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# A novel method to characterise multi-family buildings in relation to the position of wet rooms and their flow grids

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**Abstract**

The innovation of this work is the development of a novel methodology which contributes to systemize and rationalize the position of the wet rooms in multi-family buildings typology. The intention of which is to set the predominant vertical position of ducts, pipes, and wires of this kind of buildings and the repercussion of these in the facilities design. The main achievement of this study is the development of a template which allows the establishment of a specific 'label' for each dwelling and, henceforth, claims that a predominant pattern of dwellings exists in the unlimited design of residential buildings in Catalonia. The 'label' determines two critical parameters about the relationship between: a) wet rooms in and between the dwellings, to determine the predominant location of flows in the building, and b) wet rooms and the public and private spaces of the building, to determine the type of accessibility of the layouts of these flows. The main conclusion is that in the case study evaluated, there is a residential typological pattern which opens the way to the elaboration of a new catalogue for the vertical flows in public residential buildings of Catalonia which will allow the reduction of CO2 embed emissions, reduce the energy consumption and reduce the user inconveniences.

**Keywords:** residential typology; vertical ducts; bathroom; kitchen

**Citation**

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## 1. Introduction

The construction sector is rather conservative in terms of new industrialized (Blachère, G. 1977) design models, although some of the branches of buildings are already beginning to be highly industrialized (structure and construction systems) (Paricio & Sust, 1998). However, facilities are designed and installed following the same conceptual base as from the mid-twentieth century, despite it being one of the branches with the most growth and technological complexity. Throughout history, renowned architects have worked in the field of the facilities industrialization. Some of the most

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highlighted cases are B. Fuller with his Dymaxion house in 1920-1945 (Seguin & Seguin, 1973) and 4D tower in 1928 (Buckminster Fuller, 1972) or the J. Prouve with the Maison Les Jours Meilleurs in 1956 (Prouvé, J. 2014). Other influential trends of novel thinking were Archigram group and Peter Cook (Chalk *et al.,* 2018) or the support Theory from Habraken in 1962 (Habraken, 2000). These proposals dealt with the impact of the wet rooms and their facilities layout regarding the industrialized design of the building.

This study provides tools to contribute to the qualitative leap that must be taken in the design and implementation of the facilities associated with the vertical flows in multifamily residential buildings of Catalonia at present and with the available technology. This typology has been chosen as a field of work because it best reflects the continuity of the vertical flows in a building and also because it is the most predominant typology (around 50% of the total building sector of Catalonia).

In the field of multifamily buildings, a large number of studies have looked into the residential sector through different frameworks and parameters. For instance, some examples are focused on the volumetric shape of the buildings (Romero, 2013), others on the year of their construction (Valencian Institute of Building, 2011), while there are others that are focused on the space syntax parameters through the time (Yaylali Yildiz *et al.,* 2018).

Additionally, there are cases that cross variables such as the quality of the city and the territory in coordination with the optimization of the use of technologies and sustainability (Muxí & Montaner, 2013). At the specific level of wet rooms, at Spanish level, there are studies of the characterization and optimization of the functional organization chart of the wet rooms (Carreiro & López, 2019) and this concept is combined with the volume and position of the facility layouts in a study in Catalonia (Roca & Zamora, 2000). Nevertheless, none of these exhaustive works allow the characterization of the infinite multi-family residential sector according to the wet room positions.

The innovation of this work is the development of a novel methodology which contributes to the systematization and rationalization of the multi-family buildings. The case study of this methodology has been developed in Catalonia from the point of view of the position of the wet rooms within the dwelling and, in turn, the whole building.

This feature will provide a pattern of vertical facilities grids (ducts, pipes and wires) that will encourage the industrial market to assess new lines of work in the field. Additionally, the new facility core component will contribute to the need to get back to the environmental claim, in terms of reduction of $CO_2$ emissions, use of resources and waste generation, and additionally, the social demand defined by the level of users' comfort, guarantees of quality and durability, reduction of execution time and economic cost. Another purpose is that this methodology can be easily replicated in other areas or countries and even building typologies.

To guarantee the neutrality and reliability of the results from the typological analysis, a building selection from two publications has been used. These are a compendium of a multiple call for residential proposals by the public administration in Catalonia having analyzed a total of 67 buildings, randomly selected.

In order to apply the novel methodology, a template has been designed that allows the establishment of a predominant pattern in two levels: aggregation and accessibility of the wet rooms in situations both inside a dwelling and inside the building. The template presents a novel graph and nomenclature which becomes a label that enables the cataloguing of the immeasurable residential sector design.

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## 2. Novel methodology for characterizing multi-family market

To delimited the scope of the work, this study has been considered the Catalonian region market. Furthermore, as a consequence that the diversity of the residential design sector being unlimited, the work methodology has been structured in 3 levels:

- Baseline scenario: the latest compendium publication of the multi-family competitions executed by the public administration of Catalonia ensures the neutrality of the study sample.
- The template: this tool has been developed to group the several residential building designs under a limited number of typologies in relation to the position of wet rooms. The structure of this template creates a label.
- The label: it allows the establishment of whether or not it is feasible to achieve a limited and serial catalogue of components that promote the emergence of a chain of industrial production, in relation to the facilities layout.

### *2.1 Baseline scenario*

To develop the typological analysis, a building selection from two publications *Concursos d'Assistència Tècnica-CAT* (Generalitat de Catalunya, 2007) and Concurs d'Innovació Tècnica-CIT (Generalitat de Catalunya, 2007) has been considered. This publication ensures a wide representativeness of the multi-family building sector diversity (Carreiro & López, 2019).

To demonstrate if there is a predominant pattern in the location of wet rooms the key data is to know a wide range of types and not the detail of the relative quantity of each type, the final number of buildings analysed amounts to a total of 67. The publication date of the document is before the last housing crisis because the volume of the construction was more replicative. Since these publications the possibility has not existed to promote a high enough number of tenders in the residential sector to generate a new publication with a significant critical mass (Dey, 2006).

