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## **Grid as an instrument of creating of the universal space in dwelling.**

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### **1 ABSTRACT**

As a spatial form, the grid pattern has influenced a range of human activities, from urban planning, architecture, and modern art to graphic design, archaeology, and cartography. The grid is easy to lay out, easy to comprehend, and divides land into uniform units suitable for development. It is not a form, but a method of establishment of rational spatial divisions. At the same time it gives the most simple and most flexible solution. At the urban scale it organizes the city pattern with its streets and blocks, creates the architectural composition within the urban block or unit, orders the elements of the building. Grid is a highly efficient method of spatial organization from constructive point of view, but it creates difficulties in the functional organization of dwelling – universal unit can not be equally used both for the inhabited house areas and for the serving spaces. The study examines the cases of applying the grid structure in housing on the levels of the dwelling unit (flat) and spatial unit (room) and focuses on the methods of adapting the modular system to the specific living program. Grid concept creates extremely uniform, functionally universal and constructively simple spaces, but for appropriate living, it must be modified. There are several solutions depending on the size of initial cell – separation of the units with minor walls, attachment of them together, and introduction an extra cell for the technical spaces.

### **2 INTRODUCTION**

The purpose of this article is to describe the possibility of application of regular spatial grid as one of the most simple and universal solutions in dwelling architecture. Universal space in dwelling can be space, which can fit any basic activity. Universal dwelling can be based on this principle – every space inside can easy change its function. According to its concept, grid, containing just unified units, must produce just one type of space, which should be universal in the way of use. According to B. Leupen, there are 6 basic living activities: Sleeping, Get Together, Eating, Cooking, Bathing and Working. Each of them needs a very specific space, defined not only by size, but also by technical needs. Another important space, which does not hold any activity in house, but necessary to connect all of them, is circulation space. Looking at the concept of universality, it is important to define the limits of its implementation: some spaces, which are highly specialized and need equipment, such as kitchen and bathroom, usually are reduced in size till minimum and automatically then become not universal. At the same time, bathroom cannot be recognized as a space, where person spends valuable amount of time, or where people can get together. It is very utilitarian space, it needs specific installations and equipment, it is connected with the whole house technical systems, and in most of the times it doesn't play important role for understanding universality. Corridors and halls are also affecting the universality – application of any function to a room straightly depends on its access and presence of the passing through routes. In economics the house can be evaluated differently – by the total area and by the living area with exclusion of circulation and utility spaces. The living area has much more priority – it shows the real space, which can be used by residents for their everyday activities. Very often due to this reason circulation space can be excluded from the spatial scheme, and access can be provided through the rooms, which reduces the universality of such a space. It cannot be used for the activities, as sleeping and working, if the house has more than one inhabitant. Circulation space itself is not universal, but giving equal access increases the variety of use for the rooms.

Universality in use can be achieved by several techniques – by creating the spaces with equal size, access, similar spatial qualities. Each of it has one result – each space, or dwelling itself can be inhabited in different ways, which makes them universal. The constructive grid allows to create all cells uniformly without hierarchy by size and shape in the dwelling structure and spatial organization. The building itself is a tridimensional grid created by the repetition of one unit.

### 3 HISTORICAL OVERVIEW

As a spatial form, the grid pattern has influenced a range of human activities, from urban planning, architecture, and modern art to graphic design, archaeology, and cartography. The grid is easy to lay out, easy to comprehend, and divides land into uniform rectangular units suitable for development. It is not a form, but a method of establishment of spatial divisions. At the same time it gives the most simple and most flexible solution. At the urban scale it organizes the city pattern with its streets and blocks, creates the architectural composition within the urban block or unit, orders the elements of the building. Grid is the easiest and the oldest way to rationalize the space, to produce unlimited amount of identical units positioned in a strong order.

The grid plan came into widespread use in the West following the rebuilding of the Greek city of Miletus. The new city plan was strictly orthogonal, set in a square grid relative to the extant orientation lines. Its 10,000 inhabitants lived in three residential neighborhoods whose blocks were surrounded by public facilities and a central marketplace, in a clear rationalization of social space. Inside the each city district, residential units had equal shape and area. Also each unit had 4-side access from the street and could be equally divided into 4 parts. City structure was a reflection of the democracy ideology – each citizen had similar property, and for the city meetings and celebrations were provided central specialized spaces, which were at the same time the result of the union of the grid cells. The Hippodamus grid was one of the most flexible urban solutions: the size of cells was varied according to the function, main streets had different width, shape of the squares followed the social and landscape requirements. Later, during Roman times grid-based cities held highly utilitarian spaces, the proportion of grid, its position and the place of the main buildings were fixed and similar from one city to another.

