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REVIEW ARTICLE

Modelling hidden geometry in Madrid "malice houses" (1561–1788): Reversing traces in enlargements to discover original, ingenious designs

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Abstract This paper introduces a pioneering 2D analytical framework for unveiling unique "malice houses" (1561–1788)—low-rise, ugly, and uneven in appearance—in Madrid's historic city. The research focuses on how the main floor was either cleverly or awkwardly concealed, circumventing the imposed lodgement. "Malice" geometry must be uncovered, as no records or preserved examples exist.

Critical findings regarding two-storey houses and a primary approach to the non-existent "Malice" archives established essential parameters. Strategies developed include facade height regulations, traditional carpentry roof design (1636), cross-section agreement methodology, and hidden floor possibilities. The necessary structural coherence between elevation components, load-bearing wall spans, and roof design revealed crucial adjustments to explore in a basic two-span model.

The relationship between proportion, uneven elevations, and symmetrical (1–4) and asymmetrical (5–6) cross-section models is highlighted. Breakthroughs are achieved by unveiling two enlarged malice houses leading to Model 7, an incomplete cross-section with a symmetrical gable (1759) and an uneven high-rise facade with a low-rise floor (1777).

Reversing construction in later enlargement by featuring ingenious roof geometry and low-rise floors opens future research opportunities for discovering preserved historic buildings, uncommon carpentry designs and 2D-to-3D modelling in complex buildings.

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Contents

1. Introduction

Documenting architectural heritage, preserved or demolished, understanding building types from 2D records (Alkohoven, 1991; Laycock et al., 2011), and 3D historic city digital reconstruction demand an integrated approach (Haala, 2010; Balleti and Guerra, 2016; Kargas et al., 2019; Morlighem et al., 2022). Studies involve time-consuming archival and archaeological research, complex building surveys, and procedural modelling (Feilden, 2007).

Records, drawings, building rules, construction, and pattern books provide evidence of unique building knowledge, archaeology studies uncovering disappearances, construction types (Pevsner, 1976; Demir et al., 2023), transformations (Mohanapriya and Sasidhar, 2023) and data to HBIM (Degliorgi et al., 2021; Xu et al., 2024). Critical archives and the latest technology are vital tools for heritage renovations, preventive preservation, and, lately, for a 3D broad range of purposes, from a general historic city approach (Tschirschwitz et al., 2019) to buildings' detailed, such as facades (Hussein, 2024) and roofs (Massafra et al., 2020; Ozkan et al., 2024).

However, uncovering historic dwellings with little or no graphic description becomes challenging. Progress is based on exceptional findings, discovering common patterns, traces in preserved buildings (Dabbour, 2012; Gil et al., 2021), and the latest precise tools like laser-scan surveys and digital twins (Tan et al., 2022). Nevertheless, a thought-provoking question arises: How can we rebuild historic houses without documentation or preserved examples for 2D-to-3D city modelling?

This research reveals a unique typology known as "malice house" (Bermúdez, 1738), which was extensively spread in Madrid because of the establishment of the capital in 1561 and the institution of the "Regalía de Aposento" (1561—1788) (Corral, 1983). According to this Order, the owners of two-story houses were obliged to cede one to house royal bureaucrats, thus mainly conditioning the development of the city and its late reforms (1765—1788) (Marín, 1988; Camarero, 2006).

The primary feature of a "malice house" is its complex partitioning, which makes it uncomfortable to divide its use among owners and guests (Maqueda, 1996). It is believed that the owners prevented the obligation of giving up the main floor as "quarters" or paying the substitute tax (Díaz, 2010).

Along with the terms "malice house" and "of complex partitioning," there are also adjectives related to their size, describing them as low, small in dimensions, or consisting of only a ground floor (Rejón, 1788). Other descriptors refer to their illegality or infringement, noting that their construction was undocumented or unauthorised (Marín, 1988). Conversely, concerning their location, they were considered "typical of the suburb" and spanned the area near the fourth wall (1625—1868) (Gea, 2015). Finally, based on their aesthetics or external appearance, they were labelled as ugly, disproportionate (Real Provisión, 1788), and ruinous, given their poor state of preservation.

However, despite the negative connotations associated with its exterior, the malice house embodied the ingenious and mischievous solutions that owners devised to evade the charge of lodgement. It is believed there was a trick to simulate a single storey from the front, effectively concealing the second storey behind the facade. Nevertheless, as no example is preserved, the question remains:

How were these constructive deceptions achieved? Are there any manuscripts, surviving traces, or graphic documents that provide an ingenious solution or explanation of "malice"?

The ongoing project is crucial for understanding these unique facades, visible from the street but lacking documentation and preserved examples (Berlinches, 2003). The final challenge is to complete their 2D layout, including the geometry of their exterior silhouette, roof, rear construction, and critical inner floors. This work represents the latest progress in the field, addressing the graphic and bibliographic gap necessary for a comprehensive and insightful design before 3D historic city modelling can be realised.

2. Literature review and research aims: documenting houses' proportions

Exploring the volumetry of historic houses and assessing whether the proportion of their external appearance resulted from constructive know-how or arose from malpractice requires clarification of the concept of proportion. Architecture is linked to the beauty of classical order, which emerges from balance or harmony among its components (Rejón, 1788). Drawings are characterised by symmetry, rhythm, and the ratio or codification of their dimensions. This systematisation, evident in singular buildings, is also observable in contemporary collective housing projects.

The Dutch Golden Age (1602—1672) prioritised facade length as a key factor in tax strategies, making the number of floors optional. Consequently, the oldest canal houses featured narrow façades with only two to three rows of windows. In contrast, later developments (1650—1670) restricted construction to half of the plot, extending back gardens. Facades displayed neoclassical features, rhythm, harmony, and proportions of doorways and windows, enhancing verticality with pilasters (Braun and Hogenberg, 1572; Abrahamse and Rutte, 2017).

Building Acts for the reconstruction of London following the fire in 1666 mandated brick facades (Jenkins, 2012; Louw and Crayford, 1999). A new urban form emerged, inspired by the Italian model seen in Covent Garden, consisting of uniform houses facing designed squares and featuring back gardens. Subsequently, Georgian terrace houses (1714—1830) expanded into small, exclusive parks instead of squares. The façades, constructed with brick, stone, and a pitched gable, featured proportionate sash windows and door placements that exhibited balanced symmetry; columns or pilasters flanked the front entrance. Similarly, Georgian towns like Bath (Borsay, 2000; Forsyth, 2003) or the new Edinburgh (Carley et al., 2015).

Madrid, primarily constrained by its city walls (1625—1868) and lacking inner-city planning, executed reforms on a building-by-building basis. Thus, faced with the shortage of dwellings and an excess of unsightly low houses, it was decreed "to demolish the ruinous structures and erect new ones while also enhancing the existing well-built, all to achieve the "convenient proportion" (Real Provisión, 1788).

> Was there a metric proportion or codification of the houses and a harmony between their external visible parts, between the facades and the roofs?

The research argues that their long-lasting "inadequate proportion" was a tactic to circumvent tax regulations. In its investigation, two study models are distinguished: a) the "authorised proportion" model based on the preserved records in the Historical Archives of Madrid, and b) the illegal or "uneven" layout model, which remains unexplored due to the lack of records.

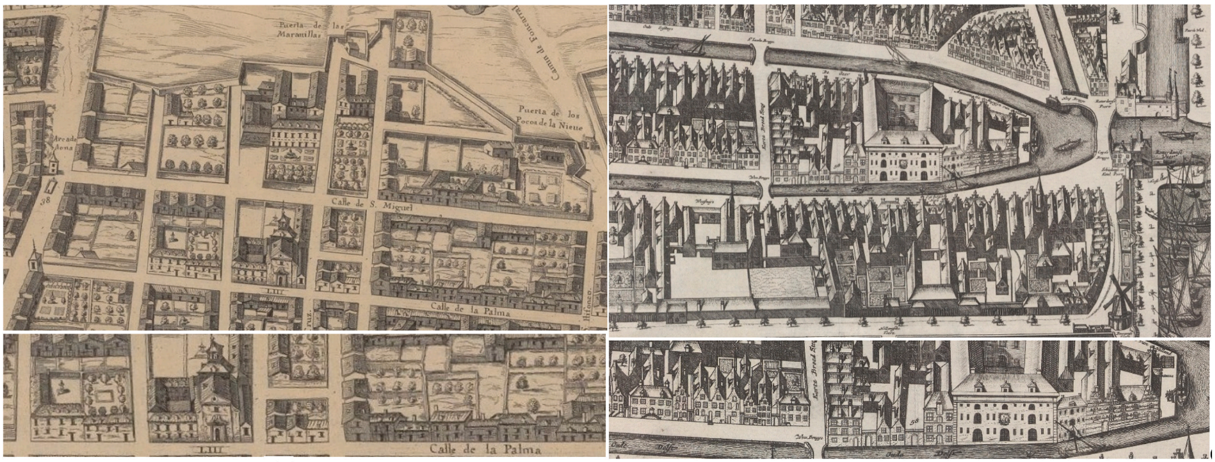
2.1. The old house's proportion: facades and gables

According to the plans and drawings of historic towns, the houses were built between party walls, each featuring unique elements on their exterior facades. Some graphics enhance the silhouette by outlining the rear buildings, which either surround an inner courtyard or are irregularly attached to the main house, as illustrated by Texeira (1656) and Verkolje (1650–1693) in Fig. 1.

The primary house structure consists of the facades and the interior load-bearing walls, separated by a distance known as the bay. The roof, or gable, is constructed atop these structural walls, with its external skirt area represented in the elevations. When illustrating the gable cross-section, the framework of trusses, supported by the load-bearing walls, is displayed. The inclination of the skirt or trusses is measured by the angle they form with the horizontal, known as the bevel, representing a pitched design for significant angles.

The gables are sometimes designed with skirts parallel to the street, featuring front and rear dormers and occasionally extending perpendicular (Fig. 1). In some regions, the load-bearing walls and trusses, along with the transverse facades and skirts, create a timber-framed box (Harris, 1978; Mosoarca and Keller, 2018). In other instances, the walls and roof frames function as independent structures. According to the Madrid treatise writer San Nicolás (1639), gables are first differentiated by their framework and the slope or angle of their inclination relative to the horizontal. Then, they are classified based on their timber joints or the system used to join their pieces. Explaining their design (Fig. 2):

> The frames can exhibit as many differences as the architect desires in his buildings, as they only vary in slope; for this reason, there can be numerous variations. We commonly use two or three, but eight are demonstrated. The trusses are thus distinguished by their



(a)
(b)

Fig. 1 General view and detail of the old houses' appearance. (a) Engraving by Pedro Texeira (1656) with gables typically parallel to the street. (b) Delft by Jan Verkolje (1650–1693) with dominant gables perpendicular to the street.

