

# Prospects for Multi-Storey Buildings with Individual Parking Lots in Front of Apartment Entrances (for Low-Mobility Groups of the Population)

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**Abstract** Creating a barrier-free environment that takes into account the needs of the low-mobility part of the population is a constant task in various areas of personal and public life organization. The emergence of mandatory design and construction standards has ensured significant progress in this area. The demand for a barrier-free environment in apartments where families without disabilities live is constantly growing. A barrier-free environment becomes a criterion for the convenience of living in general. The inclusive design that ensures this quality of the home offers various solutions. One of the unresolved problems so far is the possibility of wheelchair users living on different floors of multi-storey buildings. This is due to the difficulty of their evacuation in case of emergency shutdown of elevators. An option to solve the problem is the installation of car ramps and apartment parking lots. These ramps, under normal conditions, provide highly comfortable automobile delivery of a representative of low-mobility groups of the population directly to the apartment doors. In the event of an accident, these ramps can be used freely, without creating a queue, to ensure the descent of an accompanied disabled person or a bedridden patient on special stretchers from any floor of an

apartment building.

**Keywords** Barrier-Free Housing, Parking Lot beside to the Apartment, Apartment Buildings, Car Lifts and Ramps, Apartment Layout for a Wheelchair-Bound Family, Inclusive Design

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## **1. Introduction**

In the modern understanding, low-mobility groups of the population are people 60 years old and older, disabled people of working age 16-60 years old, disabled children under 16 years old, children under 8-10 years old, pregnant women or with young children. This is almost 30-35% of the population. The formation of an environment that ensures accessibility for low-mobility groups of the population has long been a topic of research and discussion.

The understanding of this problem formed by 1979 was reflected in his work by E. Steinfeld [1]. He compiled a bibliography on the problems of designing a barrier-free

environment, including more than a hundred different sources published at that time with annotations. Research on various aspects of this problem has been actively continued. B. B ěub ě [2] emphasizes the need to eliminate physical barriers that, in his opinion, turn disabled people into abnormal members of society. It is noted that there is a need to create a barrier-free environment for the elderly, and not only for the disabled (F.J. Costa, M. Sweet [3]). K. Rawski [4] analyzed the most typical examples of existing barriers for low-mobility groups of the population and ways to eliminate them in adaptable spaces. R. Imrie and M. Kumar [5] proposed ways to interconnect the design and implementation of public policy regarding the formation of a barrier-free environment.

As noted by S. Manley [6], barriers for the disabled appeared in residential spaces due to the initial inattention to this problem. The solution to this problem lies in the interaction between the understanding of accessibility as one of the basic human rights and technical measures. In fact, there are not very many types of barriers in the residential environment [7], and all of them can be eliminated [8] (stationary or folding ramps at height differences; differentiated handrails on stairs and ramps; special lifts; tactile surfaces; non-slip coverings of steps, ramps and platforms; special signs; minimum gaps between paving slabs and sidewalk grilles; corridors and platforms in front of doors, providing the possibility of turning a wheelchair; wider parking spaces and other things). The modern project approach is becoming one of the means of realizing the rights of persons with disabilities (S.M. Kurbatova, L. Yu. Aisner, V.V. Naumkina [9]). N.T. Prerana considers a barrier-free environment as an aspect of sustainable development [10].

R.L. Mace, G.J. Hardie, and J.P. Place consider the universal design of a barrier-free space as a reasonable and economical way to reconcile the artistic integrity of design with human needs in the environment [11]. This concept is being developed by E. Plantier-Royon. He draws attention to the need for the initial design of a barrier-free environment, and specifies seven principles of Universal Design: "Equitable Use- Flexibility in Use; Simple and Intuitive Use; Perceptible Information; Tolerance for Error; Low Physical Effort; Size and Space for Approach and Use" [12]. The most difficult spaces for the disabled are entrances and bathrooms. This aspect is considered in detail by S.Y. Lee and M.-W. Oh [13]. Specific solutions are needed in apartment buildings [14]. A.F. Mondonico, A.D. Mutaliev, and K.I. Samoilov [15] examined the planning features of highly comfortable apartments for families with wheelchair users.

H.Y. Cho, M. MacLachlan, M. Clarke, and H. Mannan evaluate the impact of an accessible home environment on the health and social activity of people with functional disabilities [16]. I.M. Lid and P.K. Solvang [17], based on an analysis of the current situation, indicate that accessibility should include biological, psychological and

social aspects in order to provide a reliable understanding of the interaction between humans and the environment. E. Kapsalis, N. Jaeger and J. Hale [18] draw attention to the direct relationship between quality of life and barrier-free spaces.

Until the last quarter of the twentieth century, the formation of a barrier-free environment for low-mobility groups of the population was recommended. Gradually, it becomes mandatory. The main parameters of the barrier-free environment, which are mandatory for use, are fixed by modern regulatory documents of many countries. For example, in the USA it is "2010 ADA Standards for Accessible Design" [19], in the Canada it is "CSA/ASC B651:23 National Standard of Canada Accessible design for the built environment" [20], in the Germany it is "DIN 18040-2:2011-09 Construction of accessible buildings – Design principles" [21], in the Spain it is "UNE-EN 17210:2021 Accessibility and usability of the built environment – Functional requirements" [22], in the Kazakhstan it is "Building regulations of the Republic of Kazakhstan. SN RK 3.06-01-2011 Accessibility of buildings and structures for groups with limited mobility" [23].

In addition to these documents, in some countries there are recommendations clarifying the application of these standards, for example: "Design manual for a barrier-free built environment" [24]; "Guidance on the 2010 ADA Standards for Accessible Design" [25]; "Accessibility for the Disabled. A Design Manual for a Barrier Free Environment" [26]; "Code of rules of the Republic of Kazakhstan. SP RK 3.06-31-2005 A residential environment with planning elements accessible to the disabled" [27]; "Code of rules of the Republic of Kazakhstan. SP RK 3.06-101-2012\* Design of buildings with accessibility for minor mobile group of population" [28]; "Barrier-Free Design Guide Based on the Alberta Building Code 2014. Safety Codes Council" [29]; "Implementing Promising Community Interventions. Chapter 26. Changing the Physical and Social Environment. Section 4. Ensuring Access for People with Disabilities" [30]; "DGNB system – New buildings criteria set. Sociocultural and functional quality. SOC2.1 / Design for All. Version 2020 International" [31], "Barrier-free apartments for senior citizens and disabled" [32] and others.

Some regulations establish such concepts as "Adapted apartment" – an apartment in an existing building, adapted for the habitation of people with limited mobility, taking into account their specific characteristics; "Special apartment" – an apartment designed taking into account the specific characteristics of the life of people with limited mobility and complex three-generation families; "Special apartment building" – a residential building with special apartments and premises or a block for service purposes" [27]. There are contradictions in some positions in the regulatory documents, which are pointed out by M. Mazz

[33].

The implementation of the concept of barrier-free design is becoming more widespread, transforming into inclusive design, as noted by A.Sharma and K.Kumar [34]. However, in some countries, interest in the formation of a barrier-free environment is gradually beginning to decline. This problem is addressed in the work of A. Porębska, J. Barnaś, P. Gajewski [35].

I. Skiba and R. Züger [36] consider the trend of increasing need for barrier-free environment in general, and not only in the context of providing amenities for people with limited mobility. Attention is drawn to the formation of a kind of “Accessibility Strategy” [37]. Hong-Li Wong [38] points to demographic changes that show an increase in the level of disability in the context of an aging population. This stimulates the formation of an inclusive environment for all. Accordingly, the question arises of the need to improve housing planning for the elderly based on the concept of lifelong housing (S.-Y. Lee, S.-E. Yoo [39]).

F. Alonso’s study [40] shows that the presence of a barrier-free environment in housing is gradually becoming a competitive advantage when choosing an apartment or house. Regardless of the physical condition of family members, a significant portion of users agree to an increase in the cost of an apartment or house in which a barrier-free environment has been created. That is, we can state the growing social benefits of building residential buildings with a barrier-free environment.

Despite the urgency of the problem of improving the barrier-free environment, the issue of ensuring the most convenient accessibility of apartments in multi-storey buildings and a more convenient layout of apartments for the disabled has not yet been studied in detail.

