuments [30] have been acquired from Natural England and Historic England under Open Government Licence. Aerodrome extents are derived from the Ordnance Survey (OS) MasterMap Topography Layer [31] (procured through Digimap's OS Collection educational license [32]), and Boundary-Line data [33] was obtained directly from OS under Open Government Licence.

2.2. Data preparation

For computational efficiency, the assessment framework first removes all elements of the input datasets which fall beyond the geographic area to be considered. Unique premises and building IDs from UKBuildings are then used to append an attribute for the minimum height of all premises within each building to all premises contained by that building. This is for use in the assessment of extension potential, as detailed in Section 2.4.

Because UKBuildings does not specify whether non-residential buildings are detached, semi-detached or terraced, premises and building IDs are used to determine a proxy indicator for this. Premises which do not share a building ID with any other premises (i.e. where they are the only premises within a building) are deemed to be detached. The remaining terraced and semi-detached premises are classified as non-detached, with these being grouped as a result of their identical treatment in Tables 2 and 3.

As the disaggregation of non-residential buildings into premises is limited to urban extents, further processing is carried out to discount non-residential building polygons occupied by more than one premises. These are disregarded in subsequent analysis as a result of the unavailability of premises footprint areas and the inability to accurately distribute building footprint areas between contained premises.

In the case study analysis 10,839 (67%) of 16,104 non-residential premises are carried forward. Although not ideal, partial consideration of non-residential premises is completed as a result of the heightened suitability of urban extents in facilitating densification (i.e. through necessary infrastructure and low availability of land) and to enable the development of the assessment framework. In total, 180,203 residential and 10,839 non-residential premises have been considered.

2.3. Identification of applicable buildings

Following data preparation, premises satisfying the requirements for PD vertical extension are identified using select by location and select by attribute tools in ArcMap [34]. The specific set of conditions required by each PD class are given in Table 2, alongside details of the data sources used. Within Table 2 a building must satisfy *all* conditions above attachment status (i.e. detached, semi-detached or terraced), whereas any one condition following this may be met. This is indicated by a horizontal rule in Table 2.

Note is also made in Table 2 where the actual assessed condition deviates from the exact criterion stated in PD rights [15–17]. An example of this is the discrepancy between the actual (1945–2019) and desired (1948–2018) periods from which buildings are deemed applicable, resulting from the grouping of building ages within the UKBuildings dataset. A similar misalignment is seen for non-residential building use categories.

The exclusion of buildings within safety hazard and military explosives areas is not considered within the framework as a result of the unavailability of data for protected sites such as these. Because of the negligible number of applicable premises likely to be within safety hazard and military explosives areas, this can be assumed to have minimal impact, with the framework being easily modified should the necessary data become available.

Table 2. Conditions required for a premises to be applicable to each vertical extension PD class.

	Part 1		Part 20			
	Class AA	Class A	Class AA	Class AB	Class AC	Class AD
Not in a national park ^a	Y	Y	Y	Y	Y	Y
Not in a world heritage site ^a	Y	Y	Y	Y	Y	Y
Not in an area of outstanding natural beauty ^a	Y	Y	Y	Y	Y	Y
Not in a conservation area ^a	Y	Y	Y	Y	Y	Y
Not in a site of special scientific interest (SSSI) ^a	Y	Y	Y	Y	Y	Y
Not within 3km of an aerodrome ^a	-	Y	Y	Y	Y	Y
Not a scheduled monument ^a	-	Y	Y	Y	Y	Y
Not in a safety hazard area ^b	-	Y	Y	Y	Y	Y
Not in a military explosives area ^b	-	Y	Y	Y	Y	Y
Constructed after 1948 ^{c,d}	Y	Y	Y	Y	Y	Y
Constructed before 2018 ^{c,d}	Y	Y	Y	Y	Y	Y
Not listed ^c		Y	Y	Y	Y	Y
In residential use ^c	Y	Y	-	-	Y	Y
In non-residential or mixed use ^{c,d}	-	-	Y	Y	-	-
A house ^c	Y	-	-	-	Y	Y
A block of flats ^c	-	Y	-	-	-	-
3 or more storeys ^c	-	Y	Y	-	-	-
Is detached	Y ^c	-	Y ^c	-	-	Y ^c
Is semi-detached	Y ^c	-	-	Y ^c	Y ^c	-
Is terraced	Y ^c	-	-	Y ^c	Y ^c	-

^a Considered using supplementary data sources (Section 2.1).

^b Omitted from analysis due to unavailability of data.

^c Considered directly using UKBuildings attributes.

^d Discrepancy between UKBuildings age classes and PD criteria (see Section 2.3).