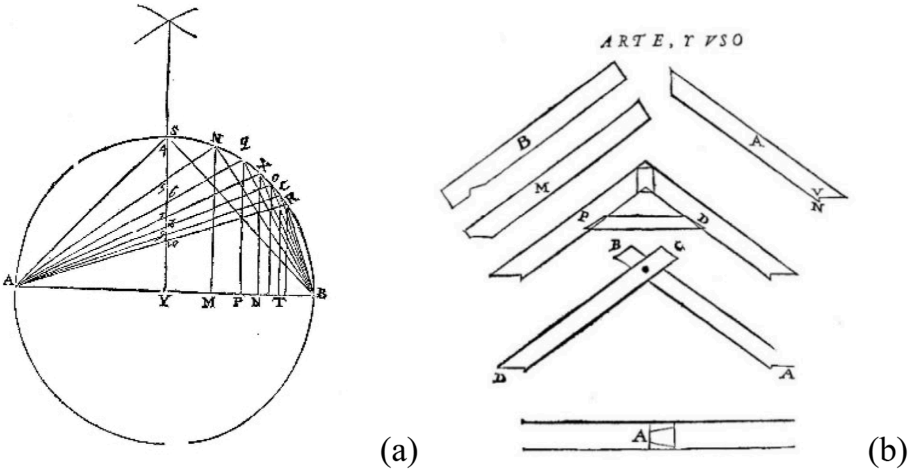


Fig. 2 The wooden-roof design process in Madrid. (a) Framework layout according to standard bevels of 4, 5, 6, 7, 8, 9, 10 and 12 agreeing with angles respectively (45°, 36°, 30°, 25.7°, 22.5°, 20°, 18° and 15°). (b) Common trusses joints (San Nicolás, 1639, C-XLVII, 77–86).

common slopes, referred to as bevels of 4, 5, 6, 7, 8, 9, 10 and 12, based on the angle their declivity forms with the horizontal (San Nicolás, 1639).

Contemporary carpentry masters, such as Muet (1626) and Savot (1624) in France, Fraiture et al. (2016), Scamozzi in Italy, Wotton and Jones in England, and Wilhelm in Germany, also showcase the most common roof designs with symmetrical geometry (Gómez, 2006). Consequently, frameworks are valid for parallel or perpendicular axes to the street, as verified in historical plans (Fig. 1) and preserved buildings. In northern Europe, slight bevels (C_4—C_7) or pitched designs (45°—25.7°) and even steeper angles (48°—58°) are typical (Harris, 1978; Reed, 2020). Conversely, large bevels (C_8—C_{12}) or low-slopes (22.5°—15°) dominate the Mediterranean area.

The two or three most used designs in Madrid are not detailed by San Nicolás in 1639. However, the prohibition against "pouring water onto the adjoining neighbours" and opening side windows necessitated inclining the gables toward the front and rear facades (Torija, 1661) and subsequent bylaws (Ardemans, 1754). This regulation, which demanded symmetry parallel to the street and established the primary bevels, according to San Nicolás (1636) and the recent records discovered in the Historical Archive of Madrid (AVM), laid the foundation for the analytical approach.

2.2. The unknown "malice houses" proportion

In addition to the above analysis, historical maps also show a predominance of plots with narrow facades and a long back, as well as the extension of houses with three or four storeys in the centre and one or two in the suburbs (Fig. 1). In Madrid, apart from Texeira's singular engraving (Gea, 2015; Escobar, 2014), it is challenging to ascertain the exterior appearance of the oldest houses. Few two-storey houses are documented, one-storey houses are rare, and original "malice houses" are non-existent in Madrid's archives (AVM-1561−1788). No buildings have been preserved (Berlinches, 2003).

Recently, investigations into the transformations of Madrid's historic centre based on historical maps from 1625 to 1750 (Ortega and Marín, 2006) and the latest research have suggested that the height of the Malice house facade is indeterminate, ranging between one and two storeys, and includes some graphic proposals (González-Redondo, 2020, 2022, 2024a, 2004b). However, its dimensions have remained undiscovered. There is still no graphic evidence of the original elevation (facade + skirt), and no research has previously explored the 2D model of the cross-section, as other historic city studies had done before a 3D design understanding.

2.3. Research aim: elevation vs cross-section agreeing models

In this context, the primary purpose is to explore the raison d'être of these "illegal" constructions, transferring this malice or ingenuity to imaginary drawings and, consequently, unknown geometry. To this end and to deepen the mystery of the facade, it is also questioned whether the gable was part of this "inconvenient proportion", either as an independent element or integrated into the silhouette visible from the street.

In its resolution, the relationship is established between its hypothetical external appearance, namely the facade and the external skirt depicted in the elevation, and the concealed construction represented in its complete cross-section. Solving the enigma involves determining the parameters of this joint geometry and assessing whether the descriptors "low, ugly, and uneven" result from technical ignorance, constructive malpractice, or skill disguised as malice. In summary, the objectives are a) to model the external appearance of the facade, b) to establish the hypotheses for integrating the gable design according to pitches, c) to conduct the joint study in the cross-section (facade + gable + rear facade), and d) to analyse the possibilities of concealing a main floor from the street.

3. Research methodology: data, hypotheses and resulting models

Modelling techniques begin by outlining 2D models based on typical buildings and structures from construction books, highlighting symmetrical patterns. This straightforward 2D modelling approach provides comprehensive information. However, the lack of preserved buildings and original evidence regarding malicious houses made the basic model seem insufficient. Research into the transformation of Madrid's historic city revealed further key evidence in enlargements, which assisted in constructing variations of cross-section models and supporting hypotheses.

The analytical approach to modelling hidden geometry in Madrid's malice houses (1561—1788) is developed according to five strategies formulated in the research (Fig. 3).

1) Graphically defining the problem of external appearance by investigating the foundations of these structures.
2) Evidencing the elevation parameters to decipher the proportion: old or neoclassical (Model 1).
3) Configuring the study model by integrating the hypotheses of "unevenness".
4) Testing coherent cross-section solutions and justifying the adjustments of the model (Models 2—6)
5) Resolving geometric ingenuity by modifying the final prototype to conceal the main floor (Model 7).

3.1. Context, concepts and nomenclature: external appearance and proportion

The research begins by exploring documentary sources, both old and modern, to first decipher the external appearance terminology and then to interpret its graphic representation.

a) The concept-drawing relationship is found in written documentation, which includes old files, construction books and regulations, and graphic documentation, which includes plans, drawings, and construction details.
b) The study's elements connect: "the whole (elevation) and its parts" (facade and roof), the documented

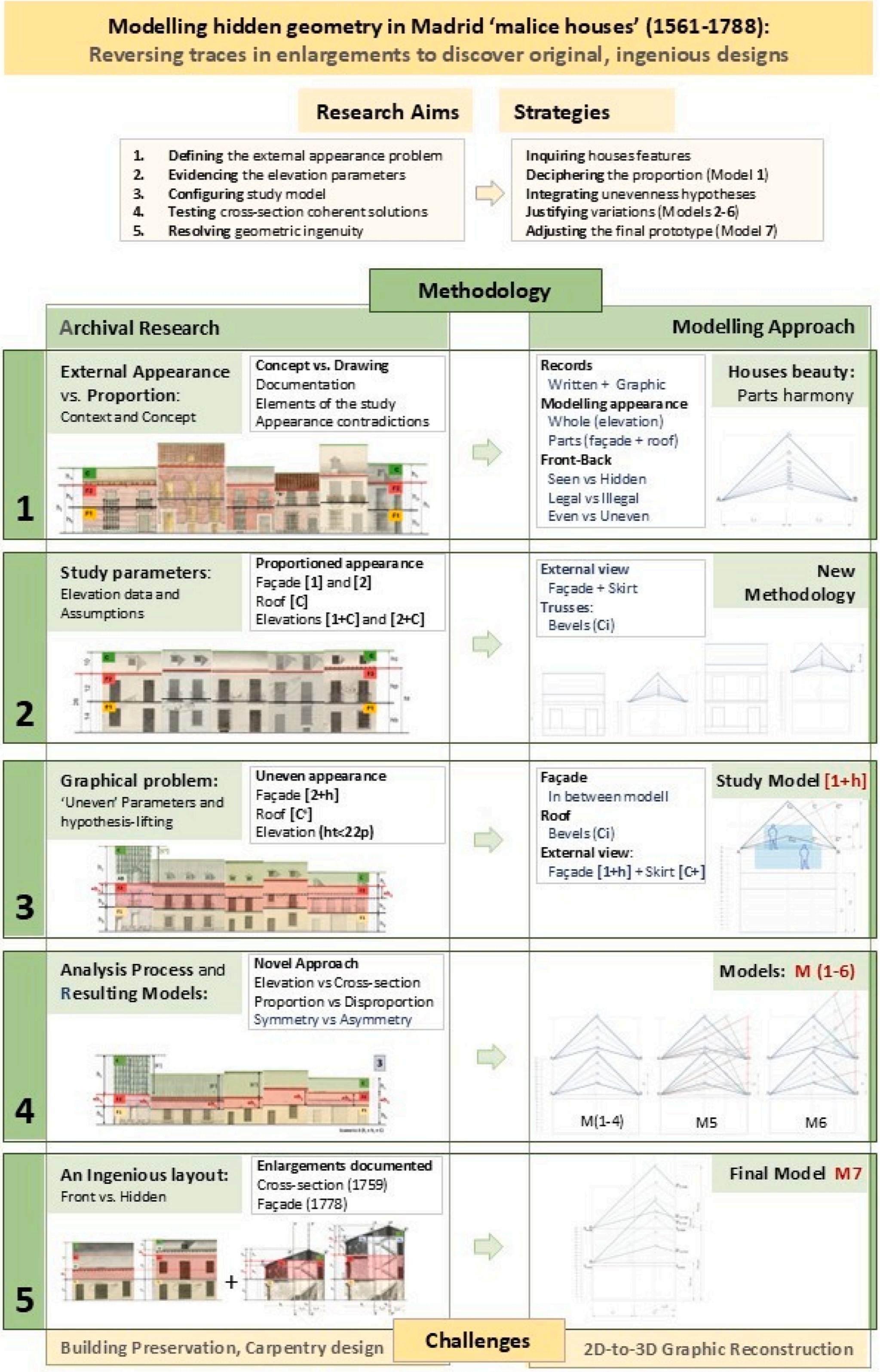


Fig. 3 Diagram illustrating the research aims, strategies, methodology and challenges (González-Redondo, E.).

authorised proportion (ancient or neoclassical), and the unevenness to be discovered (malice).

c) Appearance contradictions are seen vs hidden, legal vs illegal, and proportion vs unevenness.

3.2. Study parameters: elevation data and assumptions

The elevation components are analysed individually (facade and skirt) and then together, determining the permissible external proportion for low-rise houses (one or two storeys).

a) Facade [1] and [2]: parameters for two-storey houses [2] are established, and a new methodology is introduced for one-storey houses [1].
b) Roof [*C*]: The parameters of the outer skirt and its complete geometry (skirt-skirt) are analysed, determining the primary trusses (spans, heights and bevels).
c) One-storey elevation [$1+C$] and two-storey [$2+C$]: The authorised external view (facade + skirt) is characterised, but inconsistencies still need to be discovered.

3.3. Graphical definition: uneven parameters and hypothesis-lifting

The discovery of new parameters associated with the inconvenient external proportion is a significant step. It allows for the undocumented elevation to be defined and the graphic 2D model to be constructed, paving the way for innovative 3D solutions.

a) Facade [$2+h$]: The inconsistency up to the cornice is graphically defined with the new parameter [$+h$], and the model [$1+h$] or facade between 1 and 2 storeys is set.
b) Roof [C^+]: The height of the uneven roofs or parameter [C^+] seen in elevation is determined, thus completing the graphic problem with new hypotheses.
c) Solving the uneven elevation of height to the cornice ($h_t < 22$ p) (1 p = 28 cm): The complete model for the main elevation (facade [$1+h$] + skirt [C^+]) is created before the cross-section study.