### *2.2 Building template*

The template developed allows the establishment of the number and type of different dwelling typologies and if there is a predominant pattern. The resultant template describes each dwelling in 2 levels:

- The header describes the building: authors, location, architectonic configuration and number of facades.
- Typological description is split into two parts:
  - Building: number and use of floors, type of stairway core, number of dwellings per building.
  - Dwelling: Definition of the relationship between wet rooms at three relationship levels, between: wet rooms within the dwelling (Individual Aggregation), with neighbours (Collective Aggregation), and with public or private spaces of the building (Accessibility).

These "concepts" are presented in the template below and evaluated in a novel graph and nomenclature which produce the label.

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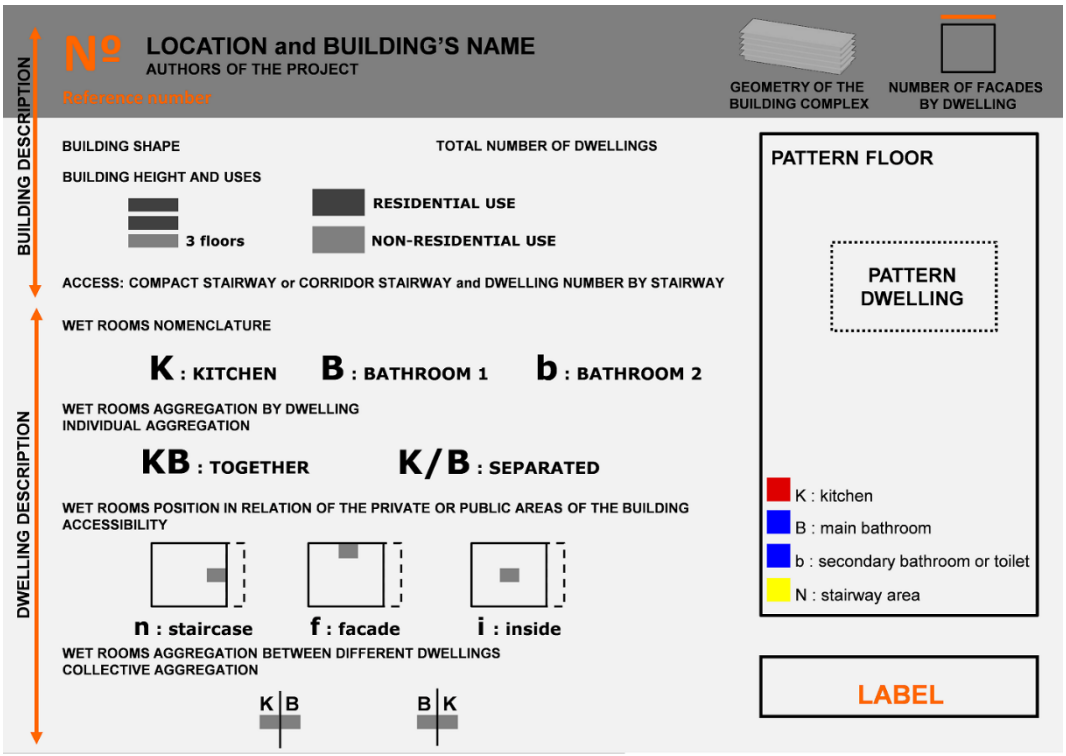
Figure 1. Template structure




Source: own elaboration.

## 2.3 *Dwelling Label. Symbolism and nomenclature*

This section describes the symbolism and nomenclature developed especially for this study.

To define the Individual Aggregation, the next acronyms have been used: 'K' represents the kitchen, 'B' for the main bathroom and 'b' for other bathroom or toilet. It depends on the relationship between these wet rooms, you can find these acronyms written together o separated by a forward slash (/). The Figure 2, the dwelling located in the left of the arrange all the wet rooms in the same point of the house and in the right, all the wet rooms are separated inside of the house.

Figure 2. Individual Aggregation examples. Left maximum level of grouping and right minimum level


Source: own elaboration.

The next step to define is the Collective Aggregation. If there are two wet rooms together from a different dwelling the acronym is '$^2$' above the letter of the wet room affected. For example, a $K^2B^2b^2$ label reflects that there are two dwellings with all the wet rooms in contact (see Figure 3).

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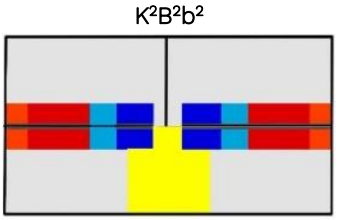
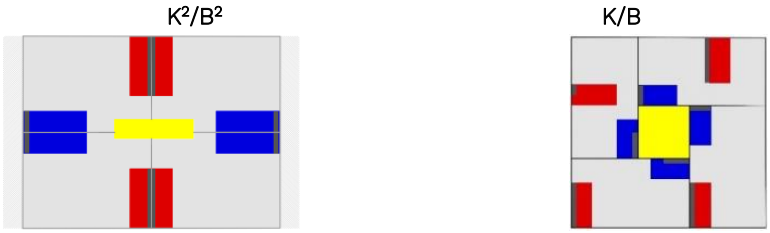
Figure 3. Collective Aggregation. Example of maximum grouping




Source: own elaboration.

Another case, is the $K^2/B^2$ label which represents a dwelling with separated wet rooms but arranged with the neighbour's wet rooms. The K/B is the most fragmented case, all wet rooms are separated inside and outside of the dwelling. This last label increases the difficulty of establishing a pattern to develop a new industrial process of production of the facilities layout (see Figure 4).