^e Detachment status for non-residential premises determined indirectly from unique premises and building ID's (see Section 2.2).

2.4. Extension potential assessment

The potential to vertically extend identified premises is then assessed, with each PD class and contained premises being considered sequentially in MATLAB [35]. The exact conditions by which each PD class are assessed is given in Table 3.

In each case, satisfaction of the conditions is evaluated for prospective two- and one-storey extensions, with the largest potential extension being assigned. In assessing the conditions in Table 3, the internal floor to ceiling height of extended storeys is assumed to be 2.3m, as recommended by the nationally described space standards [36] by which PD-delivered dwellings must comply. On top of this, a structural depth of 0.4m is assumed, representing the structural thickness of floors in extension storeys (e.g. beam depth for high-rise buildings, or joist depth for traditional low-rise residential properties). No allowance is made for dedicated service voids as 1-2 storey residential extensions would typically employ local central heating rather than mechanical ventilation from central plant.

Limiting of extended storeys' internal floor-ceiling height to the minimum floor-ceiling height of the existing building (as in Table 3) is unable to be implemented at present because of the unavailability of storey-height data. Despite this, existing floor-ceiling heights below the assumed value of 2.3m are unlikely in existing buildings in residential or commercial use.

Table 3. Conditions required to be satisfied by the extension of a building under each PD class.

	Part 1		Part 20			
	Class	Class	Class	Class	Class	Class
	AA	A	AA	AB	AC	AD
No. of extension storeys \leq no. of existing storeys	Y	Y	Y	Y	Y	Y
Internal floor-ceiling height of extended storeys \leq minimum internal floor-ceiling height of extended storeys ^a	Y	Y	Y	Y	Y	Y
Internal floor-ceiling height of extended storeys \leq 3m	Y	Y	Y	Y	Y	Y
Extension height \leq 3.5m per storey	Y	-	-	Y	Y	Y
Extended height \leq 18m	Y	-	-	Y	Y	Y
Extension height \leq 7.0m in total	-	Y	Y	-	-	-
Extended height \leq 30m	-	Y	Y	-	-	-
Extended height \leq 3.5m minimum building height	Y ^b	-	-	Y	Y	-

^a Not considered due to unavailability of data.

^b Requirement to consider minimum building height does not apply to detached premises.

2.5. Consideration of housing provision

Next, the area of floorspace able to be generated above each premises is calculated as the product of its footprint area and the number of storeys by which it may be extended. Areas are then summed within and across PD classes, whilst individual premises areas are retained for future spatial and archetype-based analyses of extension potential (Section 4.3). Areas generated at different scales (i.e. building, city and PD class level) are contextualised as an equivalent number of people housed using the minimum dwelling size (39m² for a single person) by which PD extensions must comply [36].

3. Results

The developed framework has been applied to a case study city of Sheffield, England. This area has a population of around 590,000 [37] and was selected as it contains urban, suburban, and rural regions, and a broad range of building archetypes. Sheffield's building stock is also representative of similar cities in England. The number of premises applicable to each PD class are detailed in Table 4, alongside the amount of these which may be extended by one or two storeys. Whilst PD classes delivering new residential units (Part 20: Class A-AD) are mutually exclusive, this is not the case for the extension of existing dwellings (Part 1: Class AA). This means that values for Part 1 and Part 20 are to be treated independently, with the respective 7,232,576m² and 6,816,681m² provided through dwelling extension and new unit generation not being achievable simultaneously. In terms of the equivalent number of people housed, this represents 185,451 and 174,787 people respectively, with this estimation being less accurate for Part 1 because of the minimum space standards' applicability to new dwellings rather than their enlargement [36]. It should also be recalled that values for non-residential premises (Part 20: Class AA and AB) are derived from consideration of only 67% of non-residential premises in Sheffield (Section 2.2).

Table 4. Number of premises in Sheffield applicable to each PD class and extendible by 1 or 2 storeys, and the total floorspace generated and equivalent number of people housed by this. (NB: where a building is extendible by two storeys this is not also represented as extendible by one storey to avoid double counting).

	Part 1		Part 20			
	Class AA	Class A	Class AA ^a	Class AB ^a	Class AC	Class AD
Applicable premises	95,970	5,661	44	751	26,325	21,394
Extendible by 1 storey	59,203	10	1	197	17,916	24
Extendible by 2 storeys	21,443	5,626	37	0	0	21,370
Floorspace generated (m ²)	7,232,576	1,738,412	86,504	22,261	999,485	3,970,020
Equivalent people housed	185,451 ^b	44,575	2,218	571	25,628	101,795

^a Incomplete analysis (see Section 2.2).

