Research on the Restrictive Conditions of Elevator Installation to Existing Multi-storey Apartment Buildings in China

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Abstract. During 1970s-1990s large amount of multi-storey buildings have been built without elevators in the cities of China. It is a great social demand that the elevator installation will effectively improve the living quality for aging. However, there are many technical restrictive conditions on site, which may cause costly or unavailable implementation in real project of elevator installation. This paper investigates over 3491 cases online and 66 cases in field survey in Beijing. Through discusses two pairs of comparison of elevator installation, it shows that the HALF elevator is more probability than ALIGN installation to meet the condition of the existing buildings, and the percentage of the ATTACHED elevator is higher than BRIDGED.

1. Introduction

1.1. Problem with the existing multi-storey apartment buildings
During 1970s-1990s nearly 9.59 billion square meters [1] of affordable multi-storey buildings have been built in the cities in China. However, most of them are not equipped with elevators. With the change from incremental construction to stock renewal, the installation of elevator will effectively improve the living quality for aging [2], and become an important way of its sustainable development. Some of the cities launched financial and commercial approaches to support the elevator installation [3-5]. However, there are many technical restrictive conditions on site, which may cause costly or unavailable implementation in real project of elevator installation.

1.2. Aim and purpose of research
China covers large area of several climate zones and hundreds of cities as well, while there are many common features in the restrictive conditions of elevator installation, due to the extremely high standardization in the design of such apartment buildings (Figure 1). This paper investigates over 3000 communities around 11 cities on the Internet, and compares the applicability of two common ways of elevator installation: ALIGN or HALF of the floor level. Information from field survey and measurement in Beijing residential communities compares the applicability elevator installation approaches: ATTACHED or BRIDGED (Figure 2). The implementation conditions in residential communities and buildings are comprehensively considered to explore the feasibility of elevator installation.
2. ALIGN or HALF: Internet collection

2.1. Cases distribution from Internet

2.1.1. Cities: There are 11 sample cities in the network survey, which cover all climate zones in China. The selected cities cover different building climate zones. A total of 3491 valid samples were collected in the network survey (Table 1), including the multi-storey residential samples in the 1970s and 1990s [6].

Table 1. Cases distribution on Internet collection

| City      | Beijing | Jinan | Shanghai | Nanjing | Hangzhou | Wuhan |
|-----------|---------|-------|----------|---------|----------|-------|
| No. of Cases | 1195    | 300   | 561      | 298     | 287      | 150   |

| City      | Changsha | Chongqing | Chengu | Guangzhou | Xiamen | TOTAL |
|-----------|-----------|-----------|--------|------------|--------|-------|
| No. of Cases | 24        | 25        | 153    | 411        | 87     | 3491  |

2.1.2. Types: On Internet, the sample distributions of staircase type, elevation form, amount of households in each floor and other restrictive conditions of existing multi-storey residential buildings are collected. There are mainly two types of staircases: STRAIGHT and HALF PACE. According to the elevation form with the staircase and entrance, the buildings with the half pace staircase can be divided into four types: FLAT, PROTRUDING, CONCAVE and other (Figure 3).

2.2. Classification and analysis from Internet cases

2.2.1. 95.8% of cases contain half pace staircases: Others are straight staircases and special staircases.

2.2.2. 59.9% of cases consist three or more households into each floor (Figure 3a): The floor forms a U-plan with the stairwell at the centre. Two of the households place both ends and the other middle one or more households can only share one side elevation.

2.2.3. Flat and protruding type elevations count for 70.5% in total (Figure 3b): It implies that elevator installation connecting the mid-landings of the staircase is available for large percentages (Figure 4).

2.3. Discussion on ALIGN or HALF
Considering the stop position, there are two main ways of elevator installation, ALIGN or HALF of the floor level, in the existing buildings (Figure 5). Aligned elevator stops at each entrance floor, especially on the straight stairwell, which is relatively rare; the half pace stairwell takes almost all percentages, and the elevator can also be installed directly to connect to each household. Although aligned elevator installation can achieve complete accessibility, there are many difficulties in real implementation:

1. If the elevator stopped the side without stairwell, there is no public indoors emergency space for reparation or evacuation, which does not meet the requirements of the safety regulation in China [6];
2. If it stopped beside stairwell, it cannot meet the situation of three households or more on each floor, since the middle one or more households don’t share this elevation;
3. Aligned elevator installation often needs a transit space which connected with the interior. Transit space means floor area increase, which has large amount of work, as well as a break of urban planning that taking long time for cumbersome negotiation.

![Figure 5. Ways of elevator installation](image)

(a) Aligned connect to the newly extent balcony; (b) Half and attached; (c) Half and newly built elevator hall; (d) Half and bridged; (e) Half and attached in the concave

Although elevator installation on half floor is not a theoretical "barrier free" way, it is a universal design that meets the actual needs of for most of aging people but not disabled (Table 2). There is several professional equipment especially for the moving of the disabled people.