3.4. Analysis process and resulting models: elevation vs. section

Once the elevation hypotheses are established and the bevels fixed, the external unevenness is related to a possible hidden ingenuity in symmetrical or asymmetrical cross-sections.

a) Model 1 (Proportion vs. Symmetry). The "proportionate" model recorded in the elevations relates legality and either old or neoclassical external order to the symmetrical cross-section hypothesis.
b) Models 2–4 (Disproportion vs. Symmetry). The "malice elevations", or those with uneven parameters, relate to various cross-section proposals.
c) Model 5–6 (Disproportion vs. Asymmetry). The asymmetry condition in the cross-section will relate the misleading external appearance to the concealed use of the main floor.

3.5. An ingenious layout: shown vs. hidden expertise

Integrating the previous parameters (Models 1–6) and analysing two exceptional files from the Historical Archives of Madrid dating from 1759 to 1778 resolve these singular house layouts. Thus, Model 7 relates to the poor quality of the low-rise and uneven external appearance, represented by the elevation, with a possible ingenious cross-section, or rear "know–how" design to conceal the main floor. This 2D finding is the starting point for reversing enlargement traces and discovering expert designs for the original 2D-to-3D modelling future research.

4. Analytical framework and key parameters: the legal elevation

The starting point involves analysing the available data for the two-storey structures and the hypotheses formulated to determine the legalised one-storey model. Measurements according to records are scrutinised to establish the concept of the entire exterior view (facade + skirt) or "elevation" for the old (AVM-1621–1788) (Historical Archive of the Tow of Madrid) (Fig. 4(a)) and neoclassical houses (AVM-1770–1788) (Historical Archive of the Tow of Madrid) (Fig. 4(b)). The parameters of the trusses are then examined according to San Nicolas' designs (Fig. 5(a)). Finally, symmetrical sections are drawn in coherence with one and two-storey elevations and bevels, resulting in Model 1 (Fig. 5(b)).

4.1. The crucial authorised ratio elevation

Two-storey houses were divided into the ground floor, main floor, and roof ($P_b + P_p + C$) (Fig. 4(a)), while one-storey houses were separated into the ground floor and roof ($P_b + C$). According to the preserved building licenses (AVM, 1654–1751), which include the graphic scale in Castilian feet (one foot = 28 cm), they are distinguished as follows.

4.1.1. Old two-storey elevations [$2+C$]

Insights from external parameters, dimensions, and opening layouts lead to the following conclusion (Fig. 4(a)): these approved facades are externally ordered, as their main elements (doors, windows, balconies, and dormers) follow a certain rhythm, arrangement, and symmetry. However, the validity of height regulation ($h_b + h_p + h_c$) is questionable, given the metric disparity in the ground floor height h_b (11–16 p), the main floor h_p (9–15 p), and the roof h_c (6–12 p), respectively highlighted by three colour lines: F_1 in black, F_2 in red, and C in green in Fig. 4(a).

4.1.2. Old one-storey elevations [1+C]

A new methodology is introduced to address the lack of one-storey projects. This involves maintaining the roof and

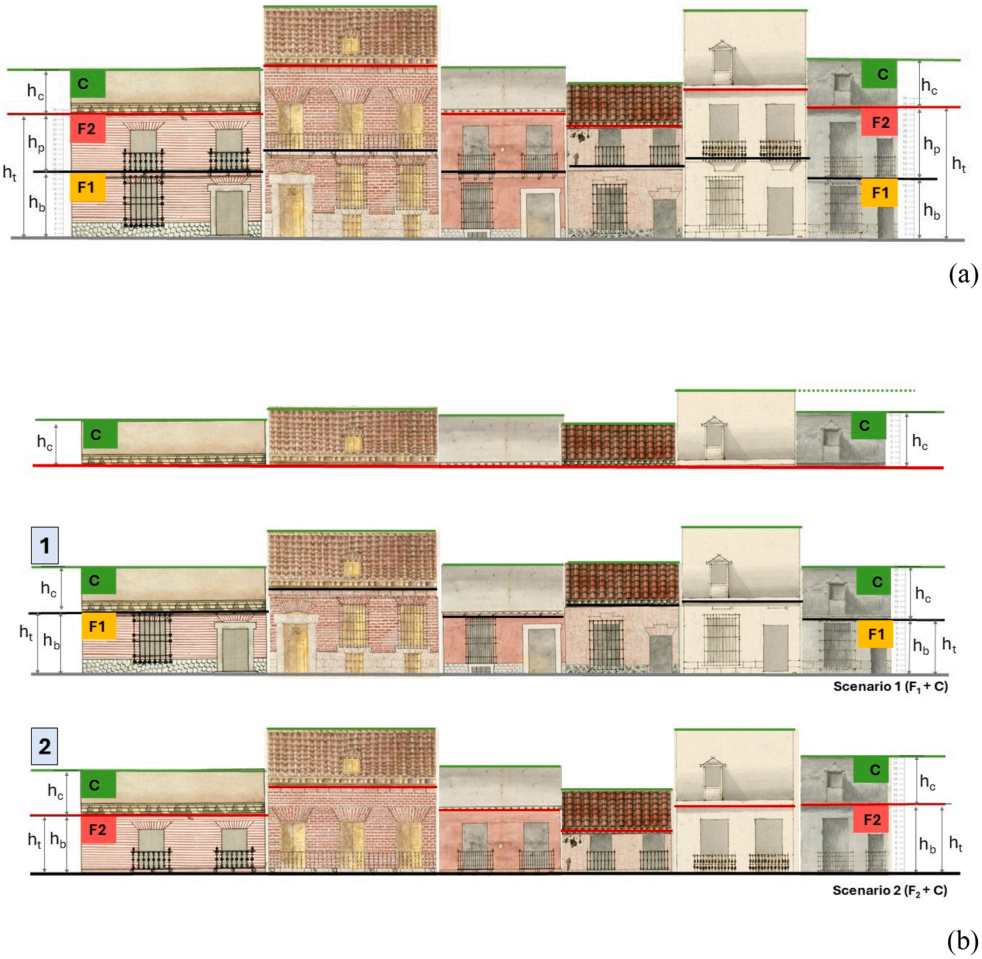


Fig. 4 A row of old proportion two-storey houses (facade + skirt) according to AVM records from the left 1.66.95—1670; 1.66.125—1722; 1.66.88—1654; 1.66.109—1694; 1.84.159—1751, and 1.84.148—1759. (a) Cut-off lines are in black, ground floor height (h_b) up to slab F_1; in red, the main floor (h_p) up to slab F_2; and in green, the roof (h_c). (b) Approaching Old one-storey houses. From the top, roof (h_c); Scenario 1 [Ground floor (h_b) + Roof (h_c)]; and Scenario 2 [Main floor (h_p) + Roof (h_c)] (González-Redondo, E.).

reducing the two storeys in Fig. 4(a) to just one, based on two scenarios shown in Fig. 4(b): a) Assume the roof is built over the ground floor, eliminating the primary. b) Consider that the main floor and the roof form a one-storey house.

The resultant proportion of the old one-storey elevation, with a metric disparity of the ground floor h_b (9—16 p), the roof h_c (6—12 p), and the total height ($h_b + h_c$), is thoroughly verified according to the proposed cut-off lines explained in both scenarios.

4.1.3. Neoclassical elevations

Next, the same methodology is employed to understand the neoclassical proportion in a row of two-storey elevations (1772—1797). In this instance, the outcome is a prototype of a two-storey house with standardised heights (h_b, h_p, h_c), as depicted in Fig. 5(a). The external appearance reveals a beauty or harmony among its components (facade + skirt). As previously mentioned, the proposed cut-off lines are now applied to neoclassic single-storey houses scenarios, resulting in measurements of similar proportions in Scenario 1: Ground floor (h_b) + Roof (h_c), and Scenario 2: Main floor (h_p) + Roof (h_c), illustrated in Fig. 5(b).

4.2. The gable: symmetrical trusses and primary bevels

The old roofs must have been simple and aligned with the two axes of symmetry mentioned. Given the prohibition against "pouring water on the neighbour" (Torija, 1661), the roof design was limited to having only front and rear skirts. As a result, the corresponding geometry, considering the symmetrical section and with the axis at C parallel to the street, is an isosceles triangle ABC formed by the two skirts AC and BC. AB represents the distance between the supports (Fig. 6(a)). With the span AB, equivalent to two bays ($L_1 + L_2$), the various designs emerge from varying angles α_i or bevels C_i and their height h_{ci}, as illustrated in the elevations (Fig. 4(a)—5(a)). Since h_A equals h_B, both front and back elevations appear identical.

4.3. Model 1: one- and two-storey houses

The exterior outline is defined by drawing the slopes and the neoclassical prototype front and rear elevations, which

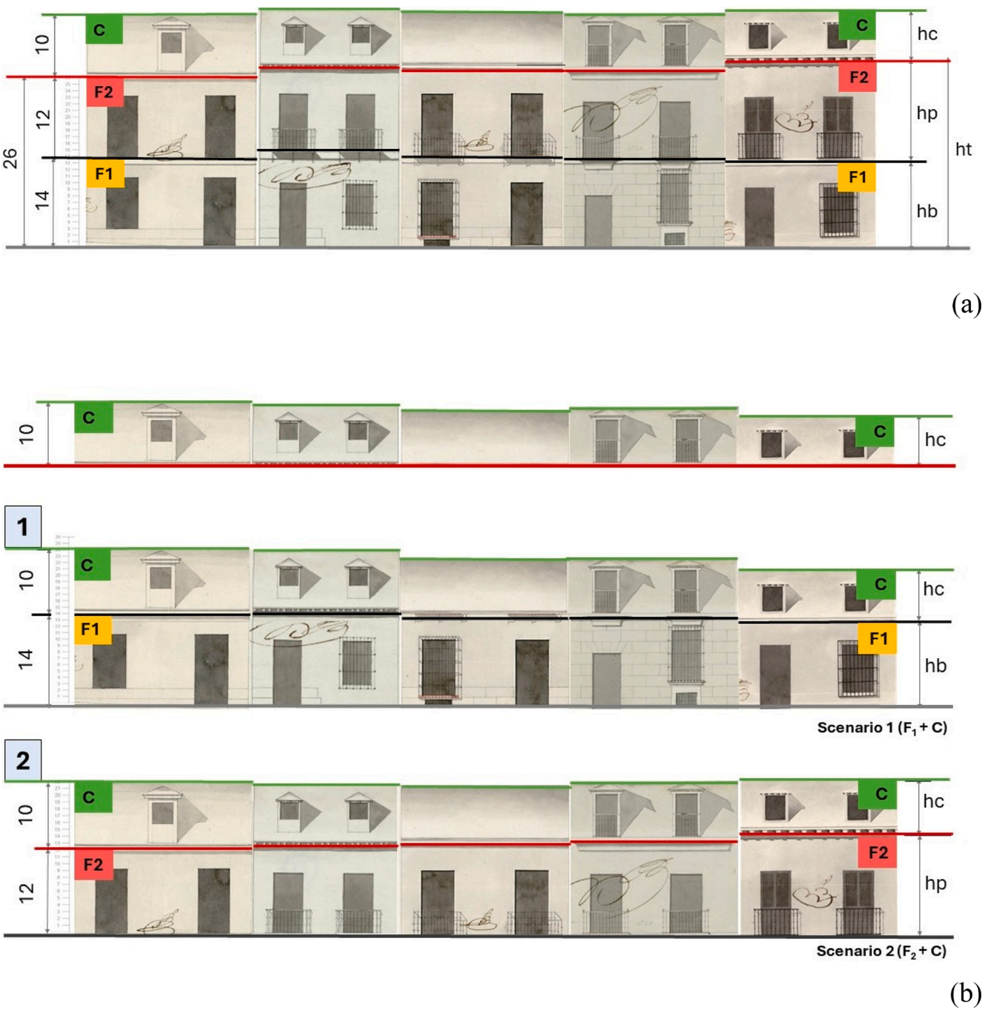


Fig. 5 A row of neoclassical proportion two-storey houses showing partial heights (h_{bi}, h_{pi}, h_{ci}) and total height ($h_b + h_p + h_c$) according to AVM records from the left 1.52.101—1792; 1.49.54—1778; 1.51.10—1789; 1.47.59—1772; and 1.55.42—1797. (a) Cut-off lines are in black, ground floor height (h_b) up to slab F_1; in red, the main floor (h_p) up to slab F_2; and in green, the roof. (b) Approaching neoclassic single-storey houses. From the top, roof (h_c); Scenario 1 [Ground floor (h_b) + Roof (h_c)]; and Scenario 2 [Main floor (h_p) + Roof (h_c)] (González-Redondo, E.).