Figure 4. Collective Aggregation. Left medium grouping, right segregate rooms

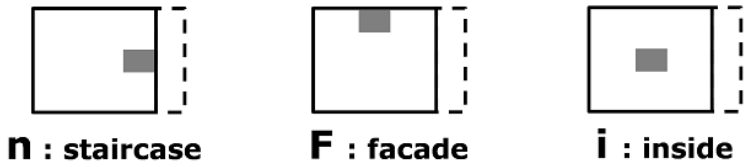



Source: own elaboration.

Once the grouping level is defined, the next step is to evaluate the position of wet rooms in relation to the public or private spaces of the building. The key factor is to establish the optimized layout of facilities in relation to maintenance tasks.

The graphical representation of this concept is reflected in Figure 5 where the wet rooms are drawn with a grey rectangle embedded in the black line square which represents the dwelling and the hall and stairway are shown as a rectangle with a broken line. This graphic is complemented with the introduction of acronyms in the before 'label', where 'n' means that the wet room is in contact with the stairway area, 'f' in contact with facade (facade at the main street, or an inner block courtyard or ventilation and service courtyard and 'I' when the wet room is inside of dwelling without contact with public areas of the building.

Figure 5. Accessibility concept. Symbolism and nomenclature




Source: own elaboration.

'f' and 'n' are walls in contact with public spaces, but there is a critical difference between them when it comes to the associated infrastructure for maintenance tasks. In the case of a facade, a scaffold must be installed in order to gain access to the facilities grid which implies a considerable economic and time cost.

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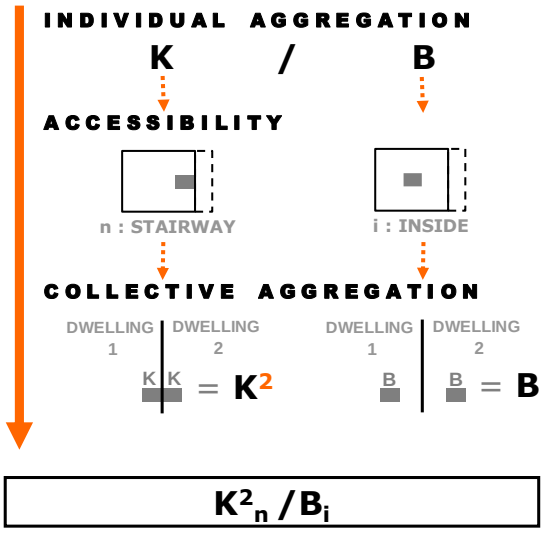
See in Figure 6, the final result of the new label for dwellings.

Figure 6. Dwelling label. Symbolism and nomenclature




Source: own elaboration.

The study of 67 residential buildings has resulted in 107 templates of different type of dwellings.

## 3. Results and discussions of the typological analysis and label result

The main objective of this labelling is to establish the final number of different labels in a dwelling typology in relation to the wet rooms and if it is possible to catalogue the residential sector.

### *3.1 Building level*

Regarding the buildings studied in Catalonia, the most predominant height is between 3 and 5 floors (exactly, 85%), and the most predominant case is a building with 4 floors (40%). The most common use of the ground floor is residential.

In terms of the stairway, there are two different typologies, when the access at the dwelling is directly from the stairway (hereafter named compact stairway) or when the access is through a corridor (hereafter named corridor stairway). 45% of the buildings studied are designed with a compact stairway (usually associated with square shape buildings) and 55% by corridor stairway (associated at narrow rectangular shape of the building).

Finally, the number of facades by dwelling, the predominant typology is dwellings with one facade (53%), followed at a considerable distance the typology with two facades (39%) and less usual, with three facades (8%).

### *3.2 Dwelling level*

The achieved results will be detailed in 3 levels: aggregation level, accessibility level, and aggregation and accessibility level at once.

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### 3.2.1 *Aggregation level*

From the results of the 107 templates, it can be said that there is a broad desire for grouping wet rooms, exactly 92% of cases.

- *Individual aggregation*

Table 1 presents the rating of the individual aggregations. As it can be observed, the classification of the resulting labels is delimited to six typologies (i.e. KBb, KB, K/Bb, KB/b, K/B, K/B/b). The KBb label is the typology with the highest number of wet rooms aggregation while the K/B/b contains the least cases. Based on the results, it can be mentioned that only five of the labels have been matched with the analysed building cases (i.e. 67 buildings), excluding the K/B/b label.

Table 1. **Rating of individual aggregation**

| Individual Aggregation | |
|---|---|
| Label | Dwelling number |
| KBb | 7 |
| KB | 40 |
| K/Bb | 9 |
| KB/b | 2 |
| K/B | 49 |
| K/B/b | - |

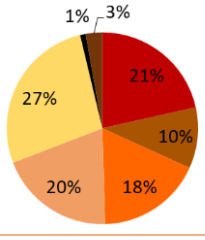
Source: own elaboration.

In terms of grouping, it is detected that more than half of analysed dwellings (54%) place wet rooms together inside the same dwelling, against 46% which detach these.

- *Collective aggregation*

Without taking into account the individual aggregation, the number of different labels in this section is 8, one of which is not represented in the study (Table 2). Once again, the most fragmentised typology was not found.

Table 2. **Rating of collective aggregation**

| Individual Aggregation | | | |
|---|---|---|---|
| Type of aggregation | | Nº dwellings | % of analysed dwellings |
| None aggregation | | 23 |  |
| K1+K2 | | 11 | |
| K1+B2 | | 19 | |
| B1+B2 | | 21 | |
| KK+BB | | 29 | |
| K1B1+K2 | | 1 | |
| K1B1+B2 | | 3 | |



Where,
K1 is the kitchen of one dwelling
K2 is the kitchen of the neighbour dwelling
B1 is the bathroom of one dwelling
B2 is the bathroom of the neighbour dwelling
+ means that both wet rooms are in touch
/ means that wet rooms are separated
KK+BB means that all wet rooms of two neighbour dwellings are together.

Source: own elaboration.