^b Estimated number of people housed *within existing households* through the enlargement of existing dwellings. This is likely to be an overestimation in practice.

4. Discussion

4.1. Potential for PD vertical extension at the city scale

4.1.1. *Number of applicable premises.* Just over 54,000 premises in Sheffield are identified as applicable to the generation of new dwellings through vertical extension (Part 20: Class A-AD), whereas this value is almost 96,000 for the enlargement of existing dwellings (Part 1: Class AA). This results from the less restrictive conditions required to be met by this PD class (Table 2) and suggests that current PD rights tend to enable the enlargement of existing dwellings rather than the provision of new residential units.

As shown in Figure 1, of the premises to which the provision of new dwellings is applicable (Part 20: Class A-AD), almost 90% are detached, semi-detached or terraced dwellinghouses (Class AC and AD), with almost all the remaining 10% being contributed by blocks of flats (Class A). This suggests that commercial buildings are significantly less suited to PD-delivered vertical extension, reinforced by the fact that just 7% of non-residential premises (Class AC and AD) are applicable to PD extension whilst this value is around 30% for residential premises (Part 20: Class A, AC and AD).

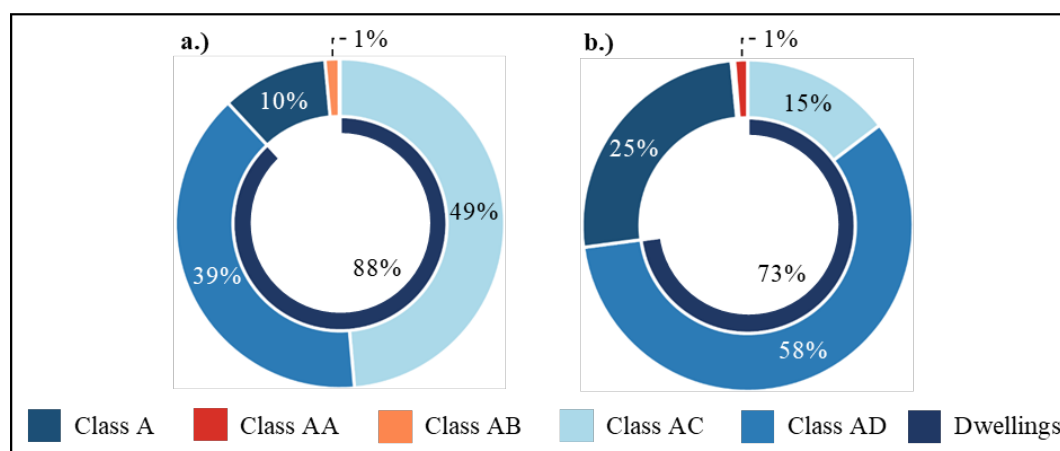


Figure 1. Percentage of PD-applicable premises (a) and generated floorspace (b) contributed by each PD class in Part 20 of the General Permitted Development Order [17].

4.1.2. Extendibility of applicable premises. As shown in Figure 2, similar proportions of the premises applicable to dwelling enlargement (Part 1: Class AA) and the generation of new residential units (Part 20: Class A-AD) are identified to be extendible (84% and 83% respectively). A greater number of two-storey extensions may be made when providing new residential units however, with this being the case for 50% of buildings in Part 20 and just 22% of buildings in Part 1. This indicates that, although the requirements for applicability to Part 20 are more stringent than for Part 1, premises in Part 20 are extendible to a greater degree on average. Considering the extendibility of individual classes within Part 20 and that buildings in Class AC and AD also appear in Part 1, this is largely attributable to the ability of almost all blocks of flats (Class A) to be extended by two storeys (Table 4).

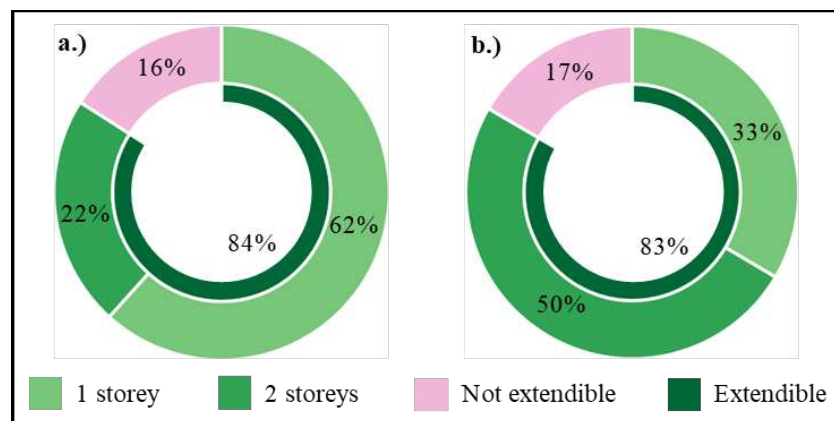


Figure 2. Percentage of PD-applicable premises extendible to different degrees in Part 1 (a) and 20 (b) of the General Permitted Development