are assumed to be identical in height. Once the primary bevels (C_i: C_4—C_{12}) are established, with angles (α_i: 45°—15°), and the parameters L_{AB} and h_{ci} are determined, various cross-sections can be obtained by changing h_{ci}, L_i, or α_i. Increasing the variable L_i decreases the slope and vice versa, as shown in Model 1 (Fig. 6(b and c)).

In all cases, the slab dividing the roof from the top floor aligns with the elevation cornice and the AB brace in the section. However, the old regulations concerning partial heights (h_{bi}, h_{pi}, h_{ci}) and total heights ($h_b + h_p + h_c$), as well as the "old proportion", need to be clarified. Consequently, intriguing questions remain:

> Was the roof height (h_{ci}) sufficient to conceal the main floor, or was it merely a living loft? Was the design issue in the facade division up to the cornice, in the roof, or its relationship defined by deliberate "deception" or "ingenuity" in the architectural sense?

Resolving these questions reveals the study's unknowns regarding unruled old houses: a) the total and partial heights and b) the layout of their elements: the external cornice (elevation), its alignment with the AB line (section), and its relationship with the use of the roof (independent or integrated). These parameters clearly articulate the unknown old model between one and two storeys, formulated next.

In summary, our examination of the two-storey elevations, both old (Fig. 4(a)) and neoclassical (Fig. 5(a)), as well as the proposed methodology for deducing the one-storey elevations (Fig. 4(b)−5(b)), clearly presents the graphic issue of the lack of records for the in-between one-to two-storey houses. This provides a solid foundation for the subsequent discussion and research.

5. Identifying the uneven elevation model: parameters and types

Considering the documented elevations and the traditional symmetrical roof model, it becomes clear that a new

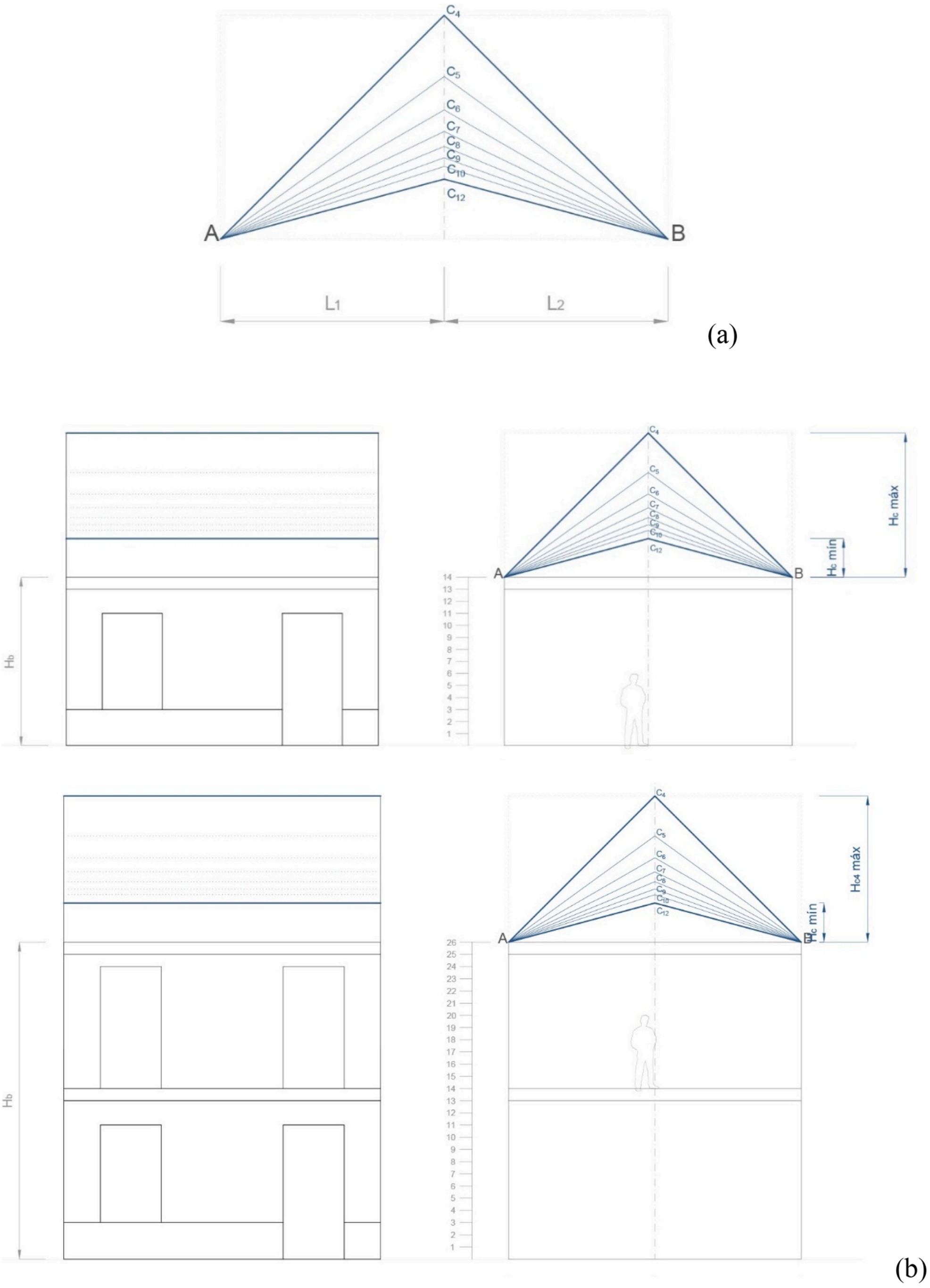


Fig. 6 Model 1. Symmetric cross-section. (a) Roof design according to San Nicolás bevels C_i: (C_4, C_5, C_6, C_7, C_8, C_9, C_{10} and C_{12}) with corresponding angles α_i: (45°, 36°, 30°, 25.7°, 22.5°, 20°, 18° and 15°). (b) One- and two-storey houses with identical front and rear elevations [h_b (14 p) $+$ h_p (12 p) $=$ 26 p], h_{ci} vary according to C_i, $AB = 28$ p ($L_1 = L_2$) (González-Redondo, E. and Bartolomé, A.).

classification is needed for the unknown model between one and two storeys. The essential trusses C_i (Fig. 6(a)), along with a skirt h_c seen on its main facade, whether old or neoclassical, may not present a misleading geometry or appear ingenious (Fig. 4(a)–5(a)). Therefore, to create an exterior malicious silhouette,

> Is it time to consider a new symmetrical yet uneven or asymmetrical layout? Does asymmetry represent a condition of unevenness or knowledge?

Addressing this external inconsistency requires progress in three areas: 1) evidence of verifiable numerical data; 2) analysis of the excessive heights, [$+h$] in facades and [C^+] in roofs, of the recently uncovered two-storey elevations (Fig. 7(a)); and 3) relating these parameters to the lack of "low-rise" houses records. With this data and the proposed methodological framework, the uneven or one-to two-storey height model described below is constructed (Fig. 7(b–d)).

5.1. External height regulation: ratio requirements ($h_t > 22$ p)

The search for early dimensional requirements concludes that the minimum height to the cornice (h_t) required for houses was 22 feet (6.1 m) (Bermúdez, 1738), a key factor in our proposed model. Subsequently, according to the neoclassical reforms aimed at beautifying the capital some decades later, all houses were required to have at least two storeys, both new and extended (RP-1788) (Real Provisión de 1788). It is deduced that there was some deception regarding the *low houses*, although it is not specified whether those built in the past had one storey or concealed a second by only appearing to have one. Therefore, our proposed classification is a significant contribution to understanding historical building regulations.

a) Low (or "inconveniently proportioned") houses were defined as those with a facade height of $h_t < 22$ p; it remains uncertain whether this measurement aligns with the full height of the ground floor (h_b).
b) Two-storey (or "conveniently proportioned") houses were characterised by the sum of the height of the ground floor (h_b) and main floor (h_p), or total height (h_{ti}), being $h_t > 22$ p (Fig. 4(a)–5(a)).