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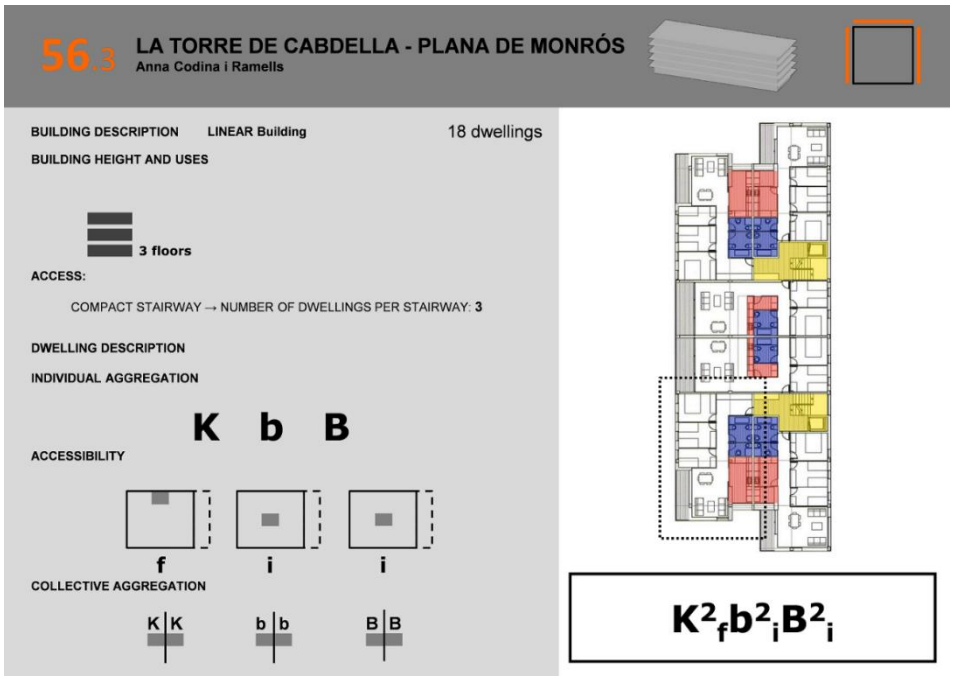
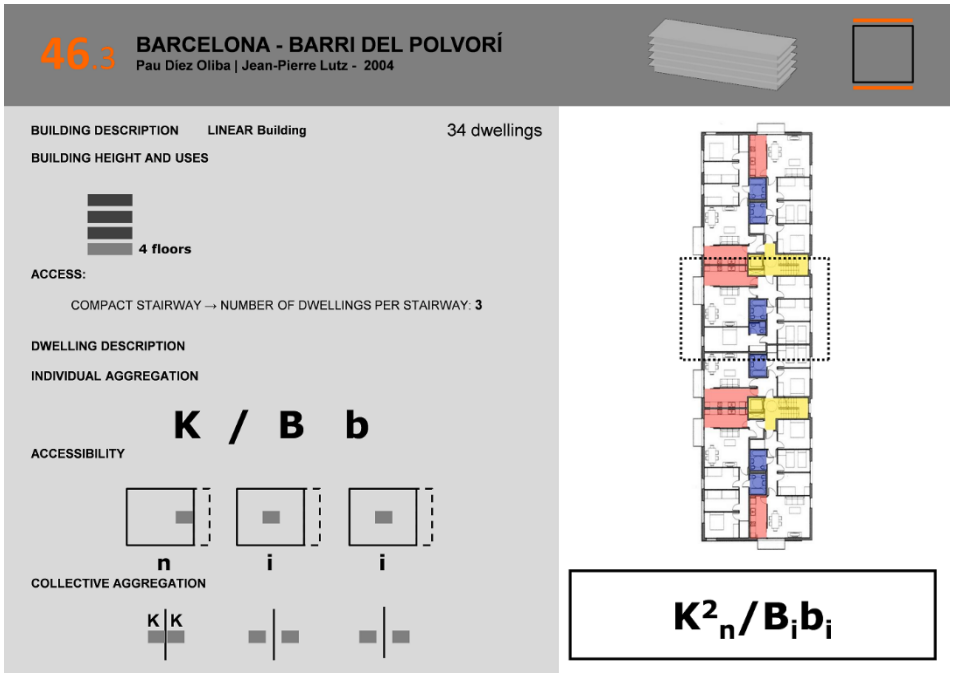
More than three quarters of dwellings (78%) promote some type of collective aggregation, the $K^2B^2b^2$ the most replicated grouping typology and the $K^2/Bb$ is the least seen. Figures 7 and 8 show some examples.

Figure 7. Maximum level of aggregation




Source: own elaboration.

Figure 8. Lowest level of aggregation




Source: own elaboration.

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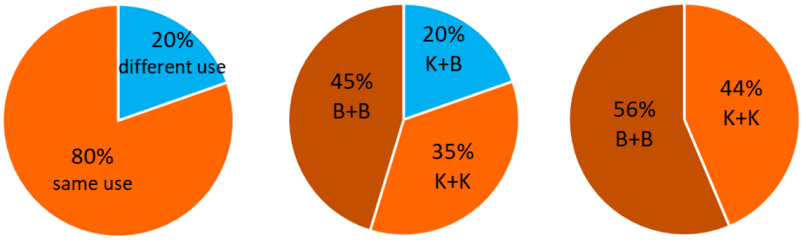
The most replicated typology is when the wet rooms are grouped together inside the dwelling and also with the neighbour (K2B2).

The next step is to identify the use of each wet room and define if the most common aggregation is of the same or different use. This considers whether kitchens (K+K) or bathrooms (B+B) or one kitchen and one bathroom (K+B) are together. The Figure 9 shows that the most replicated typology is the same use aggregation (80%): 45% grouping bathrooms and 35% kitchens. Finally, only 20% of cases group different use wet rooms, kitchen and bathroom.