## 2. Research Methods

Using the general scientific method of sequential selection and analysis of literary sources, collection of data on design materials and constructed buildings, differentiation of examples by various features, analysis and subsequent integration of the obtained results, it was possible to come to the following conclusion. To date, the vast majority of barriers that hinder the lives of people with limited mobility have been removed, thanks to the measures specified in the current regulations. However, there is one problem that has not yet received an adequate solution. This is the possibility of delivering a wheelchair user up or evacuating him down from a multi-story building when the elevators are not working (breakdown, maintenance, power outage, etc.).

An analysis of existing practice has shown that the massive use of special individual lifts in stairwells solves the problem only within the first two floors. This is unacceptable for multi-storey buildings. A few examples

of special car elevators demonstrate the problem of waiting in line to occupy an elevator platform. In addition, if the elevators break down, the situation becomes critical. The planning solution in these multi-storey buildings does not allow using another elevator.

Based on the analysis, the purpose of the study is formulated: to provide comfortable accommodation for representatives of low-mobility groups of the population in multi-storey buildings using special space-planning solutions.

To achieve this goal, the following tasks were set:

- to determine the fundamental possibility of spatial planning to ensure the unhindered arrival of cars on any floor of a multi-storey residential building;
- to determine the basic type of layout of a residential building and a separate apartment, which allows you to realize this opportunity;
- to calculate the geometric parameters of the main elements (apartment parking area, travel gallery, car ramp);
- taking into account fire safety and ease of use, to develop appropriate space-planning solutions for multi-storey residential buildings and apartments in them.

## 3. Research Area

### Design and Construction Practice

The solution to the problem is possible through the use of special individual mobile crawler-wheel lifts. Another solution involves increasing the width of the flight of stairs to install a corresponding inclined platform lift for moving along the flight of stairs. Widening the flight of stairs is necessary, since even when folded, such a lift narrows the passage necessary for evacuation. The most common lifts have a platform width of 430 mm when folded. The width of the guide structure is 160 mm. That is, the usual width of the flight of stairs, regulated by standards for multi-storey buildings, 1350 mm should be increased to 1940 mm. A slightly smaller total size is obtained if we consider the lift in operation (platform 770 mm + guide panel 160 mm) and the minimum permissible width of the passage along the stairs of 900 mm. This width is 1830 mm. With the mass use of individual crawler-wheel lifts, the width of the flight should also be increased to the same value.

However, even with a wide flight, the inconvenience lies in the constant maneuvering before installing a wheelchair on the platform and when exiting the platform on each flight of stairs. On the floor above, another disabled person must wait until the platform is free. Accordingly, time passes, which can be critical in an emergency. For example, to descend from the fifth floor, it is necessary to repeat the maneuver of entering-moving-exiting 8 times. You also need to go down to the outer doors of the exit from the

house. This is at least one more flight of stairs. In addition, it is necessary to install a platform inclined lift on each flight (two on each floor).

If a special ramp is provided, its dimensions should provide a slope of 1:20 (independent movement of a wheelchair user). That is, for one floor (~3.3 m) it is necessary to have 66.0 m of ramp with 9 landings (one flight of ramp no more than 8.0 m). Even taking into account the movement control accompaniment of a wheelchair user during an emergency evacuation, the slope of the ramp should not be steeper than 1:12. Accordingly, 39.6 m of ramp are required for one floor. The exit to this ramp should be from the landing in front of the entrance to each apartment. This implies the formation of a relatively large multi-storey block as part of a staircase in each entrance of an apartment building. Many large hospitals have such multi-storey ramps. Interesting spatial solutions with internal ramps and stairs demonstrate the “Slaughterhouse”, Shanghai City (arch. “British master architect Balfours”, 1933) and the “Centrosoyuz” office building, Moscow City (arch. Le Corbusier, P. Jeanneret, N. Colli, 1936). These examples are shown in Figure 1.



**Figure 1.** 1 – The “Slaughterhouse”, Shanghai City, 1933 (internal ramps and stairs) [61]; 2 – The “Centrosoyuz” office building, Moscow City, 1936 (internal ramps) [62]

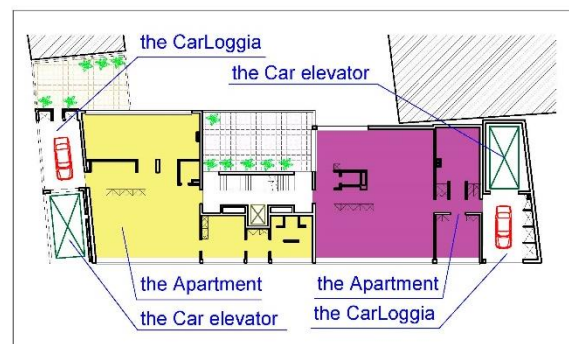
Emergency evacuation of disabled and bedridden patients can also be provided from the windows of a house into the yard or the street. However, this can only be a one-time event, given the actual operating speed of special mobile lifting and transport equipment.

It is this problem that determines the existing regulatory requirement in some countries for the placement of apartments for wheelchair users on the first (above-ground) floor of a multi-storey residential building. “If there is a

ramp, these apartments may be located within the lower three floors” [27]. Living on the first (above-ground) floor of a multi-storey residential building is not always comfortable in itself. In most cases, the above-ground floor of a multi-storey residential building is occupied by shops, service establishments, etc.

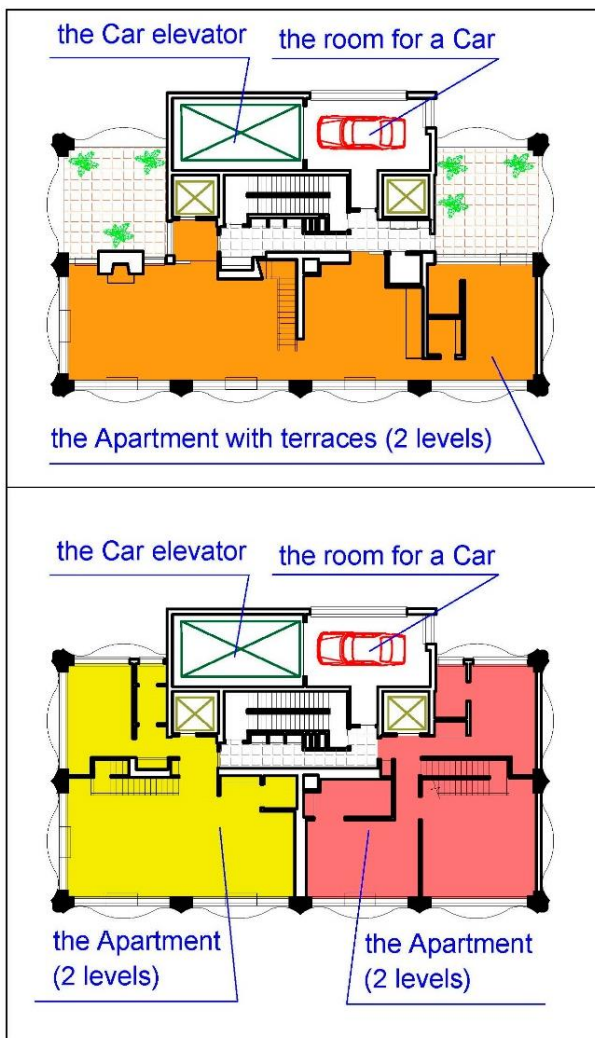
In general, based on the assumption of trouble-free operation of elevators, it is possible to significantly increase the comfort of living in a multi-storey building if it is possible to park family cars directly next to the entrance to the apartment. In the case of people with limited mobility, this creates obvious conveniences. Car elevators began to be actively used at the beginning of the last century in the USA. In most cases, this was the movement of a car from the street up one or two floors or into the basement. The main application is warehouses, stores or auto repair shops. Sometimes it was used in private homes.