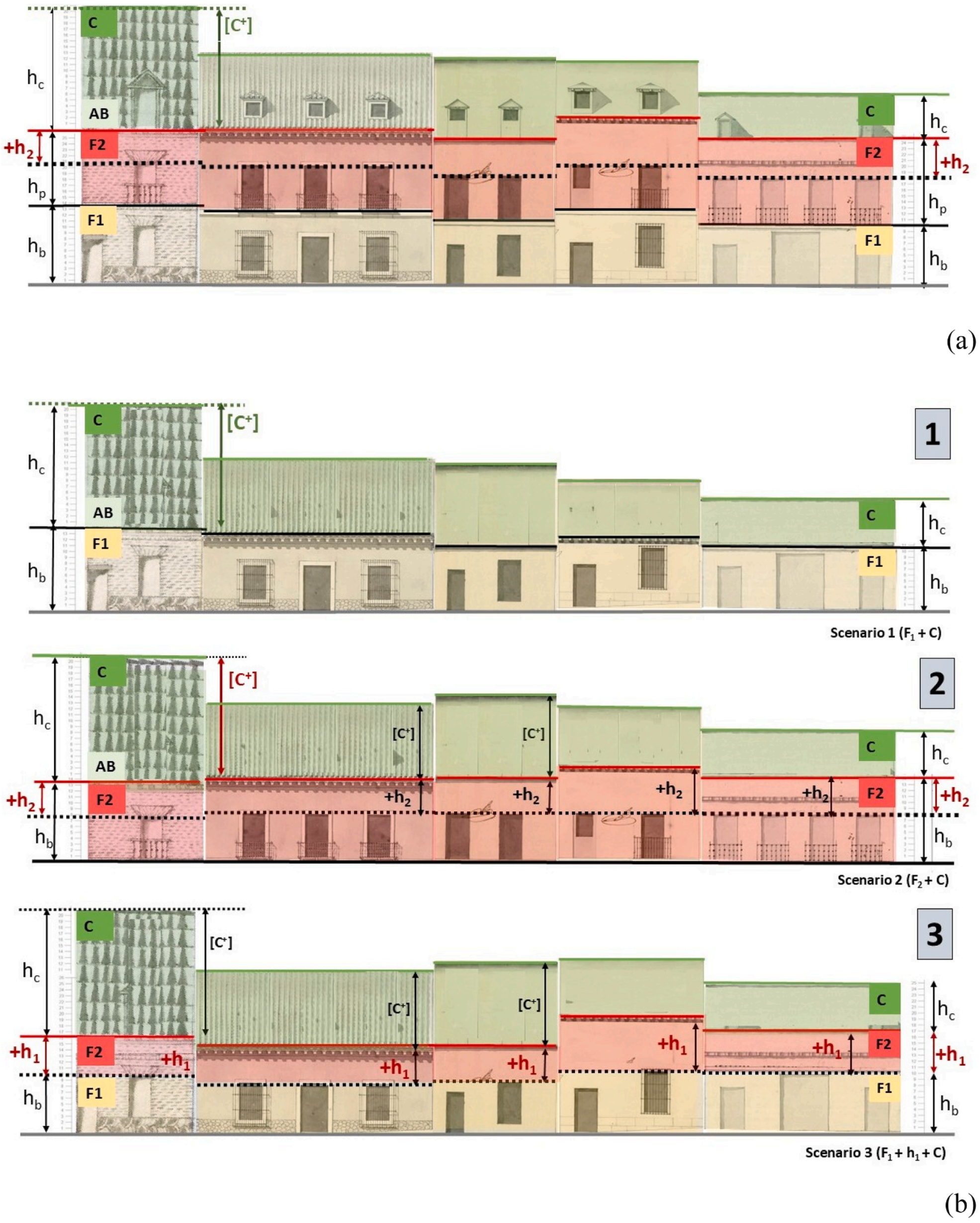


Fig. 7 Façade types [2+ h] with $h_t > 22$ p and [1+ h] with $h_t < 22$ p. (a) Two-storey facade types [2+ h] with $h_t > 22$ p showing the old parameters of external unevenness, excessive heights (h_p) and (h_c). From the left AVM-1.47.40—1742; 1.48.72—1778; 1.48.74—1778; 1.51.77—1790; and 1.50.13—1784. (b) Approaching types [1+ h] with $h_t < 22$ p according to cut-off lines (F_1, F_2, and $+h_2$). Scenario 1 [Ground floor (h_b) + Roof (h_c)]; Scenario 2 [Main floor (h_p) + Roof (h_c)] and Scenario 3 [Ground floor up to F_1 + ($+h_2$) + Roof (h_c)] (González-Redondo, E.).

While this classification is essential because it includes the height of the cornice (h_{ti}) regulation, it does not account for the height of the roof (h_{ci}) or the sum of both ($h_{ti} + h_{ci}$) and also ignores the partial values of the facade (h_{bi}) and (h_{pi}). Therefore, drawing the malice elevations, a crucial aspect of our analysis, and discovering how they concealed the main floor from the street requires the formulation of new hypotheses.

5.2. Parameter [$+h$]: excess facade height (h_{pi}) and types [$1+h$] from [$2+h$]

To date, no inconsistent elevations have been identified with a total height to the cornice $h_t < 22$ p. However, a potential discrepancy is observed in some with greater heights ($h_t > 22$ p). Hypotheses suggest that their second storey might be excessively elevated, leading to their classification as types [$2+h$], assuming the parameter [$+h$] (excess facade height) could be the dimension needed to hide the third storey (Fig. 7(a)). Similarly, the term [$1+h$] (types [$1+h$] from [$2+h$]) is applied to feature the facades of a storey of excessive height, speculating that they attempted to conceal the second storey within that [$+h$]. The proposed methodology for deducing [$1+h$] (with an extra [$+h_1$]) types from [$2+h$] elevations (with an extra [$+h_2$]), as shown in Fig. 7(b–d), is a crucial step in the analysis, providing a systematic approach to understanding and classifying facade heights.

Therefore, the combination of the two previous results, the limitation of the external height to the cornice of 22 p ($h_{ti} < 22$ p) and the parameter [$+h$], completes the classification of low or inconveniently proportioned facades built before their prohibition in 1788.

a) Single-storey facades, or type [$1+C$], were those with an external height at the cornice of less than 14 p ($h_{ti} < 14$ p) (Fig. 4(b)).
b) Malicious facades, or types [$1+h$], were those whose overall height (h_{ti}) was either uneven or excessive for one storey (14 p $< h_{ti} <$ 21 p) (Fig. 7(b–d)).

Consequently, the criteria for evaluating whether the resulting house exhibits aesthetic disproportions, unconventional solutions, or a lack of harmony are based on the heights, sizes, and arrangements of the elements (some approaches shown in González-Redondo, 2024a,b). In short, a [$1+h$] facade type features blind windows and openings of varying sizes, lacking proportion and rhythm.

The previously discussed modelling approach explains the connection between aesthetic disproportions and fraudulent intentions. The underlying rationale is based on the intent to conceal one of the two storeys, either the ground floor or the main floor. When viewed from the street, a [$1+h$] type appears in one of the following ways.

a) The main entrance and windows are placed on the ground floor, leaving the main floor with either blind or small windows, which justifies their use for storage. Consequently, comfortable living conditions cannot be shared with guests.
b) Most of the facade is blind, featuring only the main entrance on the ground floor and small windows on the main floor.

This step underscores the relevance and impact of our findings in understanding the historical context of building heights and their practical applications in building regulations and deceptive practices. So, considering the complete elevation ($h_t + h_c$) now, were there any "malicious" skirts? In addition to the parameter [$+h$], did the external skirt or roof height (h_c) also contribute to the inconsistent appearance?

5.3. Parameter [C^+]: uneven roofs and types [$1+C^+$] from [$2+C^+$]

In search for new uneven parameters; the research takes an important turn when we locate several file elevations having an excessively high outer skirt ($h_c > 10$ p). Singular projects include newly built houses (AVM-1742) and two-storey elevations that extend to the fourth floor.

As previously explained (Fig. 4(a and b)), the proposed cut-off lines (Fig. 7(a)) are now applied to uneven single-storey houses scenarios, resulting in types [$1+h$] with an extra [$+h_1$] derived from types [$2+h$] elevations, with an additional [$+h_2$]. Including the parameters [C] and [$+h_2$] into the analysis and applying the strategy of reducing the [$2+h$] houses to [$1+h$] types, some with disproportionate [C^+] roofs (Fig. 7(b–d)), the following is accomplished.

a) Classify the skirts [C^-]: Low skirts with h_c (4–6 p); [C]: Predominant skirts with hc (7–9p); and [C^+]: Skirts of excessive height or $h_c > 10$ p.
b) Determine new single-storey [$1+C^+$] or two-storey [$2+C^+$] house types.
c) Analyse the impact of this parameter [C^+] on the cross-section's layout.

6. Results modelling hidden geometry: uneven elevation vs cross-section

Conducting a thorough graphical analysis of the uneven exterior silhouette and the subsequent neoclassical requirement to enhance its suitability (RP-1788) leads to two interpretations: either a "bad job" due to clumsiness or a potential hidden skill. This discovery refines the hypotheses linking the elevation inconsistency to the models examined in cross-section (Fig. 8). First, symmetrical sections are analysed (Models 2–4), followed by asymmetrical sections (Models 5 and 6).

6.1. Disproportion vs symmetry

After determining the inconsistent elevations, $h_t < 22$ p, facade [$1+h$] and skirts [C^+], and applying the methodology to reduce the elevations of type [$2+h$] or [$2+C^+$] to types [$1+h$] or [$1+C^+$], the exterior model with facade h_t (14–21 p) and section with C_i is adjusted. By preserving the symmetry condition and establishing the maximum and minimum exterior values (h_i), solutions to conceal the main floor are tested by varying $[(h_b + h_1) + (h_c)]$ and the geometry of the roof *ABC* (Fig. 8).

6.1.1. Model 2. variations of (C_i) and ($+h_i$) with $\mathrm{hb}_{\max}$

Typically, the facade and the roof were independent; thus, in the cross-section, the *AB* line aligned with the slab and the division into one (F_1) or two floors (F_2) was delineated (Fig. 9(a)). However, this is not apparent in the $[1+h]$ facade scenario due to its excessive height (h_t: 15—21 p). The first correction involves placing a slab (F_1) at the varying values $[+h_i]$ (1 p $<[+h_i]<$ 9 p), attempting to fit the second storey (h_{pi}) between the *AB* brace and that floor.

It is found that the height (h_{pi}) is unfeasible for small values of ($+h_i$) (1 p $<[+h_i]<$ 5 p), adjusted with 6 p and feasible between (7—9 p). In these cases, the "malice or ingenuity" of the elevation $[1+h] <$ 22 p may have consisted of blinding that second storey of height $[+h]$, appearing only uneven.

6.1.2. Model 3. floor-slab AB deletion being (h_b) and (h_p) separated by F_1

To this point, line AB, which separates the top floor from the roof, was positioned at the cornice, at h_b for one-storey houses and hp for two-storey homes. However, after questioning the effectiveness of the $[1+h]$ type for (1 p $<[+h_i]<$ 5 p), Model 3 was introduced. It retains the AB points for securing the roof but adjusts the AB brace to the different values of ($+h$), like the F_1 slab.

With this modification, the elevation dimensions (facade + skirt) are combined to optimise the roof height in the section (Fig. 9(b)). This blind height $[+h]$ maintains the external disproportion while optimising the roof's use, even at slight angles, showing research advancement.

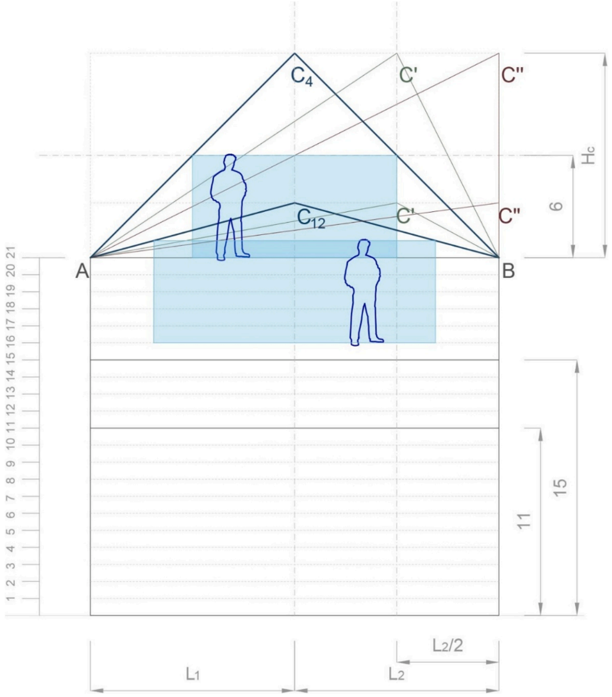


Fig. 8 Study model approaching hidden geometry features testing symmetrical 2D models (1—4) and asymmetrical (5—6). 1. Uneven facade appearance model. 2. Roof design following critical bevels. 3. Cross-section agreeing methodology. 4. Main floor hidden possibilities (González-Redondo, E. and Bartolomé, A.).