In Palladio's villa Rotonda universality of use is created by grouping 4 equal units around the central hall formed as a result of division of square into 4 parts. Two crossed corridors are the axis of symmetry, and in the spatial organization of the building there are no preferences to any place or direction. Each unit at the same time is divided into 2 smaller ones, proportioned between each other in 1:2. From the central hall there is access to the 4 minor and bigger rooms and each space is connected with the other through the system of openings. The resulting house plan grid is composed by the superimposition of two main circulation axis.

Similar situation appears in traditional Japanese house: the initial grid is created by using tatami module. (Tatami is a type of mat used for flooring in traditional Japanese houses with the sides proportioned 1:2). Combined together, tatami could create several layouts of the rooms, which at the same time shaped the building itself.

Le Corbusier in his "Modulor" proposed the grid with various cells based on the human dimensions. He studied the concept of "alveolar volume" - the living unit with dimensions 2.26x2.26x2.26m, named "a container of men, cellular volume, which allows a great variety in composition". The alveolar volume could hold only one function – bed, table, kitchen etc.

The examples of abstract exercises in creating the cubical grid structures are the works of Sol LeWitt – the American conceptualist and minimalist. From sixties he started to develop a series of works under the common name "Modular structures" – three-dimensional grids based on the repetition of the cubic modules. In his works he operates with primary forms and clear spaces - the observer can read the pure geometry, the different interpretation of the single basic cube. In his work "Paragraphs on Conceptual Art" Sol LeWitt defined his idea as "a machine, which produces art". The priority of idea over its realization makes possible an introduction of almost any material. According to LeWitt, "for each work of art, which became material, there are many immaterial variations."

### 4 GRID IN CONTEMPORARY DWELLING

Grid – based spatial organization of dwelling with straight or inclined grid can be easy readable in the dwelling structure. Grid can be the result of the constructive system, or the spatial organization and subordinates every space of the dwelling. Grid organization can be found in different architectural scales – started from the urban – organization of the quarters and blocks within the structure of the whole city, the arrangement of the buildings in one block, dwelling units in building, rooms (spatial units) in flat, furniture and equipments in each space. The grid itself can be organized as a simple repetition of a single unit with equal basic dimensions (width, height, depth), or as combination of several cells.

## 5 GRID APPLICATION IN DWELLING UNIT

### 5.1. Homogenous (cubic) grid. Villa v Beroune, HŠH architekti, Czech Republic.

Each space of dwelling independently of its function has the same size and configuration. The imaginary example of the perfect grid can be 3-dimencional cubical grid, where one unit is holding one function. The grid concept creates extremely uniform and constructively simple spaces, but at the same time using the same unit is not rational from the position of space requirements for some functions. Some secondary important spaces, where the owner spends minimal time, such as wc or wardrobes in this scheme had the same importance. Together with the modularity in plane, it often comes the uniformity in façade and usage of the single-size prefabricated panels.

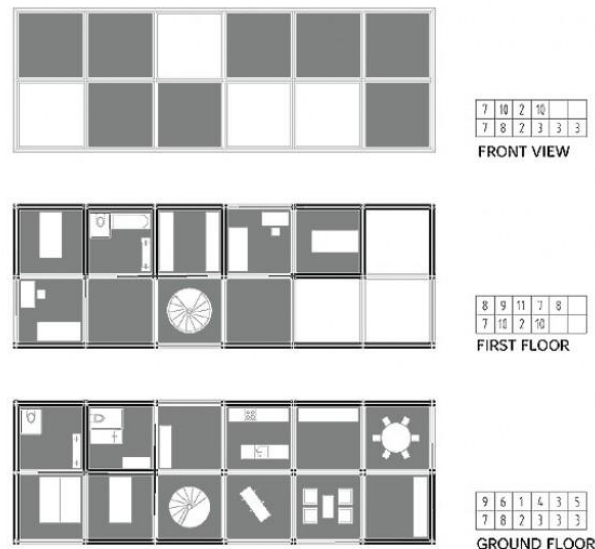


Fig. 1: Front view, first and second floors of villa in Beroun.