The idea of apartment parking in a multi-storey building was developed in detail by M. Dick and J. Kauka (the “CarLoft” bureau) in the current century. The reason was the lack of sufficient parking spaces in the Berlin-Kreuzberg area. Due to high humidity and soil mobility, the construction of an underground car park was deemed economically ineffective. The idea of apartment parking was implemented in the building “Paul-Lincke-Höfe / CarLoft” (arch. “United Architects”) [42, 43, 44, 45]. The house was built in 2007. The building has seven floors. It houses 11 apartments. Five floors have two apartments each (area 267.0 sq.m and 291.0 sq.m). Both apartments on the floor have an entrance from a common hall with a passenger lift and stairs. On the top floor there is one apartment with a large terrace (the “PanoramaLoft” – area 539.0 sq.m). Car lifts are located in the corners on the outside of the house. The driver and passengers are inside the car while driving. The apartment parking is located on the loggias (the “CarLoggia”). The loggia is sized so that it not only accommodates the car, but also allows for its simple maintenance (it is essentially a garage). Without a car, the loggia is used as an extension of the living room, play area, etc. A car parked on the loggia is partially visible from the apartment. The plan of typical floor of “Paul-Lincke-Höfe / CarLoft” is shown in Figure 2.



**Figure 2.** “Paul-Lincke-Höfe / CarLoft”, Berlin City, 2007 (a typical floor plan) [63]

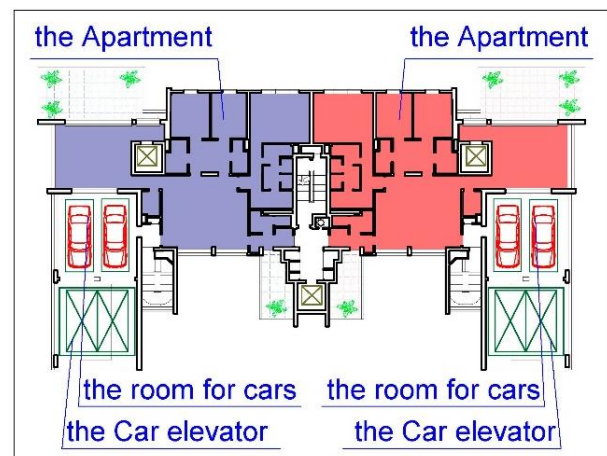
The apartment building “The 200 Eleventh Avenue” (arch. A.Selldorf – “Selldorf Architects”) in New York City was built in 2010 [46, 47]. The building has nineteen floors. There are sixteen apartments in the building (area from 120.7 sq.m to 325.2 sq.m). Fourteen apartments have an adjacent parking lot for one car. The apartments are designed in two levels. The exit to the adjacent parking lot is from the corridor. From the same corridor there is an exit to the stairs and to the passenger elevator. A car parked on the loggia is not visible from the apartment. The driver and passengers are inside the car while it is moving. The plans of typical floors of “The 200 Eleventh Avenue” are shown in Figure 3.



**Figure 3.** “The 200 Eleventh Avenue”, New York City, 2010 (typical floors plans) [64]

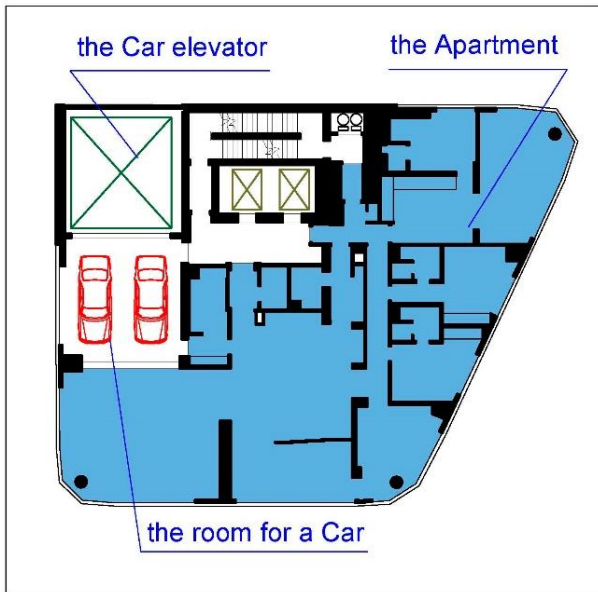
“The Hamilton Scotts / Sky Garage Apartments” (arch. “AMA Architects”) in Singapore City was built in 2012

[48, 49, 50]. The building has thirty floors. It houses 52 apartments (area of 256.0 sq.m) and 4 penthouses (area of 300.0 sq.m and 648.0 sq.m). The apartments are arranged in pairs. Elevators, located at the corners of the building in glazed shafts, lift cars to the landings in front of the living rooms. Each landing can accommodate two cars. Parked cars are fully visible from the living room. The driver and passengers leave the car while the car is moving. Car movement and parking are carried out only in automatic mode. The movement of the car in the glass elevator shaft is accentuated in the building’s exterior by the multi-colored illumination of the moving platform. Each apartment has an exit to two stairwells. The stairwell located in the middle of the building has a passenger lift lobby. From the living rooms there is an entrance to a separate small passenger lift lobby. The typical floor plan of “The Hamilton Scotts / Sky Garage Apartments” is shown in Figure 4.



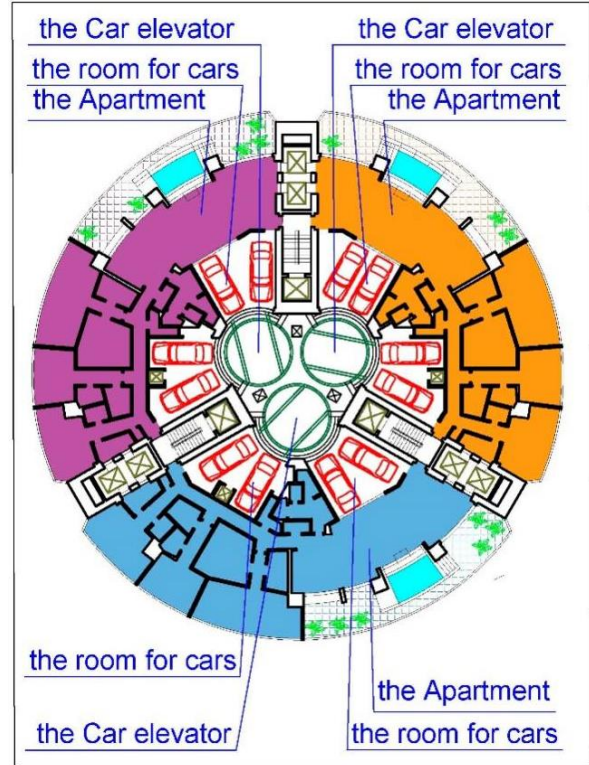
**Figure 4.** “The Hamilton Scotts / Sky Garage Apartments”, Singapore City, 2012 (a typical floor plan) [65]

“The Neue Grand” (arch. S.Rothe – “RotheLowman”) in Melbourne City was built in 2024 [51, 52, 53]. The building has twenty floors. The building has 18 apartments (area from 319.1 sq.m to 710.8 sq.m). Each apartment occupies the entire floor. 17 apartments have parking for two cars in front of the living room. An additional parking space is located in the basement. The penthouse has four parking spaces next to the living room. Two additional parking spaces are located in the basement. Each apartment is exited through the passenger lift lobby and the stairwell. From the adjoining parking area, there is an entrance to the corridor next to the living room. Parked cars are completely visible from the living room. The driver and passengers are inside the car while driving. The typical floor plan of “The Neue Grand” is shown in Figure 5.



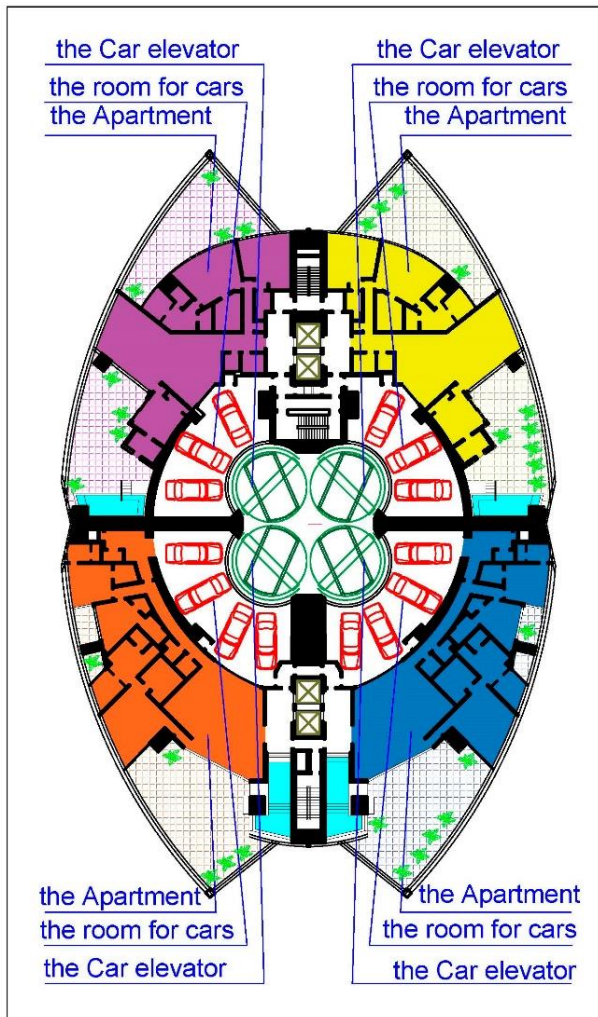
**Figure 5.** “The Neue Grand”, Melbourne City, 2024 (a typical floor plan) [66]