6.1.3. Model 4. slab F_1 shifted to minimum position (h_{bmin} = 10 p)

Recent findings suggest that the crucial aspect of the exterior appearance $[1+h]$ may have been the distortion of the exact position of the floor slab (F_1) by covering it with plaster or gaps of different sizes and disordered placements. This conjecture is reflected in Model 4 (Fig. 9(c)). In addition to maintaining symmetry and suppressing *AB*, it shifts the position of the floor slab (F_1) to a minimum height h_b of 10 p. With this height distribution, hp reflects an interior increase $[+h]$ of 4 p, enhancing the model (facade + skirt). This solution aligns with recent evidence.

In conclusion, based on the adjustments made (Models 2—4) shown in Fig. 9(a–c), although some bevels improved the use of the under-roof, only specific measurements close to 22 p would have allowed for the concealment of a second storey. This initial act of mischief or ingenuity of the $h_t <$ 22 p elevations consisted of mainly hiding the interior division from view.

a) Model 2: Features disproportionate parameters $[+h]$ or $[C^+]$.
b) Model 3: Removes the tie *AB*, leaving (h_b) and (h_p) separated by F_1.
c) Model 4: Lowers the floor F_1 to the minimum height of 10 p, hiding its placement.

6.2. Disproportion vs. asymmetry

The proposals analysed in Models 2—4 shift the consequences of the external disproportion to the cross-section by initially considering the facade and the roof independently (Model 2) and then integrating them (Models 3—4). However, additional elements must be present, as this solution, visible from the outside, does not seem innovative. The research advances by introducing the asymmetry condition as a hypothesis. Thus, it shifts the maximum height of the roof (h_c) to non-visible areas and explores different angles in front (α_1) and behind (α_2) (Fig. 10).

6.2.1. Model 5. facade $[1+h]$ and asymmetric section: ($h_{ci} = C$; $\alpha_1 \neq \alpha_2$; $AB \neq F_1$)

Previous models featured symmetrical skirts, equal height outer and rear elevations h_A and h_B, and added the parameters $[+h]$ or $[C^+]$ in Models 2—4. The new model also introduces the asymmetry condition and shifts *C* to C' and C'' (Fig. 10(a)), resulting in:

a) The heights of the front and rear elevations remain constant ($h_{\mathrm{ext}} = h_{\mathrm{int}}$), but the elevations vary, with the rear elevation being steeper ($\alpha_2 > \alpha_1$) and not conforming to the primary elevations.
b) For each roof height (h_{ci}), there is a single elevation but three possible gable ends: at the centre (*C*-axis), centred on the second bay (C'-axis), and on the rear wall (C''-axis).

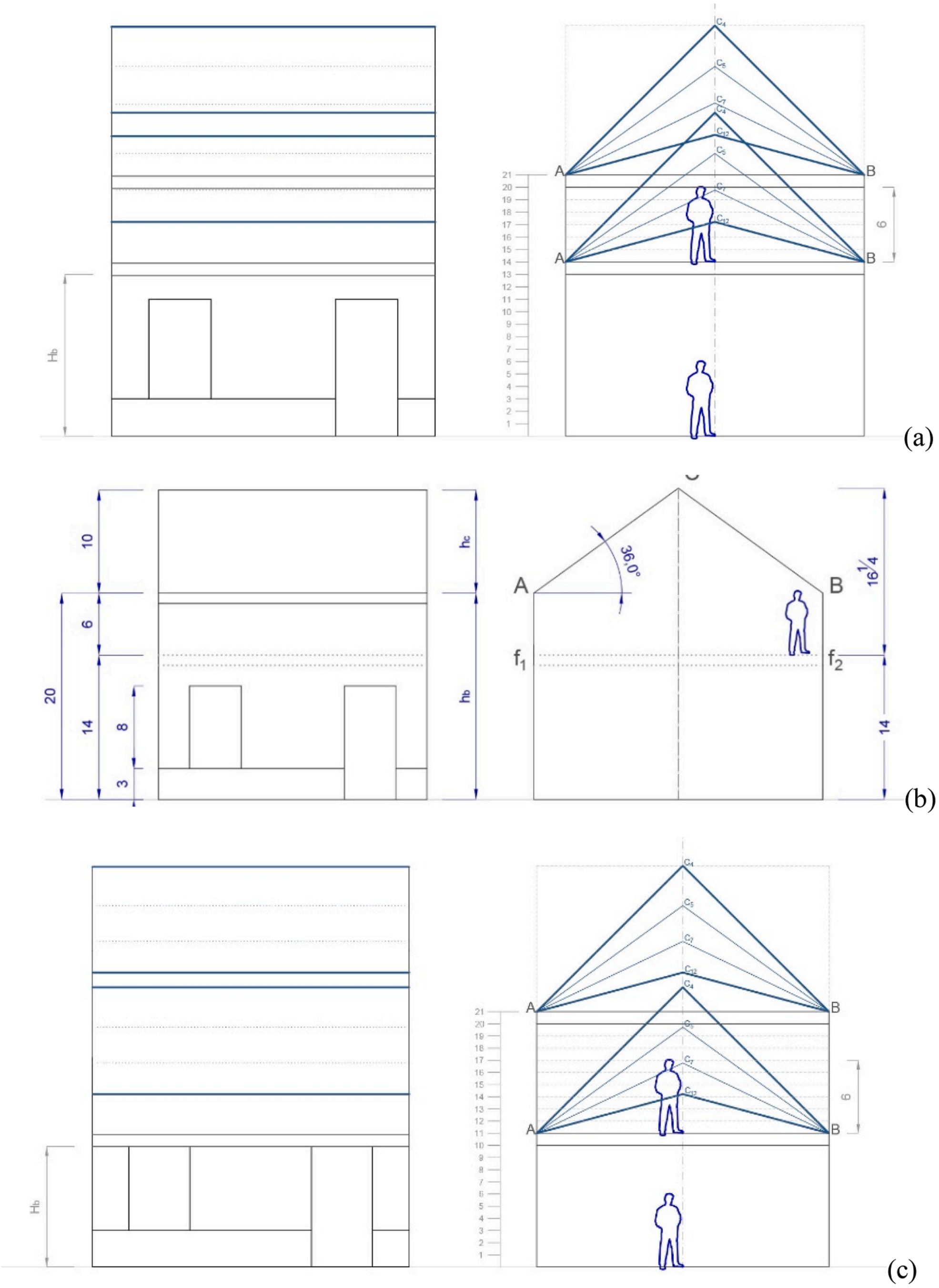


Fig. 9 Models 2—4. Disproportion vs Symmetry. (a) Model 2. Uneven facade [1+ h] with h_t:15—21 p, and symmetrical cross-section with (C_i) moving to $[+h_i]$ values to fit the second storey (1 p $< [+h_i] <$ 5 p). (b) Model 3. AB points fix the roof while shifting the brace to the different values of $[+h_i]$, dividing (h_b) and (h_p) by F_1. (c) Model 4. Floor F_1 is shifted to a minimum height $h_b = 10$ p, effectively concealing its position from the street. (González-Redondo, E. and Bartolomé, A.).

c) The joint study of the elevation and section, shifting *C* to *C*′ and *C*″, reveals differences between the visible and the hidden. From the outside, the roof appears lower than it is ($\alpha_1 < \alpha_2$), and the higher space remains hidden.

In short, this "complex" and oddly proportioned geometry does not optimise the interior space but shifts its usage from the centre to the rear. There may have been "malice" and unevenness, but it lacks ingenuity.

6.2.2. Model 6. facade [1+h], asymmetric section and uneven skirt [C$^+$]

Starting from the previous model, which shifts the *C* axis to *C*′ and *C*″, and by adding the parameter [*C*$^+$] or disproportionate skirt, Model 6 is obtained (Fig. 10(b)):

a) The height of both the front and rear elevations remain constant (Models 1—6), but as in Model 5, they vary, with ($\alpha_2 > \alpha_1$).
b) By setting the primary angles at A and the roof height at C' (half of the second bay) or C'' (rear wall), a disproportionately high roof (h_c) is achieved.

The disproportion of the skirt [C^+], which is equivalent to two storeys in some sections (C_i), is close for specific authorised elevations (AVM-1.47.40—1742) but far exceeds it for others (C_j). Therefore, after addressing the front "disproportion" parameters and analysing the coherence of the entire geometry in the section (Models 2—6), it remains to illustrate the existence of a hidden ingenuity.

7. Discussion: an ingenious geometry is hidden in the enlargements

The starting point was determining the "inconvenient proportion" of the facades, which lacked registers or preserved examples. The final challenge involved completing their layout and resolving the hidden geometry of the floors, roof and back elevation. The proposed systematic approach first analyses the "authorised proportion" elevations (Model 1), establishes the disproportion's parameters and hypotheses and examines its implications in cross-sections (Models 2—6). It remained to bridge the gap between the "low, ugly, and disproportionate" external appearance and a clever solution to conceal the main floor. New evidence emerged, allowing for the final adjustment of the model, thereby demonstrating the proposed methodology's thoroughness and the problem's successful resolution.

7.1. Malice houses enlargements to building the original model

The recent analysis of two files, which display the enlargements of two "malice houses", leads to the final adjustment in Model 7. Both drawings, the elevation on Buenavista Street (AVM-1.48.64—1778) and the cross-section on Jardines Street (AHPM-1759) (Historical Archive of Protocols of Madrid) retain relevant data from their original layout.

The elevation illustrates the final state after the elevation of the main floor and, despite its simplicity, depicts three decisive horizontal lines (Fig. 12(a, b)).

- Its initial height to the cornice (h_t) was 15 p, meaning it conformed to the type [1+h] described (Models 2—6).
- After enlargement, it was found that the ground floor was low-rise ($h_b = 10$ p), as the position of the original floor slab F_1 (Model 4) indicates a dotted line.
- The height of the main floor ($h_p = 22$ p) does not coincide with the slab (F_2), meaning there is a [$+h_2$] and therefore, the tie rod does not align with AB ($F_2 \neq AB$) (Models 3—6).

The cross-section, the only one documented to date, also represents the extension of a "malice house". Although it only includes the enlargement project, it contains a novel geometry analysed below (Fig. 13(a)).

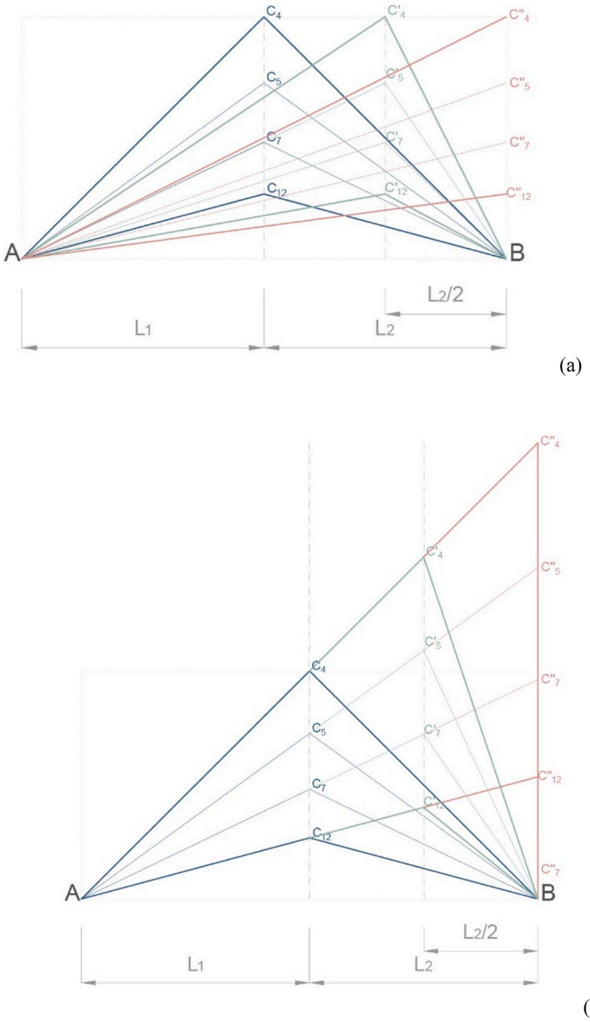


Fig. 10 Models 5—6. Disproportion vs. Asymmetry. (a) Model 5. Roof asymmetrical solutions according to bevels in A and roof height (h_c) in C, C' or C'', where (h_c) is constant. (b) Model 6. Roof asymmetrical solutions according to bevels in A and roof height (h_c) in C, C' or C'', where (h_c) changes (González-Redondo, E. and Bartolomé, A.).