**Table 2. Percentage of aging and disabled people from the cases of three units in Beijing**

| # of Unit | Total household (a) | Aging (b) | Aging and Disabled (c) | % (b/a) | % (c/a) |
|-----------|---------------------|-----------|------------------------|---------|---------|
| 1         | 17                  | 13        | 2                      | 76.47%  | 11.76%  |
| 2         | 16                  | 12        | 1                      | 75.00%  | 6.25%   |
| 3         | 10                  | 6         | 1                      | 60.00%  | 10.00%  |

Furthermore, during the renovation construction of the staircase for the elevator installation, elevator installation in half floors does not involve the reconstruction in relation of private household, and the structural rebuilding is relatively simple. Generally, it can be preliminarily verified that elevator installation in half floors can fit for most multi-storey buildings with wide adaptability.

3. ATTACHED or BRIDGED: Site survey

3.1. Approach on site survey and cases distribution
Since there are no more than 20 households in a unit in most of existing multi-storey buildings, the size of elevator does not have to be as large as the ones in the public buildings. On one hand, the larger size the elevator installation is built, the more problems it occurs: 1) shadowing towards the next north building; 2) space occupation on pathway and pipeline underground, which to change should cost even more than the elevator itself; 3) residents on the first floor will have more objections. On the other hand, the size of the elevator is limited by site conditions with two dimension: 1) Width (parallel to the elevation) and 2) Depth (perpendicular to the elevation).
Field survey and measurement include all the restrictive around the site: 1) the net width of the stairwell, 2) the range of elevator installation on the elevation, 3) the type and distance of the nearest pipe outside the stairwell, 4) the width of the pathway outside the stairwell. Through the cases analysis, this paragraph will discuss the available range of either ATTACHED or BRIDGED installation.
In the field survey, 66 samples were collected from the existing multi-storey residential areas in four urban areas of Beijing from 1970 to 1990 (Figure 6).

![Figure 6. Cases from site survey: household numbers of each floor (left) and stairwell types (right)](image)

3.2. **Restrictive conditions to the width (parallel to the elevation)**
Generally, the multi-storey attached elevator is plastered and closed to the elevation and staircase, without a separate elevator hall, and directly stops at the mid landing of the stairwell, while a bridged elevator needs a separate zone connecting the elevator and the mid landing (Figure 7).

![Figure 7. Parameters: R (the range of elevator installation on the elevation) and W (the net width of the stairwell)](image)

The attached one is often limited by the net width inside the stairwell (W) and the range of elevator installation on the elevation (R), which means the distance between the walls of the bedroom windows near both sides of the stairwell. Meanwhile, there is no limitation to the bridged one in this direction. There are two limited dimensions to consider both (Figure 8): 1) The net width of the stairwell shall meet the design width requirements of the Elevator door (E > 700mm), as well as 2) obligatory width for Fire evacuation at the unit entrance (F > 1100mm). They can be easily counted as follows:

![Figure 8. An ordinary ground floor plan of elevator installation](image)

\[
E = C - (R - W) / 2 \tag{1}
\]
\[
F = W - E \tag{2}
\]

Whereas: E, the width of elevator door; F, the width of fire evacuation; W, the net width of the
stairwell; R, the range of elevator installation on the elevation; C, width of a certain type of the elevator
*
Structure and construction technical dimension is omitted here in the rough plan, while it should be considered in the specification.

Since the $R$ values, the average ranges of elevator installation, of flat, protruding and concave staircases are 3600mm, 3700mm and 2100mm (Limited by the side walls, the $R$ value of concave staircases is much smaller), the $C$ value, width of elevator (including the structure part), is often no more than 1800mm (almost the half of $R$ value). Also, the $W$ values, the net width of the stairwell is densely distributed near the two standards of 2100m and 2400m. Then, the $R$ and $W$ values of each case are imported to count the $E$ and $F$ values, which are illustrated as follows (Figure 9):

![Figure 9](image)

**Figure 9.** Distribution charts of two restrictive condition based on site survey cases: The width of fire evacuation (left) and the width of elevator door (right)

### 3.3. Restrictive conditions to the depth (perpendicular to the elevation)

It is a big problem for the construction of elevator to occupy the pipeline and pathway. Some of the pathway width of the old community is too narrow to meet the firefighting space, even taken by the car parking. Moreover, the basement of elevator should avoid the pipeline, and the smaller volume elevator means less trouble. The distance from the nearest pipe Line ($L$) and the width of the Pathway outside the staircase ($P$) are measured (Figure 10). There is no correlation between the two values. In order to consider the combination of possible situations of elevator installation either attached or bridged, comprehensive proportion analysis is carried out for the two restrictive conditions.