Examples of skyscrapers with apartments that have adjacent parking are “The Porsche Design Tower Miami” (arch. “Sieger Suarez Architects”) [54] and “The Bentley Residences” (arch. “Sieger Suarez Architects”) [55, 56, 57] in Miami City. Completed in 2017, “The Porsche Design Tower Miami” has a round plan. There are one hundred and thirty-two apartments (ranging from 315.9 sq.m to 1,579.4 sq.m) on sixty floors. The standard solution provides for three apartments per floor. Three car elevators are located in the center. This allows for four cars to be placed near each apartment. Two cars are located next to the living room, and two cars are located near the corridor in the area of bedrooms and utility rooms. The car placement areas are isolated from each other. The driver and passengers can be inside the car while riding in the elevator. An option for automated delivery and parking of the car is possible. From the living room you can see parked cars and working car lifts in a glass shaft. Each apartment has two exits to the stairwells, located on opposite sides of the apartment. The entrance to the passenger lifts is provided from the living rooms. An additional passenger lift is provided in the parking area near the corridor. A total of 284 cars can be accommodated. The typical floor plan of “The Porsche Design Tower Miami” in Miami City is shown in Figure 6.



**Figure 6.** “The Porsche Design Tower Miami”, Miami City, 2017 (a typical floor plan) [67]

“The Bentley Residences” is scheduled for completion in 2026. The floor plan is elliptical with cut-out ends. There are 216 apartments (ranging from 325.2 sq.meters to 836.1 sq.meters) on sixty-three floors. The standard solution provides for four apartments per floor. Four car elevators are located in the center. Two apartments can accommodate three cars next to the apartments, and the other two apartments can accommodate four cars next to the apartments. The driver and passengers can remain inside the car while the car is moving. An automated car delivery and parking option is possible. Each apartment has one exit to the stairwell and the elevator lobby. In the apartments next to which four cars are located, the exit to the stairwell and the elevator lobby is provided from the living room. Parked cars and operating car elevators in the glass shaft can be seen from the living room. These apartments have an additional passenger elevator in the parking area. In apartments with three cars next to them, the exit to the stairs and elevator hall is provided from the corridor. The typical floor plans of “The Bentley Residences” in Miami City are shown in Figure 7.



**Figure 7.** “The Bentley Residences”, Miami City, ~ 2026 (a typical floor plan) [68]

Despite the high level of comfort of living, in the considered examples there are nuances that reduce the convenience of use. The main set of inconveniences can occur every day in the morning and evening, when most residents leave or return. For example, in the seven-story residential building “Paul-Lincke-Höfe” in the Berlin City, it takes about 2.5 minutes to call the elevator, enter it by car, go up and drive out to your loggia. Even with high-speed car elevators, additional time is needed to call the elevator, move and fix the car. For example, two buildings of automated garages “Autostadt Car Towers” in Wolfsburg have 19 floors each. Automatic delivery of a car from the upper level to the ground parking takes 1 minute 44 seconds. According to “Guinness World Records 2014”, at that time it was the fastest automated parking in the world.

This means that in an apartment building the entire process (the elevator call - the arrival at the platform - the elevator ride - the exit from the platform to the parking lot) takes about 5 minutes. This can lead to a queue. Moreover, if in a four- to six-story building this wait is 10-15 minutes, then in a multi-story building the waiting time can be from

half an hour or more. In passenger elevators, additional boarding of passengers is possible on different floors. In car elevators, this is not possible. Using the “Valet-Parking” service in this situation does not completely solve the problem. Another inconvenience is caused by periodic maintenance or the elimination of a possible accident. A car elevator taken out of service for the duration of the work eliminates the possibility of using cars located in the parking lots near apartments along the entire height of the building.

From the point of view of convenience for people with limited mobility, the examples considered are also not very convenient. The difficulty or impossibility of a car maneuver on the apartment lot, small distances from the edges of the lot and between cars complicate the boarding and disembarking of people with disabilities (the optimal parameters of a parking space for people with disabilities are 6.0 m x 3.6 m [41]).

## 4. Project Proposals

### 4.1. General Approach

One of the possible solutions to the problems (drive-in by car directly to the apartment doors and drive-out by car from the apartment; convenience of getting on and off cars for people with disabilities; no queue for driving up to the apartment and leaving the house) is to organize the movement of cars on ramps with the possibility of free drive-in to the doors of each apartment and the accompanying maneuver. The parametric data for this are as follows: a block of apartments 72.0 m long (maximum distance between sedimentary or seismic joints); an adjacent parking area 6.0 m wide; a driveway along these areas 8.0 m wide; a two-lane straight, curved or circular car ramp.

The ramp not only serves as a vehicle movement function, but also allows for the emergency controlled evacuation of a wheelchair user or bedridden patient on a special stretcher with wheels from any floor of the building. The optimal ramp slope for vehicle movement corresponds to the slope of the emergency ramp for the accompanied evacuation of a wheelchair user.

The block length of 72.0 m ensures the optimal placement of 7-9 standard apartments or 2-3 luxury apartments. Users of each standard apartment may have two cars. That is, each floor may accommodate 14-18 cars at the same time. According to regulatory documents of some countries [41], a single-lane ramp ensures the optimal capacity for the signalized passage of one hundred cars; a two-lane ramp ensures the optimal capacity for the unregulated passage of one thousand cars. A single-lane ramp is inconvenient not only because of the need to regulate up and down traffic, but also because of possible delays in the event of a car accident on the ramp. Considering the capacity of a two-lane ramp, the number of

floors on which apartments are located may reach 55-70. The number of floors may be limited by psychological criteria of possible driver fatigue from roundabout traffic. But this parameter is very individual. To reduce the psychological burden of uniformity of the visual picture during roundabout movement, it is possible to change the color and plastic elements of the wall decoration at each turn of the ramp. The driver can use the autopilot.

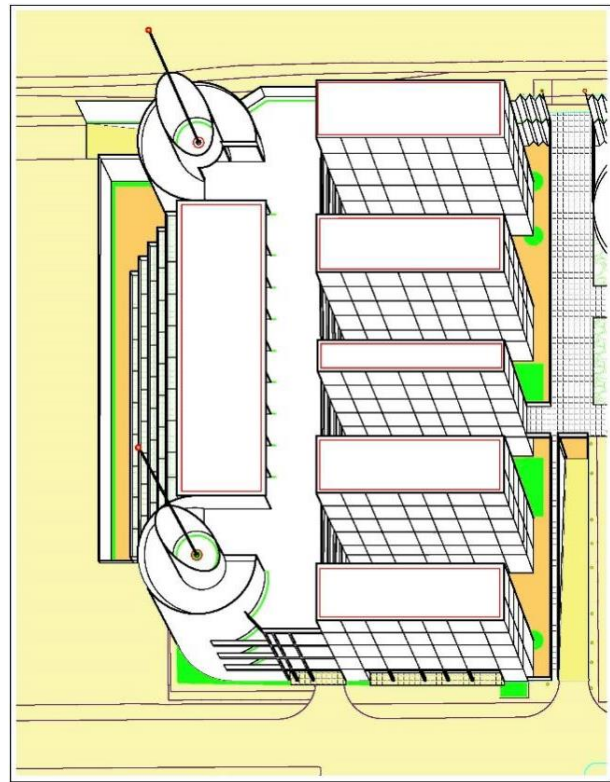
The two-lane ramp considered in the proposed options has a diameter of 30.0 m. It has two lanes for car traffic (3.7 m wide) and a sidewalk on the inner side (1.5 m wide). For the convenience of users, it is advisable to place both passenger and car elevators in the inner part of the ramp (diameter 12.5 m). If you do not make car elevators, then you can use this place for temporary parking of special-purpose vehicles (medical care, mail and goods delivery, maintenance, police). Ascending and descending a car along the ramp take a little more time than by elevator, but the inconvenience of waiting is eliminated. For example, along a circular ramp at a speed of 10.0 km per hour, you can climb to the twenty-fifth floor in a car and park near your apartment in 5-7 minutes.