(<http://www.hsharchitekti.cz/index.php?lang=cs&page=project&name=vila-v-beroune>)

Villa in Beroun was designed in 2001 by Czech architects Petr Hájek, Tomáš Hradečný and Jan Šépka for the Pszczolka family and realized in 2004. Structurally, the house itself is a 3-dimencional grid combined from 24 cubes with the side of 3m, grouped spatially as 2x6x2 into a simple block. The grid is clearly readable in plans and in facades of the building. There is no distinction between any of units; the function of each is defined only by the character of equipment. Some units have sliding walls, allowing uniting different spaces, some can be united vertically in order to provide visual connection between 2 stories. There is no specific circulation space – some rooms can be accessed only through the others. However, there can be defined the following spaces: entrance is directly connected with the spiral stair leading to the 2nd story, living-dining-cooking area, occupying 6 cubes, 2 cabinets, 4 bedrooms, wardrobe and 3 bathrooms. If the huge living space, separated just by the row of columns, is quite flexible, and there is always possibility to combine functions (cooking, dining, sport, sitting together) due to the 2 extra undefined spaces, individual areas of the house faced some problems. On the 1st floor access to the parent's bedroom is organized trough the children's bedroom, and 9 sq.m space is enormous for the single toilet. On the second story 2 units currently used just as corridors, and bringing there extra function will disturb attached working places. Constructive solution is supporting the main concept of modularity and uniformity - the building is constructed as a prefabricated steel skeleton with concrete and glass panels.

### 5.2. Square grid with big unit (5,5x5,5m). Grid House / Forte, Gimenes & Marcondes Ferraz Arquitetos.

Dwelling is composed from bigger units; each of them can hold the single function or combine several minor functions. Size of unit – 5,5x5,5m - seems to be universal from the position of holding the single function of living, kitchen, dining, home theater, studio or garage space and at the same time allows a combination of bedroom and bathroom.

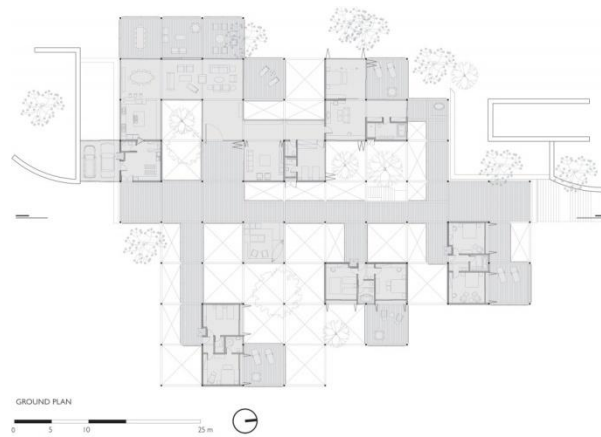


Fig. 2: The Grid house, floor plan. (<http://www.archdaily.com/28912/grid-house-forte-gimenes-marcondes-ferraz-arquitetos/>)

The Grid House is a residence designed in 2007 by Forte, Gimenes & Marcondes Ferraz Architects and it is located in Serra da Mantiqueira, Brazil. The house is built in a total plot area of 53.24 hectares, while the house and its facilities take over an area of 65,000 square meters. The structural grid was developed according to the topography of the plot of land; an area forming a small valley was chosen to construct the grid. Concrete pillars are raised above ground level and act as the foundation of this house, while large trussed structural steel beams trussed with the concrete pillars. The concrete pillars and the 11 meter long structural beams set the setting for the wooden structural grid which is composed of 5.5×5.5×3m modules. The structural grid creates solid spaces and voids, allowing for the user to walk above, within, or below the house. The void modules of the structural grid allow for the green environment to continue within the areas of the residence as trees grow within the empty space. The house itself consists of 65 modules adjusted to the site in grid order. The inhabited area is divided into 4 parts. The main building consists on various living spaces, indoor and outdoor, dining and cooking units, laundry, garage, masters' bedroom, wc blocks, open terraces, stairs. 3 separated blocks are children's or guest bedrooms together with wc and common terraces. The circulation space is solved as open terraces one or half unit wide. The house can be inhabited at the same time by 4 families, each consisting of 4 people. Big size of the unit is reasonable – bedrooms (each for 2 people) are around 19 sq.m, socialization spaces are 25 sq.m units combined together by 3 and 5.