![Figure 10](image)

**Figure 10.** Parameters: $L$ (the distance from the nearest pipeline) and $P$ (the width of the pathway outside the staircase)

For the BRIDGED elevator, the length of the corridor is 1500mm (enough space for the entrance gate on the new side wall), and the elevator is often large with a depth of about 2000mm, whose basement takes 1500-3500mm distance from the elevation. While the ATTACHED elevator is smaller, with a total depth of about 1800m, whose basement takes 1800mm space from the elevation. The distance and the type of the pipeline has been carefully checked from the cases, and the distribution illustrates as below (Figure 11 left).

According to the firefight regulation, the pathway must be no less than 4000mm. Thus, the BRIDGED elevator need a pathway width of more than 7500mm, while for ATTACHED it needs to be 5800mm. the width of the existing pathway from the cases is measured and illustrated as follows (Figure 11 right):

![Figure 11](image)
Figure 11. Distribution charts of two restrictive condition based on site survey cases: the distance from the nearest pipeline (left) and the width of the pathway outside the staircase (right)

Since the $P$ and $L$ values show as above, the available margins both for bridged and attached can be found. Also, the type of the nearest pipeline to the elevation needs to be checked, because different type means different difficulties under renovation (Table 3). For example, plumbing pipes are much easier than the gas, since the renovation to a part of plumbing pipe does not stop the system, while for the gas or heating (if in winter) it has to.

Table 3. Types and case numbers of the nearest pipeline to the elevation

| Type of pipeline | Numbers | Type of pipeline | Numbers | Type of pipeline | Numbers |
|------------------|---------|------------------|---------|------------------|---------|
| Plumbing         | 25      | Gas              | 7       | Telecom / Electricity | 2       |
| Water meter      | 9       | Heating          | 6       | Fire hydrant      | 1       |
| Water supply     | 9       | Rain             | 3       | Other             | 4       |

3.4. Discussion on ATTACHED or BRIDGED

From the restrictive conditions to the width (parallel to the elevation), 62% of the cases with an $F$ value more than 1100mm imply that the ATTACHED elevator can be implemented, while for the other cases accounting 38%, BRIDGED elevator have to be considered. Considering the two restrictive conditions to the depth (perpendicular to the elevation), the conditions for elevator installation can be divided into five situations (Figure 12).

Figure 12. Correlation analysis of the critical range under the $P$ and $L$ conditions

Figure 13. Type of site condition (detail as below)
### 3.4.1. Zone A (31.4%) is difficult for elevator installation.
The width of the external stairway is narrow (< 8000mm), which does not meet the width of the firefight passage, no matter the ATTACHED or BRIDGED (Figure 13-a). If it is available, the pathway can be extended to take the original greening or parking (Figure 13-b).

### 3.4.2. Zone B (5.9%) is suitable for ONLY BRIDGED if there are no other pipelines further.
The width of the pathway outside the stairwell (>7500mm) and the distribution of the pipeline are close to the building (<1500mm) (Figure 13-c).

### 3.4.3. Zone C (47.1%) is suitable for ONLY ATTACHED.
The pathway is wide enough to install attached elevators (>5800mm), and the pipe is enough far away from the elevation (>1800mm) (Figure 13-d).

### 3.4.4. Zone D (13.7%) may be suitable for ATTACHED or BRIDGED conditionally.
If the pipeline type is easy to change, such as water pipe, the cases in the portrait part are available to build attached elevator; if it appropriately reduces the length of the corridor, the cases in the landscape part are available to build bridged elevator; and the corner of zone D can be implemented either of above (Figure 13-e).

### 3.4.5. Zone E (2.0%) are suitable for both ATTACHED and BRIDGED.
The pathway is wide (>7500mm) and the pipeline is far (>3500mm), considering the cost, ATTACHED is recommended (Figure 13-f).

### 4. Conclusion and discussion
In this paper, the implementation conditions to the elevator installation in existing multi-storey apartment buildings were illustrated, and were discussed on suitable comparison between ALIGN and HALF, between ATTACHED and BRIDGED.

1) Although there is a theoretical advantage of ALIGN elevator installation, but there are many restrictions on real implementation, while the HALF elevator installation cannot fully solve the problem of accessibility, but it has greatly improved for the most residents. According to the result of Internet collection, the HALF elevator is more probability to meet the condition of the existing buildings

2) In the site survey, the applicable proportion of the two types, ATTACHED and BRIDGED, is critically determined. According to the result of cases study, the percentage of the ATTACHED elevator is higher than BRIDGED. The size of elevator is strictly limited, and recommended around 1800mm by 1800mm, which may be suitable for most of the condition.

### 5. References
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