7.2. Analytical approach validation: preserved traces and reversing process

The original elevation (Fig. 12(a)) and the cross-section silhouette (Fig. 13(a)) are reconstructed, considering the original traces shown in the enlarged elevation while preserving the section's layout and simplifying the elevations [2+h] to types [1+h].

The elevation retains the external uneven measurements of Models 2—6.

- The facade is of type [1+h] $<$ 22 p and resembles a "low-rise house".
- The front skirt is larger than the rear, leading to an "inconsistent appearance".
- The floor slab F_1 is hidden from view, and since the height [+h] is blind, it seems to have only one storey.

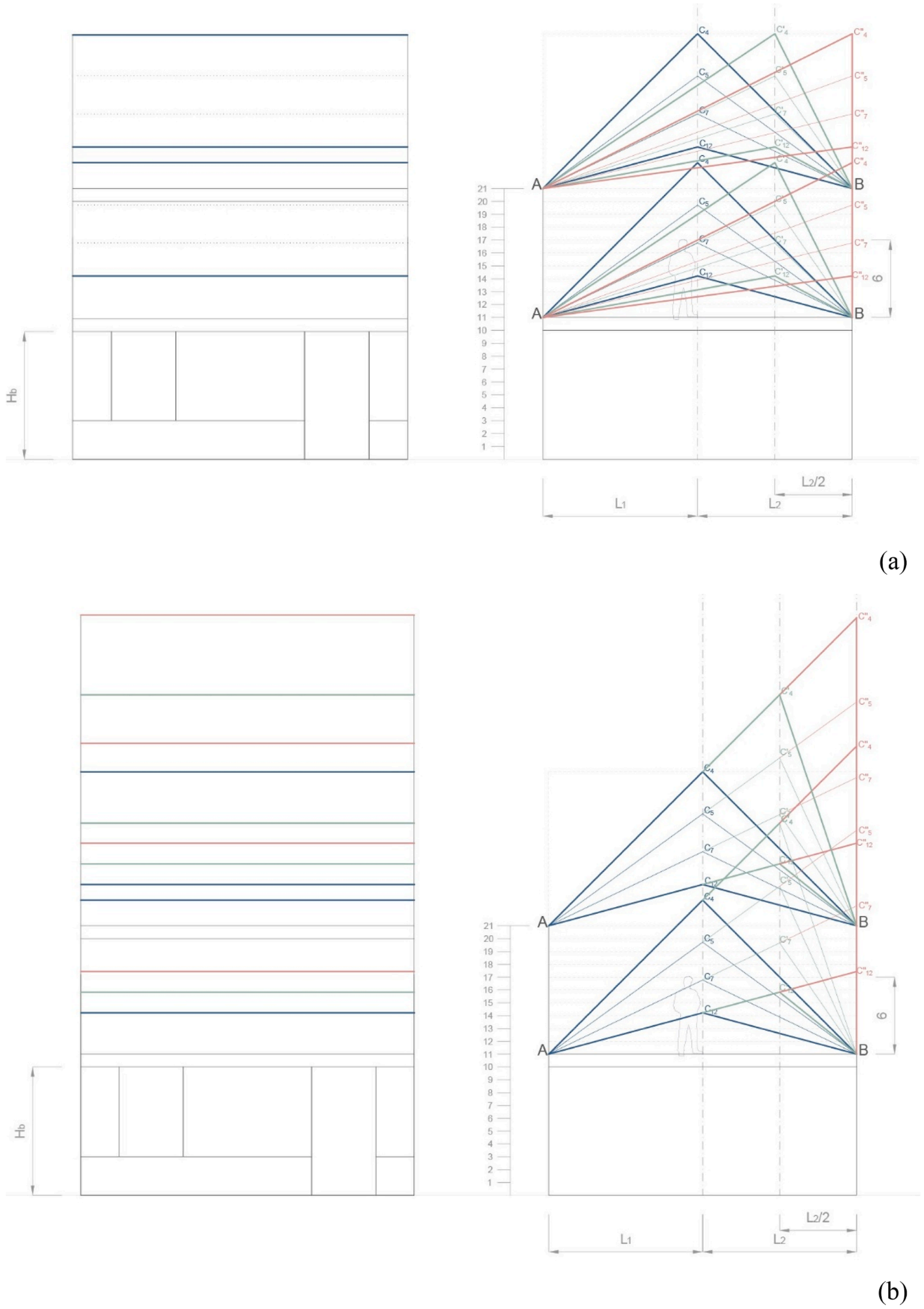


Fig. 11 Models 5—6. Facade [1+ h] and Asymmetric cross-section possibilities searching for rear malice according to C_i and roof support at C, C', C'', $\alpha_1 \neq \alpha_2$. (a) Model 5. Front and rear h_{ci} are constant while varying bevels C_i. (b) Model 6. h_{ci} change (González-Redondo, E. and Bartolomé, A.).

The cross-section conceals the first floor using the geometry tested in Models 5—6.

- The axis of symmetry at *C* in Models 2—4 has shifted to *C'* in Models 5—6.
- The angle employed is a light slope, typical of Madrid.

7.3. Resulting geometry: a hidden ingenuity

The above parameters (Models 1—6) are shown in Figs. 4—11. As illustrated in Figs. 12—13, an ingenious geometry is achieved by raising the rear height from *B* to *B*' (Model 7).

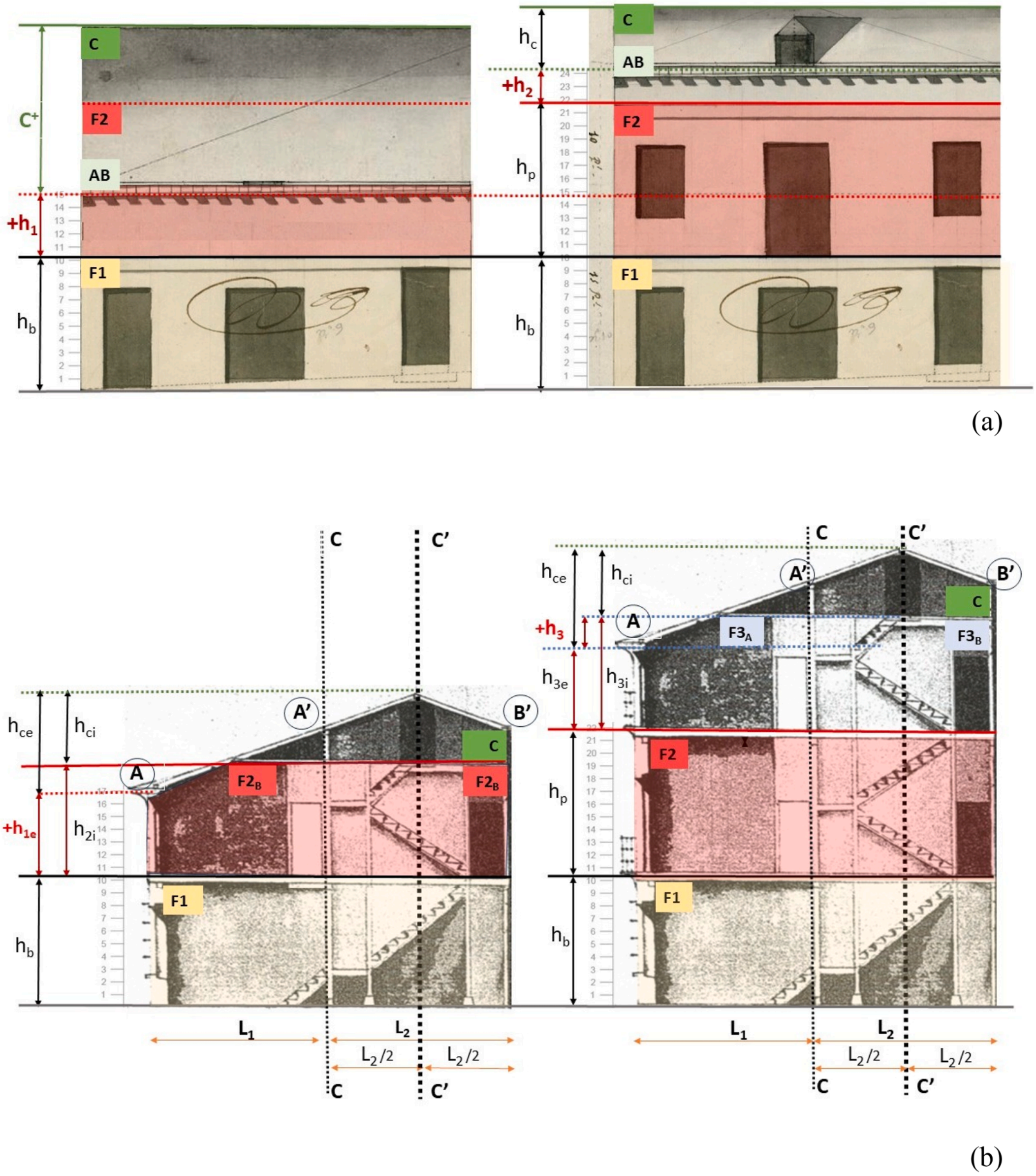


Fig. 12 Reversing malice house enlargements showing original traces and tested methodology. (a) On the right, the final elevation ($h_t = 25$ p): in black, the slab F_1 ($h_b = 10$ p); in red dotted line, the original height up to the cornice (h_b); in red F_2, and green cornice AB from AVM-1.48.64—1778. On the left, the original elevation approach [1+ h] of $h_t = 15$ p, assuming F_1 is concealed ($h_b = 10$ p), considering F_2 higher than AB, thus concealed in the skirt [C^+]. (b) Cross-section: Unequal skirts but a single angle at A, A' and B' and crucial horizontal lines: h_b (10 p) and $F_3 \neq AB$ (AHPM-1759). On the left, approaching the original cross-section, preserving the roof's final geometry and crucial lines to build the [1+ h] type (González-Redondo, E.).

7.3.1. The main floor is hidden (Fig. 13)

- The roof rests on *AB*', achieving a greater height in the rear ($h_{ext} < h_{int}$), strategically hidden from the street (rear malice).
- The loft floor (F_2) is adjusted to a variable position independent of cornice *A*, optimising the top floor's utility.
- The higher the [$+h$], the better the use at the front; however, it is always possible to hide the first floor, even with small [$+h$] values and low angles.