### 5.3. Grid with joined units. Patchwork house Müllheim, 2005, Pfeifer Roser Kuhn Architekten



Fig. 3: Patchwork House, plans of the three stories. (<http://www.pfeifer-kuhn.de/index.php?id=25&L=en>)

Spatial scheme based on the clear readable grid, where most of the units are the same, and some of them are organized as double or triple basic unit. Different size of the units gives minimal specialization of spaces.

The Patchwork house is an interpretation of the traditional semi-detached house, where the dwellings are interlinked and interwoven. A house is designed for two families who want to live together under one roof, but at the same to have independent areas. The residential structure rotates around a common hall. The large hall separates the two areas on the ground floor and it is used as a common recreation area, is rotated by 90 degrees upstairs and opened there individual living areas. The open hallway that crosses the volume of the building, offers much potential for future modifications or repurposing. Both units face in all directions: the ground floor faces north and south, the upper floor west and east, the top floor either north or south. The spatial boundary between both parts is not clearly drawn, allowing a variety of different patterns of usage to result. Flexible spatial scheme is achieved by using the strict module in construction: house itself is a square 16x16 m divided into 3 units 4x4 from each side. Lining spaces have free function: each dwelling has 4 basic

units on 3 different stories. Also service spaces occupy their own unit. The central corridor unites 3 modules of each story. Also the living/dining room of the house and office space have double size.

#### **5.4. Grid with 2 units - one for the inhabited space and one for the utility spaces. Apartment Building in Brünnen, KIT, Austria**

There are 2 basic modules of the grid, which makes the spatial organization and dwelling structure more complex. The pattern of spatial divisions now becomes not just a simple intersection of parallel lines, it has its own rhythm. Space is used more effectively with applying units with different sizes and configurations. Still there is a basic division only between main dwelling functions and utility spaces.

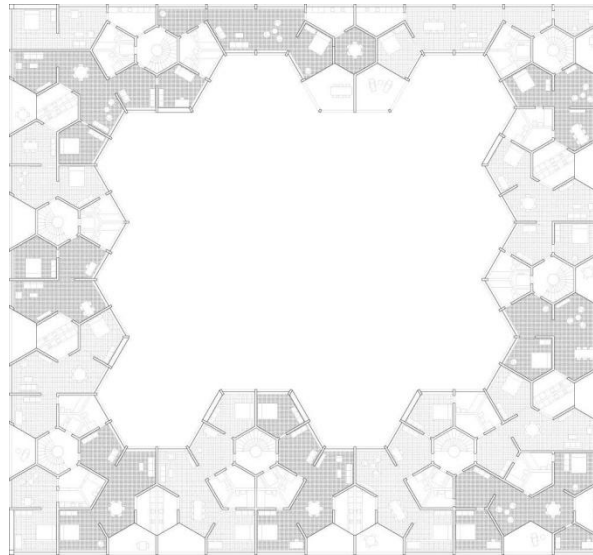


Fig. 4: Apartment Building in Brünnen, plan of the typical storey. (<http://www.archdaily.com/138771/apartment-building-in-brunnen-kit/>)

Kit Architects in 2010 have finished the design for an apartment building in Brünnen, the city of Bern in Switzerland with unique master plan scheme resembling a honeycomb structure. Spatial structure is organized by irregular pentagonal units with area around 15 sq.m grouped around hexagonal cores. Each dwelling can have from 2 to 6 similar pentagonal units – living, dining, working room or bedroom. Kitchen and terrace have their own semi-hexagonal unit. There is no separate circulation space – access to the bedroom can be organized through the living or working space, which limits the universality of use. But within the spaces, where the daytime activities occur, combination of 2 or 3 irregular units can create highly universal space – due to the equal space qualities and central position of kitchen. Dwelling units have no identical geometrical shape, but due to the similar size, lack of straight angles and clearly readable hexagonal grid, they are perceived as one module. But from the other side, prevailing of the acute angles in each room gives an extra need in designing furniture, which will fit in it. Chosen form of grid is economically and ecologically rational: it is compact and has similar modular construction elements both in inner and outer walls. The facades are also developed through the idea of modular units: spatial grid of columns and slabs with infill of solid panels or glass.