Figure 8. **Percentage of collective aggregation by uses**




Where, 'K' is kitchen and 'B' is bathroom

Source: own elaboration.

- *Individual and Collective aggregation at once*

In this case, the number of labels increases exponentially but remains limited. Exactly, 34 different labels of which only 20 typologies are found in this study. Once again, the absent typologies are when the position of wet rooms is most fragmented. (Table 3).

Table 3. **Rating of individual and collective aggregation**

| Individual and Collective Aggregation | | | | | |
|---|---|---|---|---|---|
| highest aggregation level | | medium aggregation level | | lowest aggregation level | |
| label | number of dwellings | Label | number of dwellings | label | number of dwellings |
| $K^2B^2b^2$ | 2 | $K^2/B^2b^2$ | 1 | $K^2/B^2$ | 25 |
| $K^2B^2b$ | 2 | $K^2B^2/b^2$ | - | $K^2/B$ | 5 |
| $KB^2b^2$ | 1 | | | $K/B^2$ | 11 |
| $K^2Bb$ | 1 | $K^2/B^2b$ | 3 | K/B | 8 |
| $KB^2b$ | - | $K/B^2b^2$ | 2 | | |
| KBb | 1 | | | $K^2/B^2/b^2$ | - |
| | | $K^2B^2/b$ | 1 | $K^2/B^2/b$ | - |
| $K^2B^2$ | 13 | $K^2B/b^2$ | - | $K/B^2/b^2$ | - |
| $K^2B$ | 4 | $KB^2/b^2$ | - | $K^2/B/b$ | - |
| $KB^2$ | 10 | | | $K/B^2/b$ | - |
| KB | 13 | $K^2/Bb$ | 2 | | |
| | | $K/B^2b$ | - | K/B/b | - |
| | | | | | |
| | | $K^2B/b$ | - | | |
| | | $KB^2/b$ | - | | |
| | | $KB/b^2$ | - | | |
| | | | | | |
| | | K/Bb | 1 | | |
| | | KB/b | 1 | | |

Source: own elaboration.

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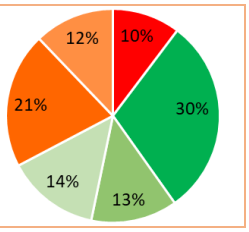
### *3.2.2 Accessibility level*

The importance of analysing the relationship of wet rooms with the public or private spaces of the building is due to the repercussion on the facilities grids maintenance tasks over the lifespan of the building (Ritter y Lopes, 2018). The only way to eliminate the right of way of the facilities grids in dwellings is by locating wet rooms in contact with publics spaces. This approach ensures the users comfort over the lifespan of the building (Slaughter, 2001).

This section has the largest number of different labels, 126, but the number is still limited. Table 4 shows the percentages of accessibility level, where the highest value of representation corresponds to the dwellings which connect all wet rooms with the stairway area (30%, see an example in Figure 10) while the least represented is the typology which locate all wet rooms inside the dwelling (10%, see Figure 11).

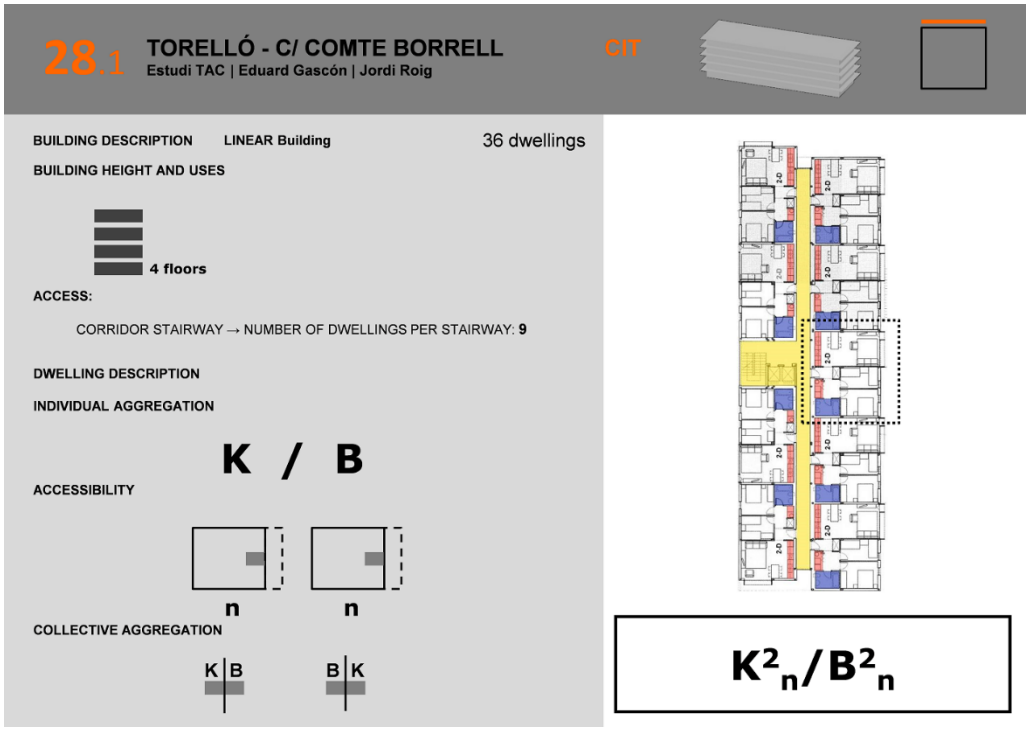
Table 4. **Accessibility level percentages**

| | |
|---|---|
| | All wet rooms are located inside the dwelling |
| | All wet rooms are located attached to the facade |
| | All wet rooms are located attached to the stairway area |
| | One wet room is in contact with facade and one the stairway |
| | One wet room is inside and one in contact with the stairway |
| | One wet room is inside and one in contact with the facade |




Source: own elaboration.

Figure 9. **Contact with stairway**




Source: own elaboration.