All PD-applicable detached houses (Part 20: Class AD) are identified to be extendible by at least one storey, with two storeys being able to be added to almost all (>99%) of these. This contrasts with semi-detached and terraced houses (Part 20: Class AC), for which 70% of buildings are extendible and none of which are extendible by two storeys. A decrease in extendibility is also seen for non-residential that are semi-detached or terraced (Part 20: Class AB), with just 25% of these being extendible compared with 85% of detached commercial premises (Part 20: Class AA). Again, no instances of two storey extension are observed for semi-detached/terraced commercial premises (Part 20: Class AB), whereas almost all detached commercial premises may be extended by two storeys. The disparity between detached and semi-detached/terraced properties is likely to result from the requirement to consider the height of adjoining properties as per Table 3. The limit of a large number of PD-delivered vertical extension to a single storey may therefore be attributed to this single clause.

4.1.3. Floorspace generated. In total, 7,232,576m² and 6,816,681m² of internal floorspace are deliverable through the extension of existing dwellings (Part 1) and the provision of new residential units above existing residential and commercial buildings (Part 20) respectively. The magnitude of difference between these values is less than for the number of applicable dwellings (Section 4.1.1) as a result of the larger average extendibility of premises within Part 20 (Section 4.1.2).

Considering only the extension of detached, semi-detached, and terraced houses, it is revealed that 46% more floorspace may be generated through the enlargement of existing dwellings (Part 1: Class AA) than the generation of new units (Part 20: Class AC and AD). This confirms the aforementioned suggestion of PD rights' bias towards the enlargement of dwellings, suggesting their role in increasing housing supply may be less than otherwise reported.

As shown in Figure 1(b), almost 2/3 of floorspace that may be generated for new residential units (Part 20) is above existing detached dwellings (Class AD), resulting from the large number of these that may be extended by two storeys (Section 4.1.2). For the same reason but accounting for the smaller number of PD-applicable premises, the extension of blocks of flats (Class A) represents a further 25%

of generatable floor area, with semi-detached and terraced dwellings (Class AC) making up 15%. The floor area contributed by non-residential buildings (Class AA and AB) is therefore just over 1%, the vast majority of which is made by Class AA (detached commercial buildings).

4.1.4. Equivalent housing provision. Table 4 shows that 175,000 people could be housed through the generation of new residential units above existing buildings in Sheffield. This represents a potential population increase of almost 1/3 [37], though actual deliverable values are likely to be lower than this as a result the unsuitability of some identified premises and the success rate of the prior approval process.

Sheffield's current government-imposed housing target is 40,000 homes by 2038 [38], meaning PD rights are capable of delivering more than four times the number of houses required in the case study area over the next 16 years. This shows the significant potential for housing provision through PD vertical extension, despite this value being based upon single person dwellings, which is not reflective of actual housing demand.

4.2. Uptake and limitations of PD rights

The number of residential units deliverable through PD vertical extensions in Sheffield is significantly larger than the 444 vertical extensions for which prior approval has been submitted *nationally* to date [23]. This suggests that limited uptake is not because of the non-applicability or inextendibility of existing buildings, but rather from wider barriers to vertical extension [24] or a lack of appetite specifically for PD extensions. The constraints imposed by PD rights and the onerous nature of the prior approval process may be contributing to this, creating a preference for conventional planning applications as a result of the increased flexibility they offer at minimal additional inconvenience.

As nearly 3/4 of deliverable units are above existing dwellings (Class AC and AD) (Figure 1b), which existing occupiers are likely to have limited desire to extend, the potential of PD rights may be more limited than otherwise suggested. This concern is exacerbated by the fact that dwellings may alternatively be enlarged under Part 1: Class AA, which would serve to increase a property's value whilst providing further benefit and no loss of amenity to the existing the occupier

4.3. Concluding remarks and further work

The developed framework's ability to assess the extendibility of individual buildings and regions has been shown through its application to a case study area. This also offers insight on the location and typology of extendible buildings, facilitating future geospatial analysis of vertical extension potential. The assessment framework has also been developed such that it is easy to adapt when additional data becomes available or further criteria are desired to be considered. This enables future increases in both accuracy (e.g. complete consideration of non-residential buildings or PD right criteria) and scope (e.g. consideration of reserve structural capacities, cost, and ease of extension). There is also potential for further work considering the impacts (e.g. on infrastructure and service provision) of the identified degree and location of permissible extensions.