#### **5.5. Dwelling with constructive grid. Container housing, Social housing competition proposal, Arqydis.**

House is composed from similar constructive blocks with individual planning inside of each block. Universal space can be understood now not as a set of identical rooms of one house, but as a variety of arrangements inside one spatial unit. Very often house is thought to be expanded, and setting the constructive module is a way to limit and to guide initiated by inhabitants expansion in the environment of multi-unit or detached dwelling.



Fig. 5: Container housing: the typical floor plans of 2 story and 5 story buildings.

(<http://www.plataformaarquitectura.cl/2010/05/13/propuesta-de-vivienda-social-en-contenedores-arqydis/>)

Ivan Henriquez Rebolledo Arqydis and Williams designed the social housing project based on reusing the old shipping containers with dimensions of 2,44x6 m as universal spatial unit, which gives an economical housing solution and positive environmental impact. Architects applied this idea into two different dwelling types, one in double-story blocks and the other in apartment dwelling. The project "VC1" is a set of semi-detached houses consisting of 2 story dwelling that are an attachment of 3 containers, where the containers are stacked and have a reinforced steel structure. Gaps left in the different floors are designed for future expansion. The initial area of the house is 42 sq.m, which can be expanded till 56 sq.m with attaching an extra container. The 5-story apartment building also consists of expandable 3-container units, which are composed from 2 containers. The sizes of dwellings are the same –42 and 56 sq.m. In some containers there is an extension of balcony. The bigger unit contains several functions – kitchen, living area, bedroom, wc, stair. The smaller unit basically is a bedroom, but the extension can be used also as a set of 2 rooms, working space, living room or bedroom. Before the extension, the space is used as a big terrace. Using old containers together with low costs gives some architectural and spatial problems – narrow space 2,44m wide is not comfortable for the most activities: the rooms are extremely narrow and small (kitchen – around 4 sq.m, bedroom – 9 sq.m).

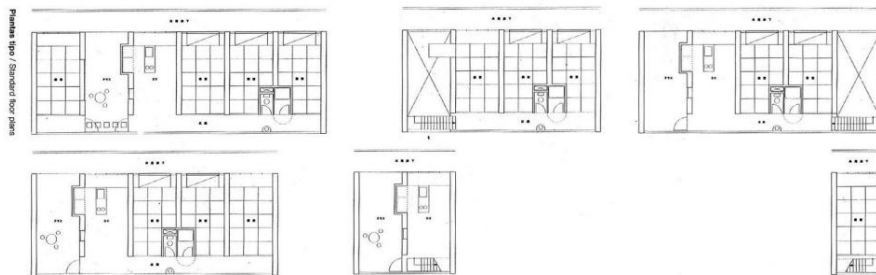


Fig. 6: Gifu Kitagata apartment building dwelling units. (<http://gifuprefecture.blogspot.com/>)

### 5.6. Room as house block. Gifu Kitagata Apartment Building, Sejima wing – Japan.

The whole building is constructed from one type of spatial unit – a room, combined together in different ways. The apartment building is part of a large scale public housing reconstruction project located near Gifu City, Japan. In order to minimize construction waste and to achieve standardization architect used a room 2,5x5m as a single spatial unit of the building. Each apartment consists on 5-6 modules, which can have vertical or horizontal connections. Basically the functions of unit are kitchen/dining, bedroom, terrace, tatami room, which are linked in front by narrow sun room (engawa). Each apartment has 3-5 entrances, which can be used differently depending on the owner's lifestyle. On the façade unrepeatable composition of dwelling units, each with its own terrace, gives variety in visual appearance and certain anonymity.

### 5.7. Multiunit house: one dwelling – one grid cell. Garden City K66, OFIS arhitekti

The whole structure of multifamily house is based on the grid, where one dwelling acts as a grid unit. There can be different spatial arrangements inside one unit, bigger flats are just combination of 2-3 cells. Apartment itself becomes one functional unit – together with public, office or green space. Building itself becomes a spatial grid of equal modules filled with different functions.