The presence of a car ramp with a sidewalk allows for the placement of apartments for families with wheelchair users on all floors. As noted earlier, some regulations state that such apartments can only be placed on the first floor of multi-story buildings [27]. This is due to the need for problem-free evacuation of a wheelchair user in the event of an emergency power outage and inoperative elevators. A wheelchair user can move down the sidewalk on a car ramp or on the ramp itself without hindrance, without creating inconvenience for those wheelchair users who are being evacuated from other floors of the building.

The idea initially emerged during the execution of the competition project for the reconstruction of the Crescenzago micro district in Milan City (arch. K.V. Martinson, A.R. Kit, K.I. Samoilov, 2019) [58]. Part of the project was a multifunctional residential complex for socially protected groups of the population with 305 apartments: 45 apartments for people with reduced mobility with individual floor's parking directly at the entrances to the apartments and terraces; 260 apartments for small families and single citizens working in the field of services for people with disabilities. The complex has 5 residential floors. The ground floor is intended for commercial and public purposes. The two-level underground parking has 384 semi-open spaces with individual tool cells in partition cabinets. On each floor, next to the line of car passage, there is an area for walking and rest. Communication between all floors is provided by stairs, elevators, and two-circular two-lane car ramps. The roofs of the car ramps are used for summer recreation areas. At the tops of the central parts of the ramps are located wind turbines of the rotor type. The semi-passable roof of the mansard type serves as a support for solar panels. The general appearance of this complex is shown in Figure 8.

The evolution and detailing of this idea led to the

emergence of several options for the layout of multi-storey buildings with individual parking lots in front of apartment entrances.

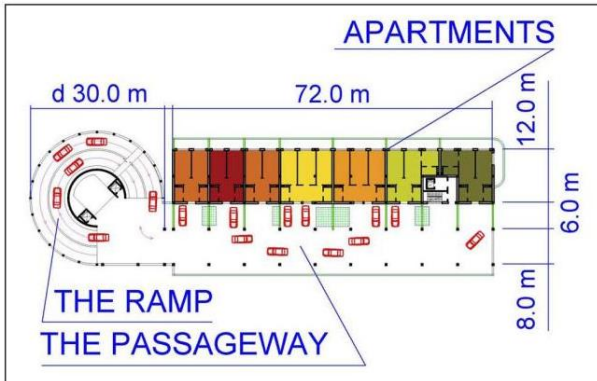


**Figure 8.** The Multifunctional residential complex for socially protected groups of the population with 305 apartments in Crescenzago micro district, Milan City – general view (competitive project, 2019) [58]

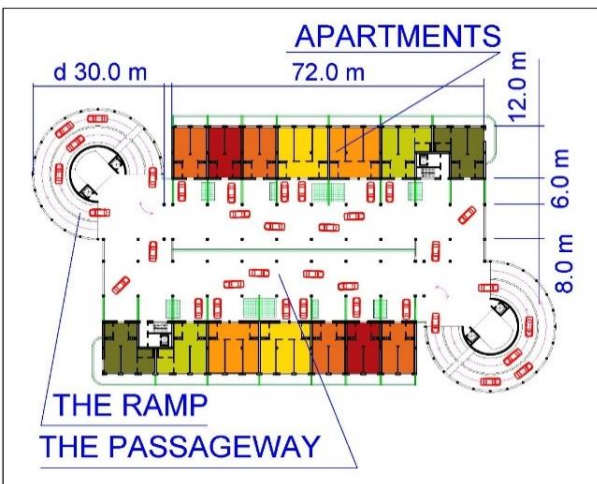
#### 4.2. Type 1 – the Linear Layout

A variant of the linear layout of the house with a circular car ramp at the end consists of a block with apartments and a passage along them (axial dimensions 72.0 x 26.0 m), as well as a two-lane ramp (diameter 30.0 m). The apartment block contains apartments (~ 94.0 sq.m; ~ 120.0 sq.m; ~ 142.0 sq.m) with loggias.

The size of the apartments can be changed depending on the design assignment. This unit includes a stairwell and a passenger elevator. From the main two-lane passage, exit to the ramp is carried out in a straight line. The car ramp adjacent to the end has a diameter of 30.0 m (in axes). The ramp includes two passenger elevators (it is possible to accommodate two additional car elevators). This variant of the linear layout of the house with individual Parking lots in front of the entrances to the apartments (circular car ramp at the end) is shown in Figure 9. Mirroring of such blocks is possible. This will provide the opportunity to choose a ramp for maneuver. A mirror solution of the linear layout of the house with individual parking lots in front of the entrances to the apartments (circular car ramps at the end) is shown in Figure 10.



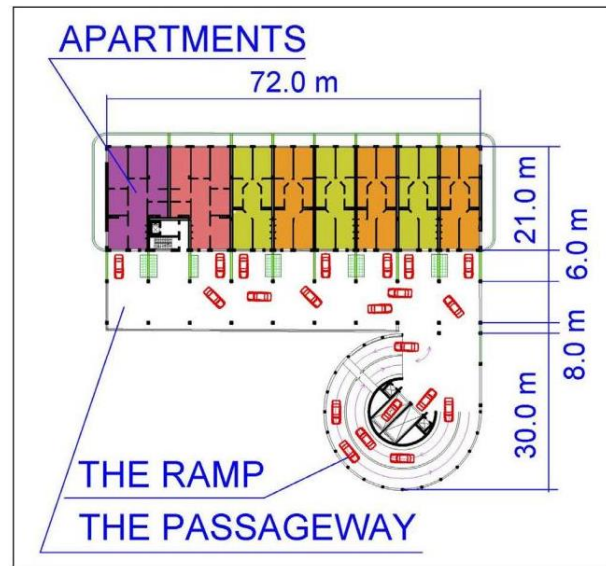
**Figure 9.** A variant of the linear layout of the house with individual Parking lots in front of the entrances to the apartments (circular car ramp at the end) – a typical floor plan



**Figure 10.** The mirror solution of the variant of the linear layout of the house with individual Parking lots in front of the entrances to the apartments (circular car ramps at the end) – a typical floor plan

Another car ramp maneuver is possible if the circular car ramp is located on the side. In the variant with larger apartments (~ 166.0 sq.m; ~ 228.0 sq.m), the main block has dimensions of 72.0 x 35.0 m. The block has an independent staircase and a passenger elevator. From the

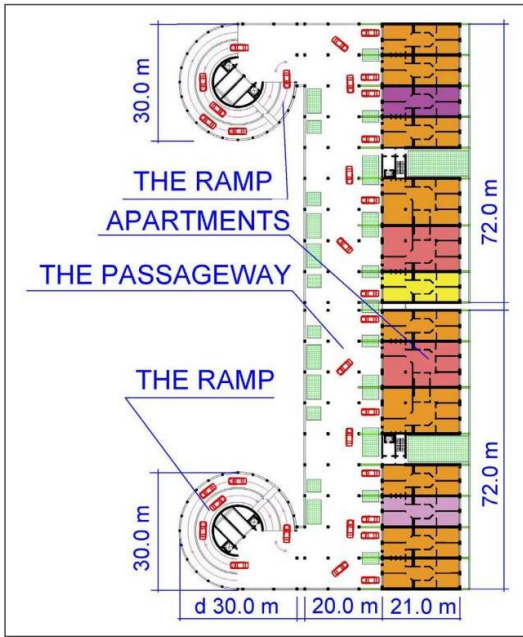
main two-lane passage, exit to the ramp is carried out with a turn. The car ramp adjacent to the side has a diameter of 30.0 m (in axes). The ramp includes two passenger elevators (it is possible to accommodate two additional car elevators). A variant of the linear layout of the house with individual Parking lots in front of the entrances to the apartments (circular car ramp on the side) is shown in Figure 11.