7.3.2. Mastery of an incomplete symmetry (Fig. 13)

- A single angle is maintained on both slopes ($\alpha_1 = \alpha_2$), at points *AA*' (front) and *B*' (rear), as observed in Models 1—4.
- This bevel remains independent of the bay spans (L_1 and L_2), whether equal or unequal.
- C' is consistently located at $L_2/2$. Therefore, the maximum height (h_c) shifts to the second bay (L_2).
- It represents an incomplete symmetry ending at point B', and no B exists. Therefore, the front and rear elevations are unequal ($h_A \neq h_{B'}$).

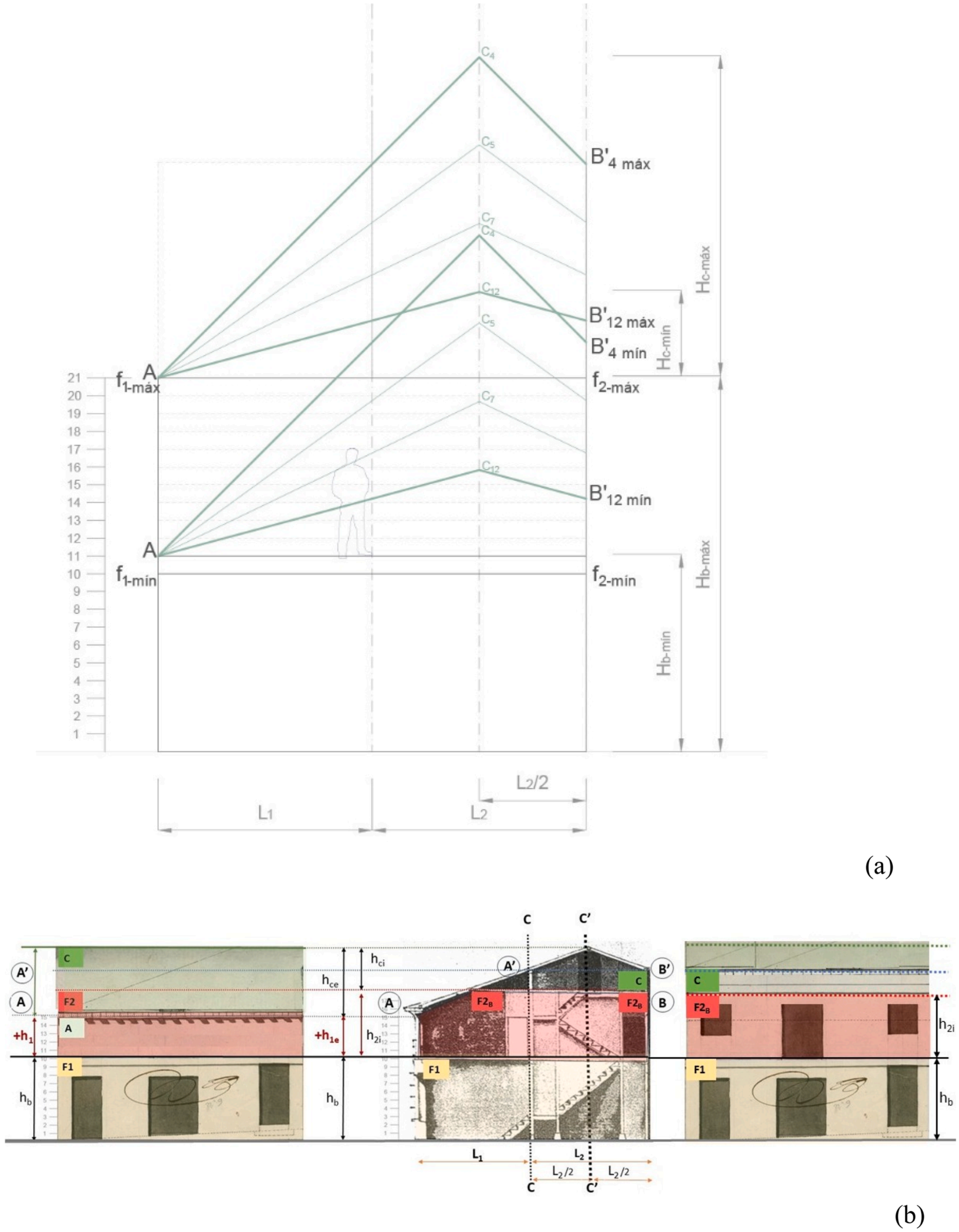


Fig. 13 Model 7. Findings on ingenious geometry. (a) Cross-section. Asymmetrical and incomplete section with the axis shifted to C' having a single angle (at A, A' and B'). Assuming Models 1—6 parameters and the rear height from B to B', the exterior and interior elevations do not coincide, thus hiding the main floor open to the backyard (González-Redondo, E. and Bartolomé, A.). (b) Reversing enlargements. From the left [1+ h] front elevation, cross-section and 2-storey rear elevation.

7.4. Findings interpretation and implications

Unlike other historical cities' early developments, such as Amsterdam, which expanded through new construction by demolishing its walls, and London, which was rebuilt after the Great Fire of 1666, Madrid's city walls limited its growth until 1868. For a long time, it was believed that most preserved buildings in the historic centre dated back to the 1850s and 1860s due to the uniformity that modern balconies conferred to facades. However, research has revealed that building regulations were enforced on newly constructed and relatively unknown enlarged structures. Only through archival research and thorough examinations of load-bearing walls and facade features, including doorways, windows, and balcony sizes and arrangements, can evidence of the expansion of old buildings lead to a more rigorous approach to dating older constructions.

7.4.1. Reshaping our understanding of Madrid's architectural evolution

Symmetrical models are prevalent in Northern Europe, characterised by buildings with identical bay spans, matching front and back elevations, and symmetrical skirts. In contrast, asymmetrical geometries, arising from varying load-bearing wall spacing or differing roof support heights, present challenges for investigation. Previous research highlighted two bay floor plan scenarios: identical spans and varying spans (González-Redondo, 2022, González-Redondo, 2024a,b). However, the lack of elevation and cross-section evidence hinders further study.

This research acknowledges that load-bearing walls were preserved during expansions, providing crucial evidence of a technical foundation when considering the possibilities for inverted roof support designs. Therefore, the significant relationship between these parameters—spans (L_i) associated with load-bearing walls and roof supports (A, B, and C)—justifies the approach to symmetrical and asymmetrical models with integrated or independent geometry.

7.4.2. Discovering malice House's design and its impact on the historical context

Buildings expanded from one to two or three floors, from two to three, with some increasing from two to four and only a few extending from two to five (González-Redondo, 2022, 2024a,b). The authors strongly believe that the parameter ($+h$), in [$1+h$] and [$2+h$] types, is crucial for understanding roof design and its relationship with the later prohibition of dormers. Although still under study, two pieces of evidence are critical for a new integrated approach.

a) On-site surveys indicate that many preserved buildings, ranging from two to five stories, feature taller rear structures than their front counterparts. These buildings showcase spans of varying sizes, with the roof's peak at C', half of the second span $L_2/2$.
b) Recent archival research has uncovered files suggesting that a main floor was planned for construction on the existing ground floor; however, only the front is depicted, and some indicate that the back part was already built. This finding may shed new light on future hypotheses.

8. Conclusion

Research has revealed what can be graphically interpreted as "malice" in the facade and geometrical ingenuity or "know-how" in the cross-section. These findings shed new light on the historical architecture studied.

1) Our analysis of new evidence has brought to light the parameters of the uneven elevation (facade + external skirt): $h_t < 22$ p, facade [$1+h$] and skirt [C^+]. These dimensions align with "malice", a crucial architectural concept of Madrid's low-rise, ugly, and uneven houses, underscoring the significance of our research findings.
2) The proposed methodology, an innovative approach based on five strategies that integrate Models' 1—6 parameters, connects the elevation's external aspect with the cross-section's hidden geometry. It reveals the relationship between the top floor and the roof, offering a new perspective on design knowledge.
3) The reconstruction of the inverse process from the enlarged to the original "malice house", including the preserved traces, reveals the original silhouette, clarifying the unknowns raised and ensuring the accuracy and reliability of the findings.
4) Model 7 reveals the ingenious geometry. The result is a symmetrical (constant angle) but incomplete cross-section with a displaced C-axis to C'. The elevations, front and rear, have the same total height (C'), but their skirts (h_{cext}) and ($h_{c\text{int}}$) and facades (h_{text} and $h_{t\text{int}}$) are unequal.

The resulting roof geometry and a deeper understanding of carpentry solutions open new research possibilities. The next crucial step in reconstructing the historic city is to analyse the newly documented extensions, search for evidence of low floors (10 feet), as in Fig. 12, and roofs of ingenious geometry, as in Fig. 13, while verifying unevenly preserved buildings. This ongoing research promises to reveal even more about Madrid's historical architecture through 3D modelling, which significantly advances our understanding of the city's architectural development and carpentry knowledge.

9. Studies on limitations and directions for future research

Enlargements occurred in three directions: vertically (z-axis), by adding new floors to existing buildings, as indicated by elevation evidence, and horizontally (x and y-axis) in backyards, by extending structures across the building plot, as suggested by floor plan evidence. The pursuit of further advancement through an agreement between elevations (h_b, h_p, h_c), load-bearing wall spans (L_i), and roof design (ABC) revealed key parameters to explore in a basic two-span model (L_1 and L_2).

However, the preserved enlarged buildings are complex, with front and back constructions often inconsistent along the three axes.

a) Enlarged facade analysis aims to uncover historical traces, as some preserved buildings exhibit false balcony rhythms, indicating facade renovations made in pursuit of aesthetic proportions.
b) Floor plans illustrate load-bearing walls and certain inconsistencies in the front and back constructions.
c) Cross-section data focuses on the relationship between load-bearing walls and roof structures of preserved

buildings, supporting the search for original design solutions.

Additionally, the on-site survey indicates larger first bays and a taller back construction. This junction between the front and back constructions presents critical data to explore, considering C, C', C'', B, and B' as key parameters. It seems crucial to determine where the back construction began.

Future research aiming to reverse the enlargements of original buildings suggests retracing steps along the three axes. New data from facade enlargement files, a thorough on-site survey, and necessary hypotheses strive to unveil essential model evidence and key patterns in the more complex preserved models.

HBIM (Historic Building Information Modelling) is essential for advancing research, particularly by linking archival discoveries with physical evidence in preserved buildings. By integrating survey data, historical records, interpretative hypotheses, and material analysis into detailed 3D models, HBIM supports accurate reconstruction and architectural interpretation.

Several resources enhance the potential for HBIM-based studies in Madrid. These include the *Geoportal*, which offers historical maps dating back to 1860; the *General Urban Plan of Madrid*, which provides AutoCAD floor plans of catalogued buildings; and external data from Google Earth. Additionally, recent cadastral data offers basic 3D models of existing buildings, though these models lack roof geometry due to their origin in tax-related floor area estimations.

To reverse historic building traces, future HBIM research should focus on a) reconstructing roof geometries, b) modelling from partial archival sources, c) creating parametric models of historic building types, and d) ensuring documentation and traceability.

City Council support and funding are essential to enable this work and ensure the long-term value of integrating HBIM with archival resources in heritage research and preservation.

Declaration of competing interest

The author declares that she has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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