References

- [1] Wilcox S, Perry J, Stephens M, Williams P and Young G 2018 *UK Housing Review Briefing Paper 2018*
- [2] Office for National Statistics 2021 Ratio of house price to workplace-based earnings (lower quartile and median), 1997 to 2020 *House price to Work. Earn. ratio*
- [3] Shelter 2019 *This is England: A picture of homelessness in 2019*
- [4] The Conservative Party 2019 *The Conservative and Unionist Party Manifesto 2019*
- [5] Ministry of Housing Communities & Local Government 2021 Table 118: annual net additional dwellings and components, England and the regions *Live tables Hous. supply net Addit. dwellings*
- [6] United Nations Framework Convention on Climate Change 2015 *The Paris Agreement Conf. Parties its twenty-first Sess.*

- [7] HM Government 2019 *Climate Change Act 2008 (2050 Target Amendment) Order 2019* vol 2
- [8] UKGBC 2021 *Net Zero Whole Life Carbon Roadmap*
- [9] HM Government 2021 *The Building Regulations 2010: Approved Document L (conservation of fuel and power)*
- [10] Architects' Journal 2019 RetroFirst – A campaign by The Architects' Journal
- [11] World Green Building Council 2019 *Bringing embodied carbon upfront*
- [12] Bettencourt L M A, Lobo J, Helbing D, Kühnert C and West G B 2007 Growth, innovation, scaling, and the pace of life in cities *Proc. Natl. Acad. Sci. U. S. A.* **104** 7301–6
- [13] Norman J, MacLean H L and Kennedy C A 2006 Comparing high and low residential density: Life-Cycle Analysis of Energy Use and Greenhouse Gas Emissions *J. Urban Plan. Dev.* **132** 10–21
- [14] Gillott C, Densley Tingley D and Davison B 2021 The Potential of Vertical Extensions: A Case Study Analysis. *IOP Conf. Ser.: Earth Environ. Sci.*
- [15] HM Government 2020 *The Town and Country Planning (Permitted Development and Miscellaneous Amendments) (England) (Coronavirus) Regulations 2020*
- [16] HM Government 2020 *The Town and Country Planning (General Permitted Development) (England) (Amendment) (No. 2) Order 2020*
- [17] HM Government 2015 *The Town and Country Planning (General Permitted Development) (England) Order 2015*
- [18] Ministry of Housing Communities & Local Government 2020 Fast-tracked approval for building upwards: key facts brief *GOV.UK*
- [19] Morris M 2022 Upward Extensions: Adding 2 Storeys to Your House Without Planning Permission
- [20] Knowles T 2020 Residential knock down/re-build and upward extensions...and the need to take account of aerodromes? *Plan. Matters*
- [21] Department for Communities and Local Government 2017 *Summary of responses to the technical consultation on implementation of planning changes, consultation on upward extensions and Rural Planning Review Call for Evidence*
- [22] Whitney H 2020 New homes: extending into the sky! *Plan. Matters*
- [23] Department for Levelling Up Housing and Communities 2021 Table PDR2: District planning authorities - applications for prior approvals for permitted developments *Live tables Plan. Appl. Stat.*
- [24] Gillott C, Densley Tingley D and Davison B 2021 *Drivers, barriers and enablers of building reuse: construction sector views on vertical extensions* Unpublished
- [25] Geomni 2020 UKBuildings Dataset
- [26] Geomni 2021 *UKBuildings Reference Guide*
- [27] Natural England 2021 National Parks (England) *data.gov.uk*
- [28] Natural England 2020 Areas of outstanding natural beauty (England) *data.gov.uk*
- [29] Natural England 2021 Sites of Special Scientific Interest Units (England) *data.gov.uk*
- [30] Historic England 2021 Listing data from the National Heritage List for England
- [31] Ordnance Survey 2021 OS MasterMap Topography Layer
- [32] EDINA 2022 Ordnance Survey Digimap
- [33] Ordnance Survey Boundary-Line *OS Prod.*
- [34] ESRI 2021 ArcGIS Desktop
- [35] Mathworks 2021 MATLAB
- [36] Department for Housing Communities and Local Government 2015 *Technical housing standards - nationally described space standard*
- [37] Office for National Statistics 2021 Estimates of the population for the UK, England and Wales, Scotland and Northern Ireland
- [38] Sheffield City Council: Housing Technical Notes 2020 *The Sheffield Plan*