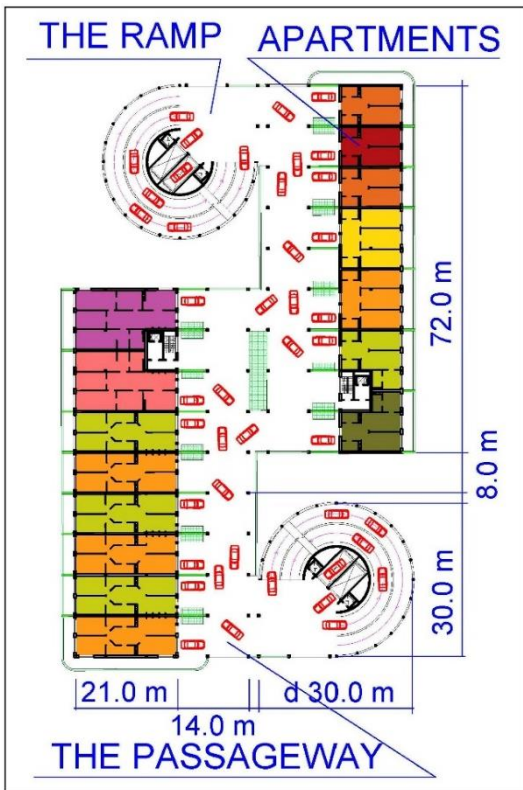
**Figure 11.** A variant of the linear layout of the house with individual parking lots in front of the entrances to the apartments (circular car ramp on the side) – a typical floor plan

It is possible to connect two blocks with ramps in a linear or a mirror version. A two-block version of the linear layout of the house with individual parking lots in front of the entrances to the apartments (circular car ramps on the side) is shown in Figure 12.

A more compact two-block version of the linear layout of the house with individual parking lots in front of the entrances to the apartments (circular car ramps on the side) is shown in Figure 13.



**Figure 12.** A two-block version of the linear layout of the house with individual parking lots in front of the entrances to the apartments (circular car ramps on the side) is a typical floor plan



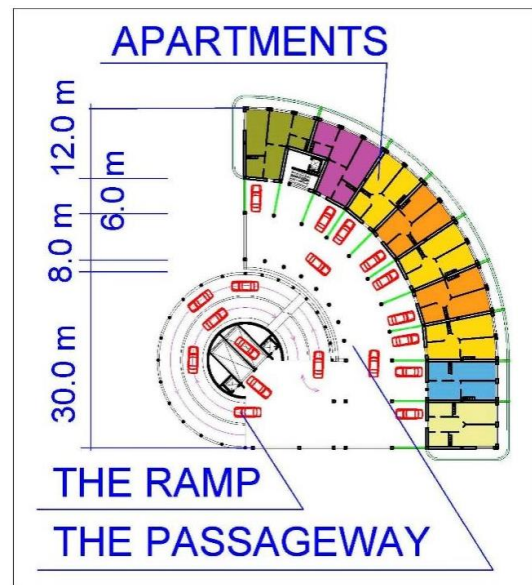
**Figure 13.** A two-block version of a linear (mirror) layout of a house with individual parking in front of the entrances to the apartments (circular car ramps on the side) – a typical floor

**4.3. Type 2 – the fan Layout**

An another possibility is demonstrated by the variant of a fan-shaped layout of the house with individual parking

lots in front of the entrances to the apartments.

A circular car ramp with car and passenger elevators is located in the center. The arc block includes apartments with an area of ~ 94.0 sq.m; 112.0 sq.m; 151.0 sq.m. This block has an independent staircase and a passenger elevator. From the arc driveway, a maneuver is carried out onto a two-lane circular ramp with passenger and car elevators. The variant of a fan-shaped layout of the house with individual parking lots in front of the entrances to the apartments (a circular car ramp in the center) is shown in Figure 14.

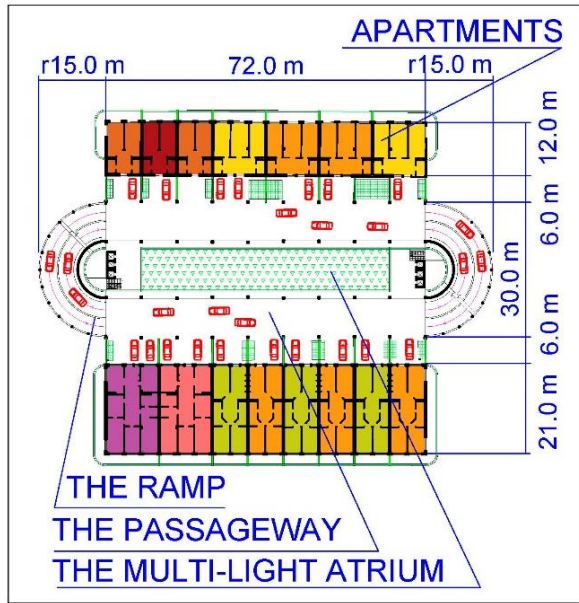


**Figure 14.** A variant of a fan-shaped layout of a house with individual parking spaces in front of the entrances to the apartments (a circular car ramp in the center) – a typical floor plan

**4.4. Type 3 – the Linear Atrium Layout**

A direct access to the ramp from the longitudinal driveway is provided by the option with two-lane arced car ramps at the ends of the main block. This block has dimensions of 72.0 x 66.0 m (in axes). In the middle there is an atrium with stairs and passenger elevators. The atrium occupies the entire height of the building. It is adjoined by driveways along the parking lots in front of the entrances to the apartments with loggias. The apartments on one side differ in area from the apartments on the other side. A special feature of this solution is that the apartments and driveways on opposite sides are not located on the same level. They are shifted by half the height of the floor.

This is explained by the need to maintain an optimal slope on the car ramps. The length of the driveway along the arced car ramp allows you to overcome a height of half a floor. The second half of the height is overcome on the opposite arced ramp. A two-block version of a linear layout of a house with individual parking in front of the entrances to the apartments (arc-shaped car ramps at the ends) is shown in Figure 15.

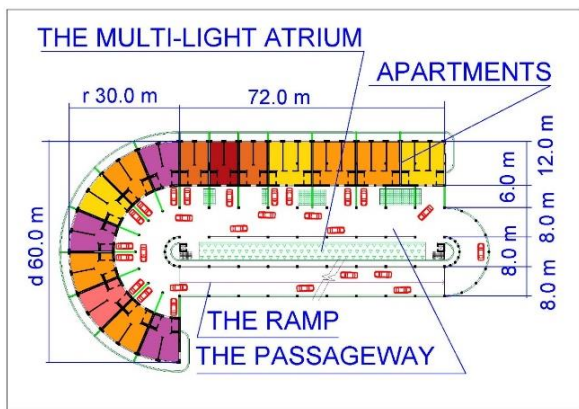


**Figure 15.** A two-block version of a linear layout of a house with individual parking in front of the entrances to the apartments (arc-shaped car ramps at the ends) – a typical floor plan

**4.5. Type 3 – the Linear-Arc Layout**

The linear-arc layout option for the house assumes a linear two-lane car ramp. The length of this ramp (~ 72.0 m) provides a normal slope within the height of one floor. This ramp is separated from the driveway along the apartments by an atrium.