Fig. 7: Plan of the west building of Garden City. (<http://www.archdaily.com/80131/garden-city-k66-ofis-arhitekti/>)

Garden City proposal from Slovenian group OFIS Arkitekti includes two mix-used building, which spatial solution is based on a grid 10x10m. That was the most sufficient modular grid to fit all programs (housing, public, office, service, and garage). Plans and volumes are flexible and adaptable, so distribution of programs can change according to the demands of investor or changes in the market needs. One volume occupies the space of 10x6 modules (with a passage in the middle), second – 6x12 modules. Each building have several circulation cores, and flats, public spaces, offices, gardens, sport, leisure facilities are distributed around and mixed at every story. Combination and number of units is different at each level. Modularity is expressed also in dwelling's design: there are several types of flats developed as vertical or horizontal attachment of 1-3 units with the areas 100, 150, 200 and 300 sq.m. All units have similar spatial organization: the layout is changing due to the orientation of dwelling. The smallest flat always has bigger living/dining room and one bedroom. The 150 sq.m apartment is a result of the filling the space above the passage – 50sq.m half unit acts as an extra bedroom. Double size flats (in one story or duplex) are both the result of joining and rotating of one living/dining unit, and sleeping one with 2 bedrooms. Triple size flat has one extra living area, which has possibility to be divided according to the owner's needs. Some flats also have private garden of 100 sq.m.

### 5.8. Grid as basis for the urban solution. High Density Residential Building / Solano & Catalán, Elena Saricu, Bucharest, Romania



Fig. 8: Siteplan of residential complex in Bucharest. (<http://www.archdaily.com/109973/high-density-residential-building-solano-catalan-elena-saricu/>)

Grid is superimposed over the project site, and its cells can be the structural units of residential building, or the units of landscape.

Residential complex in Bucharest was built by Spanish developers in 2010. The general plan is a product of the application of 23x23m grid to the site, which provided dense arrangement of 9 high-storey buildings. Planning grid defines the arrangement of buildings in 5 parallel rows despite the trapezoidal shape of the site. The distances between buildings are similar from all sides and equal to the width of the unit. Each building is constructed from 3 volumes, the middle one is lower and provides the usable roof and extra lighting for the sides. The alternation of the lower and higher units creates the regular pattern. The grid system is readable also in the spatial organization of each house. The square blocks are divided into 3 stripes, each of them consists of 3,5 square spatial units, 2 bedrooms + wc, or kitchen + living blocks. The circulation core is in the center of building. The distance of 23m as a grid unit provides narrow and darkened space between 12 story buildings, and at the same time gives to it extra thickness, which results as some dark spaces in flats.

## 6 CONCLUSION

The review of several projects from different architectural scales and from different times is showing the development and possible application of the grid spatial system. The structure can be applied into the different levels: at urban level grid is defining the street system and the system of parcels, at the level of neighborhood – the arrangement of buildings and open spaces, within the building – the division into living units, in the flat – the spatial elements – rooms.

The application of the grid is easy and gives some economical and environmental advantages. It allows to produce industrial series of prefabricated elements of construction, which in its combinations can produce different living patterns. At the same time creation of unified spaces have one disadvantage – the program of domestic activities requires spaces different by size. The smallest space is a toilet, or storage with the area about 1.5 sq.m, the biggest (minimal required) is 16 sq.m living area. As it is seen from the examples, usage of the unified grid creates the spaces, which are oversized, or undersized. The solution in this case is to design more complicated grid with several different units, or to give a possibility for division or attachment of cells.

Second important issue is the size of the grid unit suitable for housing. In selected projects there are several basic cells: 2.26x2.26x2.26m, 3x3x3m, 2.5x5x3m, 4x4x3m, 5.5x5.5x3m, 10x10x3m, 23x23m. The areas of the cells are consequently: 5 sq.m, 9 sq.m, 10 sq.m, 16 sq.m, 30 sq.m, 100 sq.m, 529 sq.m. The dimensions are increasing together with increasing of the scale. Also comparison with the minimal standard of room (16sq.m) allows to understand the universality of the space to fit any activity. The lower numbers of the row are showing the cells with potential to be united and the higher – to be divided.

The present work is focused mainly on the analysis of the dwellings and its inner spaces, but the modular grid can be found also at the urban level. Within the city the set of basic activities is different – it could contain dwellings, business, social, sportive function, recreation and utility areas with its different sizes. At the same time the idea of universal urban unit must be viewed regarding the timeline of the processes of urban changes, which can be measured by years.

Dwelling and working space with constantly changing layout are potential fields of application of grid system, which should be developed from the simple unit repetition to the more complicated, individualized pattern combined from the set of universal spaces.

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