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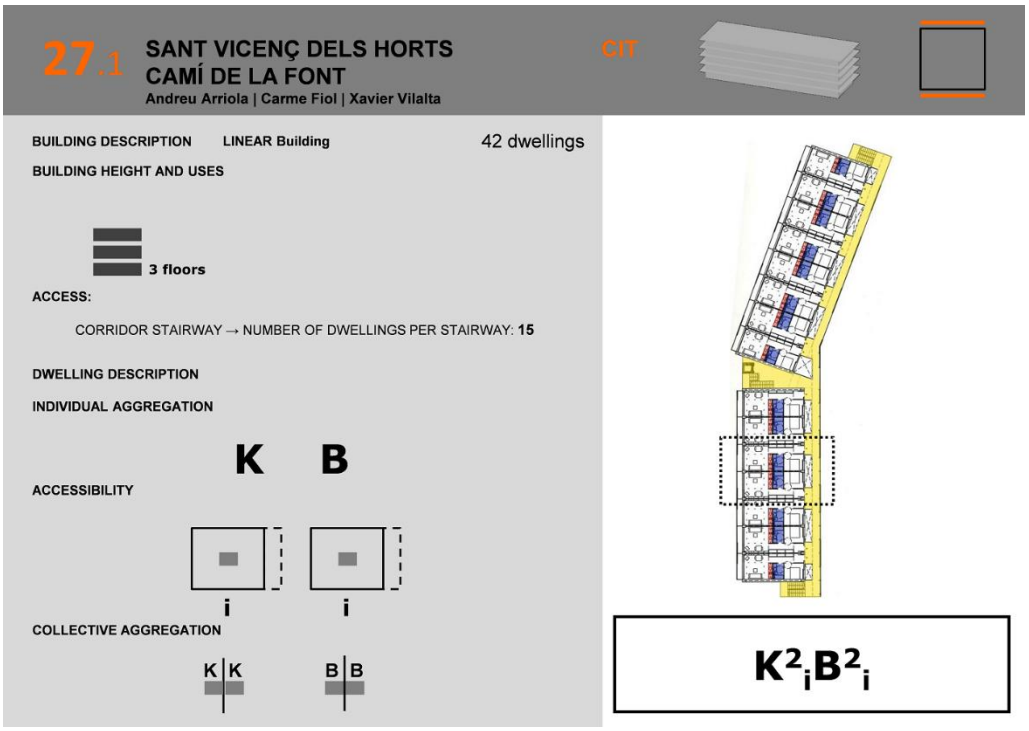
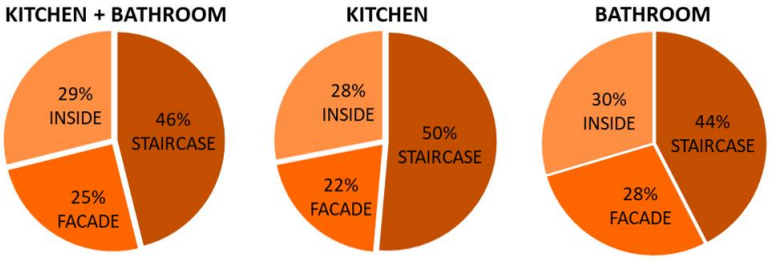
Figure 10. Inside dwelling




Source: own elaboration.

In more than half of the cases have at least one wet room in contact with a public area of the building. Considering the use of wet rooms, the most replicated case is the kitchen in relation with the stairway area, which promotes the access to the facilities grid from public area without additional infrastructure. You can observe the detailed results in the Figure 12.

Figure 11. Position of wet rooms according to their use




Source: own elaboration.

To finish the analysis of the accessibility level, it is worth highlighting a couple of typological particularities which are not important at label level but are a consequence of the design bases and have impact on the design of the facilities grid.

The first case is the wet rooms located in the central part of the dwelling. In 10% of cases, the architect has had special sensitivity in the design placing an annexed service courtyard that allows the transport of the facilities grids and carries out maintenance tasks, eliminating right of path for users (Figure 13). Moreover, they take advantage of the courtyard as a project strategy that enhances the entry of natural light and natural ventilation into the interior of the dwelling; and in some cases as a space for natural drying of clothes.