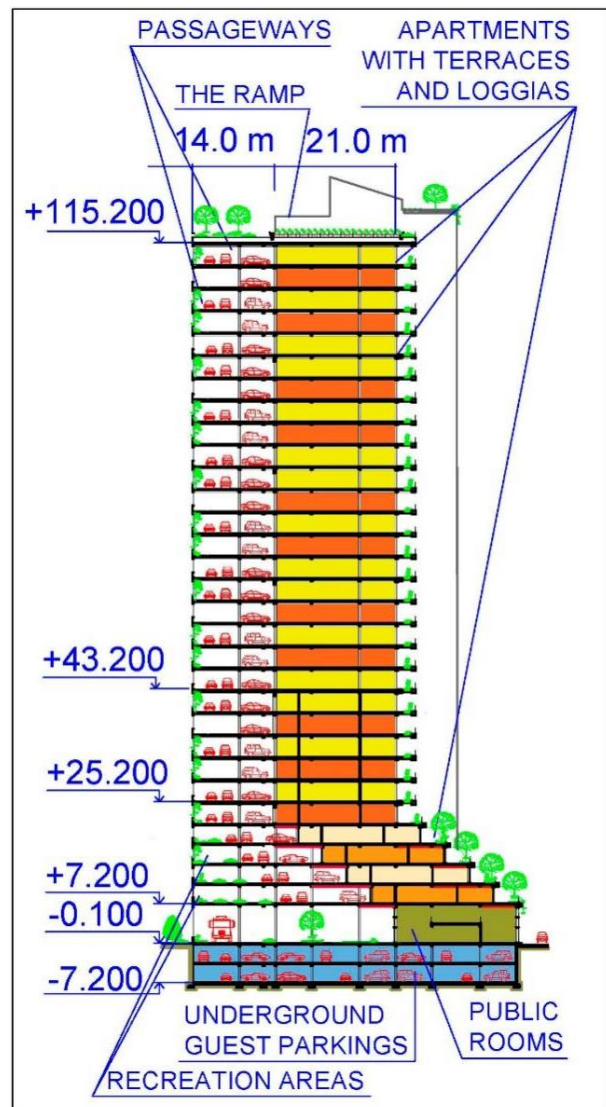
Stairs and passenger elevators are located at the places of the arc turns. The linear-arc layout option for the house with individual parking in front of the entrances to the apartments (straight longitudinal car ramp) is shown in Figure 16.



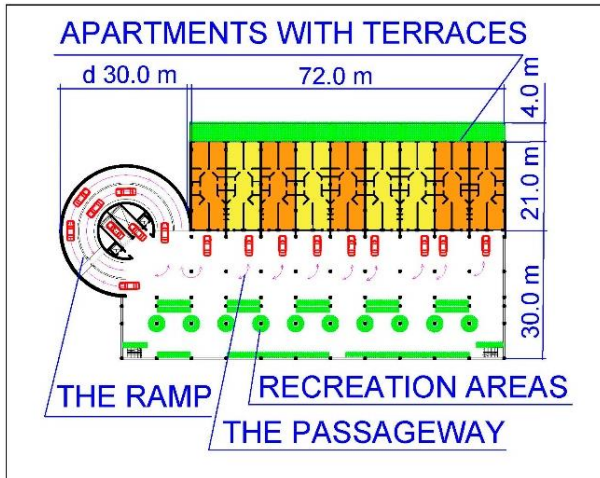
**Figure 16.** A variant of a linear-arc layout of a house with individual parking spaces in front of the entrances to the apartments (straight longitudinal car ramp) – a typical floor plan

**4.6. The Structure of the House**

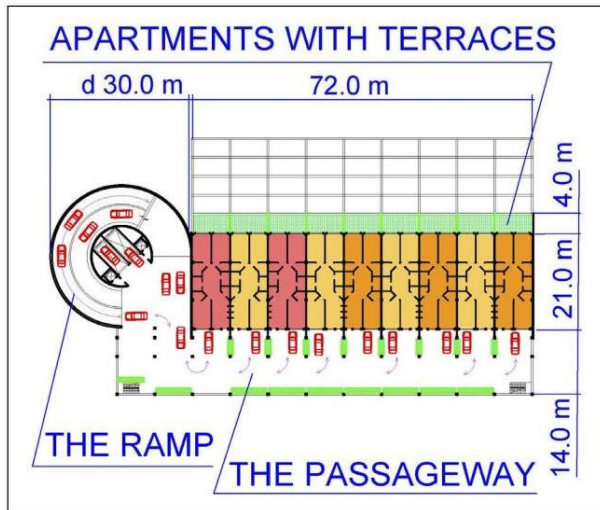
In various layout options for apartments, driveways and car ramps, it is possible to use a stepped layout. This solution allows for increased comfort in apartments due to wide terraces and additional recreation areas next to the apartment. An example of such a solution based on a layout with a side ramp is shown in Figures 17, 18 and 19. In this option, apartments on the first five floors have terraces. Recreation areas are located next to them. Apartments on floors 6-31 have loggias. The ground floor is occupied by public spaces. A guest parking lot is located in the two-story basement.



**Figure 17.** A cross-section of a stepped house with individual parking spaces in front of the apartment entrances



**Figure 18.** The layout of the first floor (elevation +7.200) of a stepped house with individual parking spaces in front of the entrances to the apartments (a circular car ramp on the side)



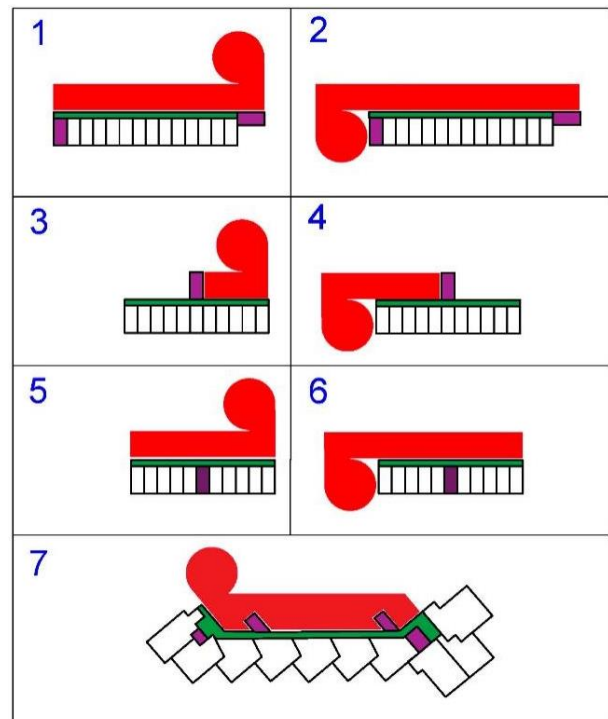
**Figure 19.** The layout of the fifth floor (elevation +21.600) of a stepped building with individual parking spaces in front of the entrances to the apartments (a circular car ramp on the side)

The comfortable presence of convenient car parking at the entrance to the apartment implies that the layout of the apartment is very convenient for users with disabilities. The minimum mandatory planning requirements for apartments for wheelchair users are set out in a number of regulatory and advisory documents, which were specified in the Introduction. However, creating not a minimally convenient, but a maximally comfortable space for wheelchair users implies a significant change in the parameters of travel and maneuvering. There are examples of highly comfortable solutions for sanitary facilities and kitchens [59, 60]. Some regulatory documents provide recommended layouts for “special apartments” [27, P. 8-9]. These planning solutions can be improved.

A small typical apartment with individual parking in front of the entrance consists of the following rooms: the entrance hall (16.7 sq.m); the toilet (6.5 sq.m); the

bathroom (6.5 sq.m); the living room (20.8 sq.m); the bedroom (20.8 sq.m); the loggia (16.5 sq.m). The overall dimensions of the apartment are 18.0 m x 8.0 m (in axes). From the individual parking area in front of the entrance, the user enters the entrance hall. From the entrance hall there is an entrance to the toilet, bathroom, living room and bedroom. From the bedroom and living room there is an exit to the loggia. The diagonal configuration of the walls with doors to the living room and bedroom provides convenient maneuvering of a wheelchair.

The considered solution can also be used in the reconstruction of existing standard houses with a gallery layout. The most convenient solution is possible in houses where the staircase and elevator nodes are located at the ends or in the middle (inside). Then all apartments receive additional amenities related to parking cars directly at the entrance to the apartment. If the central staircase and elevator node is located outside, then only a part of apartments, receive these additional amenities. The interpretation of this possibility of increasing the comfort of apartments depends on specific conditions – for example, the house in Stuttgart. These options are schematically shown in Figure 20.

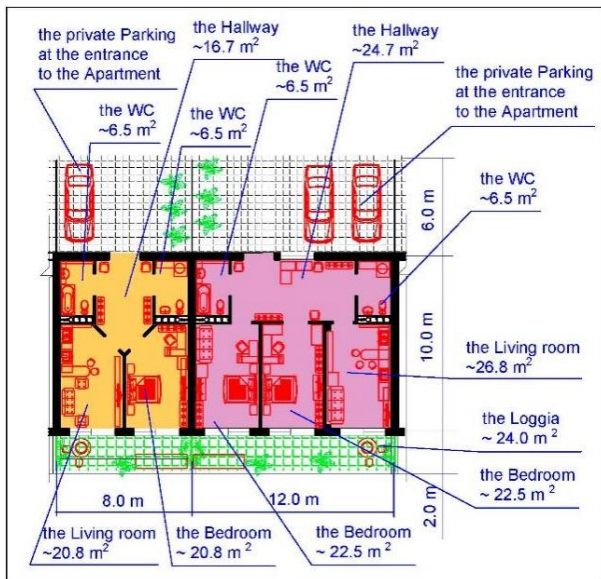


**Figure 20.** Options for adding a passageway with a ramp (red) to existing gallery layout houses (staircase and elevator nodes – purple; galleries – green): 1, 2 – Typical houses with stair and elevator nodes at ends; 3, 4 – Typical houses with a central stair and elevator node outside; 5, 6 – Typical with a central stair and elevator node inside; 7 – The residential house in Stuttgart

#### 4.7. Apartment Layouts

A typical medium-sized apartment with individual parking in front of the entrance consists of the following

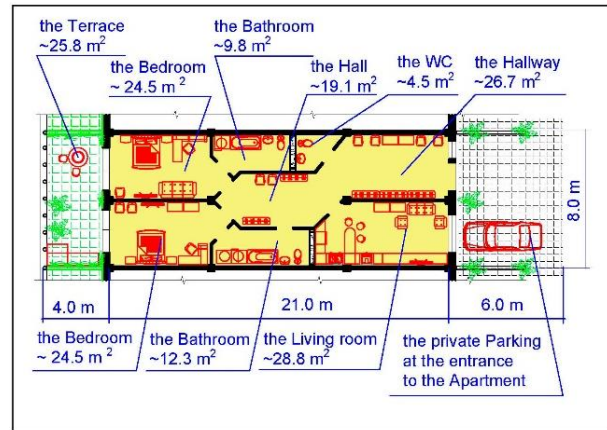
rooms: the entrance hall (24.7 sq.m); the toilet (6.5 sq.m); the bathroom (6.5 sq.m); the living room (26.8 sq.m); the bedroom (22.5 sq.m); the bedroom (22.5 sq.m); the loggia (24.0 sq.m). The overall dimensions of the apartment are 18.0 m x 12.0 m (in axes). From the individual parking area in front of the entrance, the user enters the entrance hall. From the entrance hall there is an entrance to the toilet, bathroom, living room and both bedrooms. From the bedrooms and the living room there is an exit to the loggia. The configuration of the walls of the entrance hall with doors to the living room and bedrooms provides convenient maneuvering of a wheelchair. Variants of typical layouts of small and medium-sized apartments with individual parking in front of the entrance are in Figure 21.



**Figure 21.** Options for typical layouts of small and medium-sized apartments with individual parking in front of the entrance

A large typical highly comfortable apartment with individual parking in front of the entrance consists of the following rooms: the entrance hall (26.7 sq.m); the toilet (4.5 sq.m); the hall (19.1 sq.m); the living room with the kitchen (28.8 sq.m); the bedroom (24.5 sq.m) with the bathroom (9.8 sq.m); the bedroom (24.5 sq.m) with the bathroom (12.3 sq.m); the terrace or the loggia (28.5 sq.m).

The overall dimensions of the apartment are 31.0 m x 8.0 m (in axes). From the individual parking area in front of the entrance, the user enters the entrance hall. From the entrance hall there is an entrance to the toilet and hall. From the hall there is an entrance to the living room with kitchen, two bedrooms and a bathroom. Each bedroom has an entrance to the bathroom and the terrace. The windows of the entrance hall and living room overlook the individual parking area in front of the entrance to the apartment. The bedroom windows overlook the terrace or loggia. The diagonal configuration of the walls with doors provides convenient maneuvering of a wheelchair. A typical layout of a large apartment with individual parking in front of the entrance is shown in Figure 22.



**Figure 22.** A typical layout option for a large apartment with individual parking in front of the entrance

## 5. Conclusions

The problem of creating a fully-fledged and comfortable environment for people with limited mobility is now recognized as relevant for a socially oriented state. Involving people with limited mobility (especially wheelchair users) in active economic activity through employment in various enterprises and organizations (cashiers in supermarkets, ticket registrars at airports, consultants at public service centers, telecom operators, programmers, designers, stock brokers, legal consultants, etc.) turns them into an economically active group of the population. This, in turn, makes this group of the population objectively sufficiently creditworthy, allowing it to become attractive to banks in terms of providing preferential mortgage loans. Accordingly, the combination of social benefits and wages allows the client to purchase a fairly comfortable apartment of large area, in which the problem of movement and maneuvering in a muscular or electro-mechanical wheelchair is solved in the most convenient way. Even greater prospects for the comfortable housing market are opened by the desire of some residents to simply create a barrier-free environment in the apartment (even if there are no disabled members of the family).

Formation of a comfortable environment for people with limited mobility is one of the urgent tasks of modern design. Minimum mandatory planning requirements are set out in a number of regulatory and advisory documents. The most difficult planning task is to solve the problem of convenient movement and maneuvering of wheelchair users. This concerns not only the premises, but also the adjacent territory.

One of the aspects of creating an environment convenient for people with limited mobility is organizing car parking directly at the entrance to apartments. It is advisable to organize the delivery of cars to these sites using two-lane car ramps of various configurations. Using only car elevators is of little promise, as delays in

movement and queues are possible.

It is the two-lane car ramps that make it possible to eliminate congestion of general evacuation traffic in an emergency situation. In this case, it is possible to use both lanes for vehicles moving in the same direction (down). An emergency stop of the car in one lane allows you to bypass it in another lane.

In the absence of a car or elevator failure, the presence of a ramp allows a wheelchair user, a patient lying on a stretcher or a baby in a stroller to be evacuated relatively quickly. In the event of a local emergency (suppression of illegal activities, urgent medical care, an accident of engineering systems, etc.), special services vehicles quickly and almost unhindered ascend the ramp to the place of the accident.

The semi-open nature of the space of two-lane car ramps eliminates critical smoke in the event of a fire in the car. Smoke is localized naturally without the use of special smoke ventilation systems. The semi-openness of two-lane car ramps under normal conditions significantly reduces the concentration of exhaust gases from moving vehicles.

Each layout option has its pros and cons. Linear and Fan-shaped layouts are convenient because only cars from a specific floor maneuver along the passage. There is no through traffic. This movement is concentrated within the framework. However, the prolonged circular movement of cars in ramps creates some inconvenience for drivers. Linear-atrium and Linear-arc layouts are more convenient from the point of view of driving a car, since turns alternate with straight sections. However, cars from the upper floors pass through all the lower floors, creating certain inconveniences in terms of high traffic intensity along the apartments.

The options considered allow placing apartments for people with limited mobility not only on the first floors of residential buildings (as recommended by some regulatory documents, given the complexity of evacuating wheelchair users in the event of an emergency shutdown of elevators). Planning solutions for apartments also require improvement. The solution to the problems of creating a comfortable environment for wheelchair users implies further multi-variant development taking into account the use of various design schemes for residential buildings. And houses with adjacent car parks can turn from isolated, a kind of “exotic” objects, into ordinary components of multi-story urban development.

Such houses occupy a larger area than ordinary apartment buildings. In the context of the neighborhood, this is partially offset by parking spaces. One car in a regular parking lot occupies approximately 40.0 sq.m: 18.0 sq.m parking space (3.0 x 6.0 m) + 12.0 sq.m through passage area in which exit/check-in with a turn (3.0 x 4.0 m) takes place. Approximately 2.0 sq.m of the common exit area is also being added. That is, if there are multi-level parking lots, the total area of the neighborhood occupied by parking lots does not increase. It's just that these parking

lots, in fact, turn out to be attached to residential buildings. At the same time, the comfort of living in the house increases significantly (convenient and quick access to your car).

Naturally, houses with apartment parking lots and car ramps in most cases can only be the result of new construction (it is possible to add a floor-by-floor parking area and car ramps to enter existing houses with a “gallery layout”). The number of such houses in new buildings or in the reconstruction of residential areas is determined based on the analysis of statistical data on the number of families with low mobility members. Additional data can be provided by sociological surveys that determine the number of families who want to have an apartment with appropriate amenities that take into account the needs of older people.

The high level of comfort of living in such houses makes them commercially attractive. This, combined with the positive social effect of caring for the needs of people with limited mobility, compensates for a slight increase in the area of the residential neighborhood.

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