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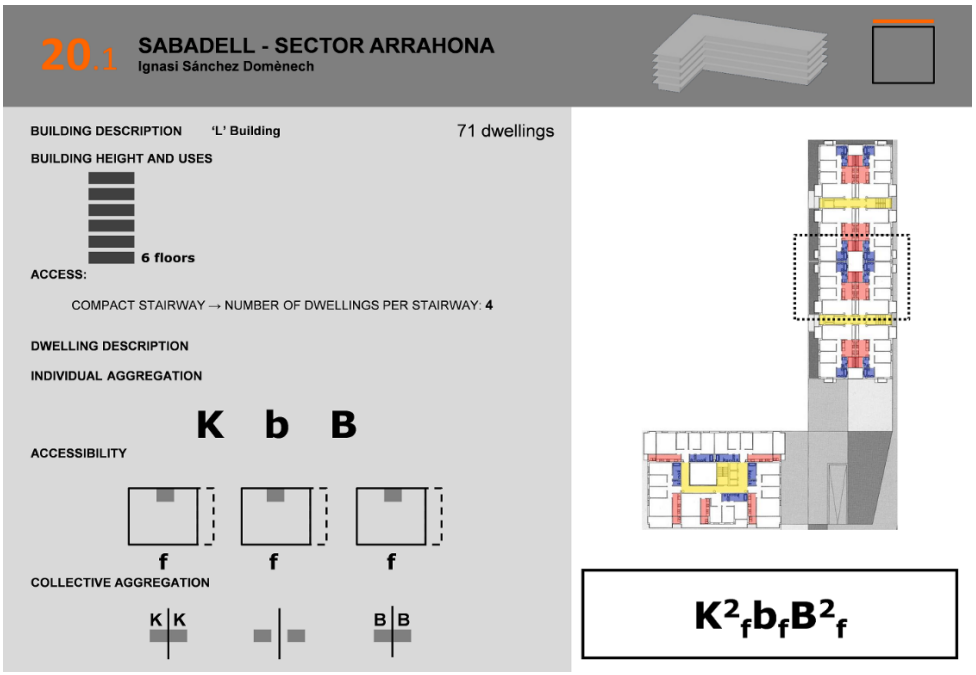
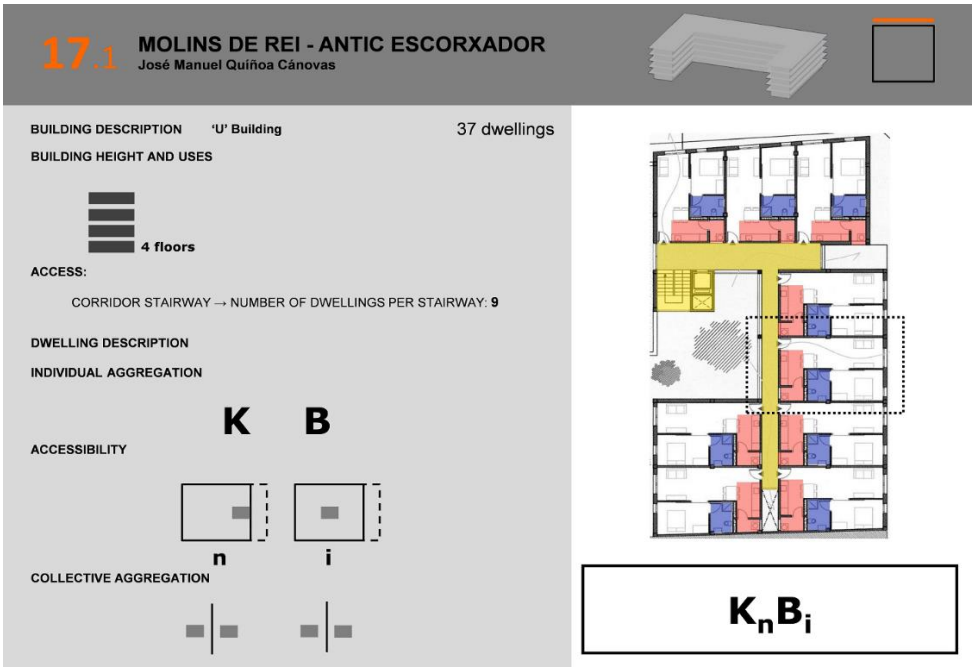
Figure 12. Dwelling with a courtyard attached at the wet rooms




Source: own elaboration.

The second feature is the typology that groups the kitchen and the bathrooms (9%) in a single package, where one wet room is linked with the stairway area and the other one is inside the dwelling. This provision would allow more flexibility in the design strategies of a new model of facilities grid. The interior facilities grid can be connected with the same vertical grid of the wet room connected in the stairway area (see Figure 14) with regard to increasing the horizontal facilities grid of the dwelling.

Figure 13. Example of dwellings with one room annexed at stairway and one inside



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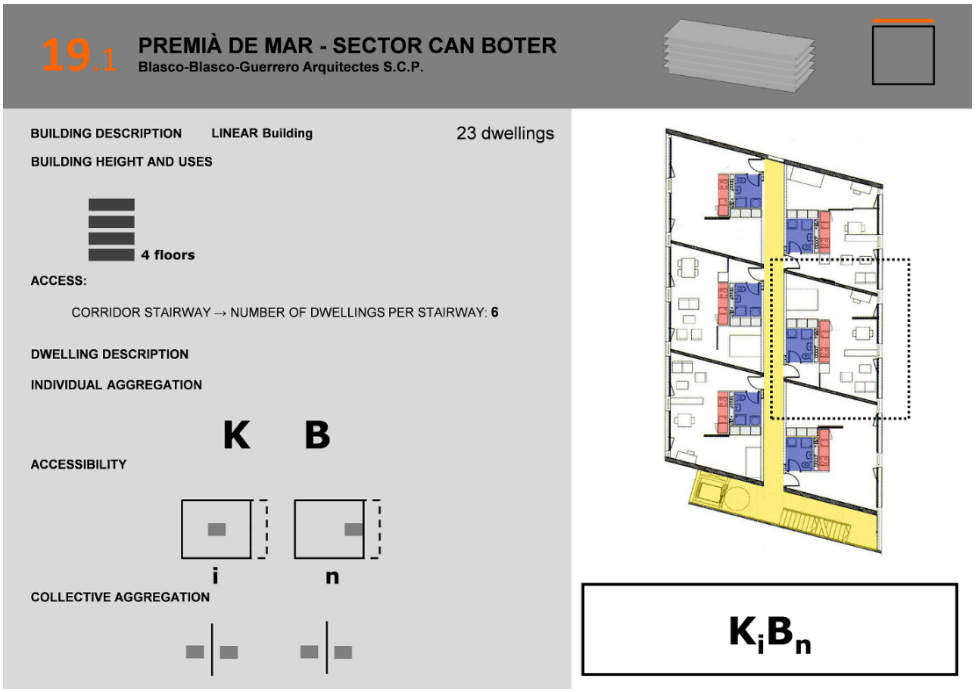


Source: own elaboration.

### *3.2.3 Aggregation and Accessibility simultaneously*

In this section, the number of labels increase considerably. As a result of this, a diagram graph has been developed to provide point clouds with the most replicated typologies. The framed circles in black correspond to the dwellings published in the CIT and the symbolism and nomenclature are summarised below.

Wet rooms:

K: Kitchen; B: Bathroom 1; b: Bathroom 2 or toilet

Position of wet rooms in relation to public and private areas of the building:

'I'=interior: all wet rooms placed inside dwelling
'f'=façana: all wet rooms attached to a facade
'n'=nucli: all wet rooms attached to the stairway area
i-f: one wet room placed inside and the other attached to a facade
n-i: one wet room attached to the stairway area and the other inside
n-f: one wet room attached to the stairway area and the other to the façade

Number of facades by dwelling:

- dwelling with 1 facade
- dwelling with 2 opposite facades
- dwelling with 2 consecutive facades
- dwelling with 3 facades

Accessibility levels:

- Group A: K and B attached to public areas of the building
- Group B: K and B attached to private areas of the building
- Group C: hybrid solution. One room attached to public area and the other to private

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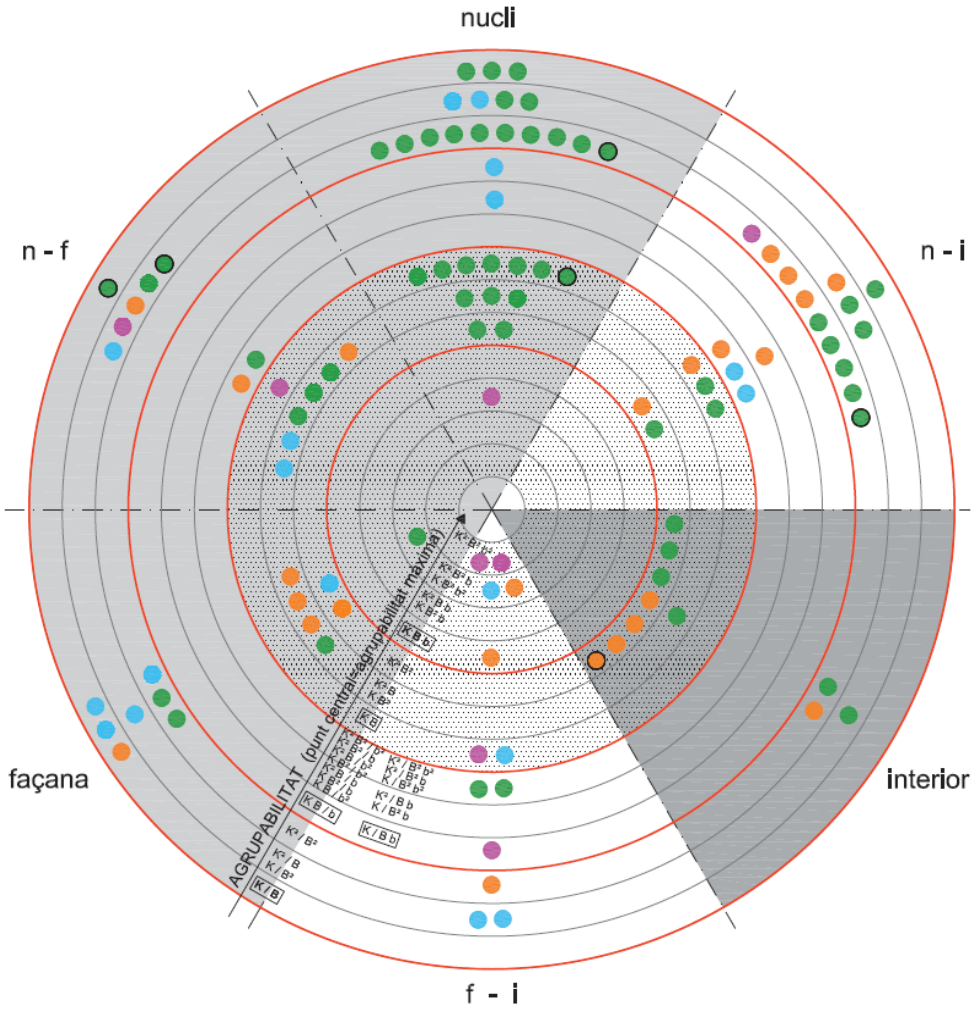
The main conclusion from the above graph (Fig. 15) is that there are three important tendencies at accessibility level: Group A includes dwellings with all the wet rooms attached to public areas of the building (57%); Group B is the opposite case, all the rooms are inside (10%); and Group C, the hybrid solution (33%).

Figure 14. **Residential point cloud graph**




Source: own elaboration.

## 4. Conclusions

The main conclusion is that there is a residential typology pattern regarding the position of the wet rooms in a multi-family building. This fact opens up the opportunity to create a new design of the facilities grid which can be marketable through a catalogue.

Partial conclusions:

With relation to the building description, the height of the building has to be considered as a decisive point to establish rules in a new model of facility grid design in multi-family building. In this study and for Catalonia the average is between 3 and 5 floors.

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Regarding the aggregation level, without considering the architectural composition, 92% of the dwellings group some wet rooms and, consequently, this trend promotes new design strategies of facilities grids.

Before of this analysis, it can establish that not all the dwelling typologies bring the same benefits. The typologies, that attach all the wet rooms in the same point of the house, minimising of the horizontal facilities grids within the dwelling. On the other hand, the types that only come together as wet rooms between different dwellings, but not within the dwelling itself, as an initial review it doesn't seem beneficial to minimize the interior facility grids, because some flows need one meter by dwelling in order to measure the user consumption, and as a consequence this grid need one single point to access.

When there is an aggregation of the wet rooms between different dwellings (80% of the analysed cases), at first sight, we could think that there is not any benefit, but it could potentially have in a new facilities grid design that takes benefit of the agglutination of the flows by a same application.

Finally, regarding the accessibility of wet rooms, the results obtained show that there is interest in promoting the accessibility of facilities grids through public spaces of a building (30% of cases are liked with the stairway area). As a consequence of this input, at the time to stablish the bases of a new facilities grid design, it is considered appropriated to introduce instruments to promote the register and accessibility of the grids in each plant without it incurs an extra cost to carry out the maintenance tasks.

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