A NEW PERSPECTIVE ON URBAN ARCHITECTURE: STREETS ABOVE GROUND FOR BETTER ADAPTATION WITH NATURE

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ABSTRACT
The theme of this research is to change urban architecture to reduce the use of natural resources, especially land, and to remove obstacles in the form of roads that cut the natural fabric into unconnected cells. By creating more self-sufficient cities that produce on vertical farms within the city itself, urban–rural movements can be reduced. This will reduce the need for roads and cars and lead to less arable land that can be returned to nature. A circulating ecozone will reduce movements between towns. Finally, by replacing some of the horizontal movements in the city with vertical movements within the multifunctional towers (modules), the remaining horizontal movements between modules can be raised above the ground through bridges connecting them or replaced by aerial movements. In this way the earth, except for the foundations of the modules, is freed for nature and man and has no more obstacles for the movement of nature in the form of roads.
Keywords: sustainable city, streets above ground, vertical farms.

1 INTRODUCTION

The modern use of nature by man has reached certain important milestones. For example, according to the Food and Agriculture Organization (FAO) of the United Nations, the use of habitable land has reached half. Of these, arable land makes up 12.5%, pastures 21% and cities 1%, which is the same 34.5% occupied by nature. The remaining 31% is desert, glaciers 11% and degraded areas 9% unsuitable for life (Fig. 1). Another problem is the highways and railways that stretch between cities; they tear nature into separate, loosely connected cells. And although measures are being taken to combat this phenomenon, they are clearly insufficient. Cities themselves pose almost insurmountable obstacles to nature. This is a large area of land with a hard cover, making it difficult to filter water into the ground and leading to the wash-off of dirt from the streets into rivers, as well as contributing to a local increase in temperature. Food waste in cities, without proper processing, also leads to an increase in temperature. Let us pose the question of what can be done with the help of architecture to eliminate these negative phenomena. Urbanisation is thus a unidirectional process of absorption of areas belonging to nature or human cultivation, leading to environmental problems or exacerbating existing ones. For example, Elmqvist et al. [1] state that cities are growing, conquering more and more territories from nature as the rural population transitions to urban population, which is unidirectional. This leads to a change in land use from rural to urban, which implies a significant change in the characteristics of land cover to the worse side compared to wildlife. Roggema [2] states that urban expansion leads directly to physical changes such as soil alteration and disturbance, habitat loss or degradation. The author enumerates in detail the problems that urbanization entails, especially emphasizing those of planetary importance. It is also argued that it is unlikely that urban planning alone will help humanity to operate within planetary boundaries; however, the invention of new models of urbanization may prove useful in transforming the impact of cities from a burden to a boon. Wu et al. [3] analyse the changes in land use caused by urbanization and the impact of

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urbanization policies on its progress. They record the negative changes caused by urbanization on food security. As a result of the analysis, they conclude that urbanization policies can not only significantly affect the rate of urbanization, but also cannot change the trend of increasing urbanized area. ‘The rapid urbanization has led to extensive land use change particularly in those developing countries. In line with the development of urbanization, arable land is decreasing dramatically, which presents the threat to the food security for human being’ [4]. The work in UN Habitat [5] is devoted to the threats caused by global warming and, first of all, to the urban population living in the coastal zone. The emphasis is placed on the mutual connection between the process of urbanization and climate change. World Meteorological Organization [6] describe the problems of modern cities, namely greenhouse gas emissions, heat stress, hurricanes and floods. It calls for changes in urban planning to adapt to these threats.

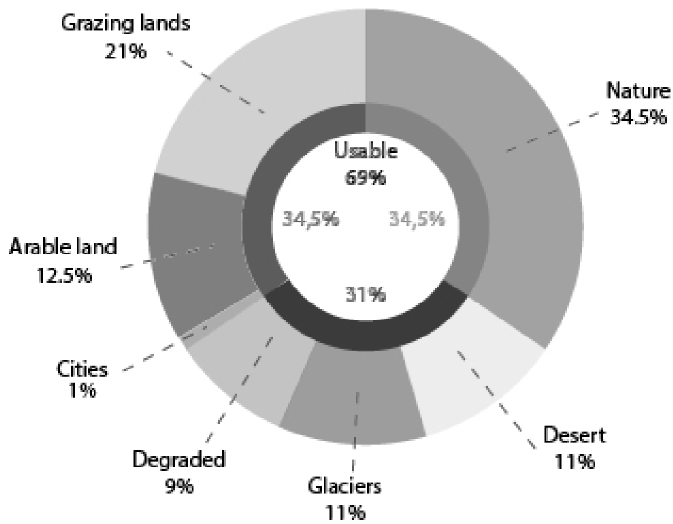

Figure 1: Distribution of land by type of land use (based on FAO data).

As a solution, it is proposed to use multifunctional high-rise buildings (modules), which, occupying a minimum area on the ground would provide a high density of functions per unit area. Such modules can be united into clusters using bridges above the ground; these bridges will serve as a modern street, both its above-ground part with shops, cafes, theatres, and underground, allowing the modules to exchange resources among themselves for greater stability. In fact, a cluster is the smallest stable unit of a city. Since the volume of traffic of both people and resources that currently exists cannot be accommodated in streets above ground, it is therefore necessary to radically reduce it. For this reason, the following solutions are proposed. Active use of vertical farms with artificial lighting [7], which will make it possible to effectively use the internal dark spaces of the modules and reduce travel between city and village, which means fewer roads and cars. The use of modern universal factories located inside each module, so that in order to produce products it would not be necessary to transport them from the factory to the city, often from another continent, but it would be possible to purchase an information model and produce the product locally at the place of consumption, and after its use it could be was disposed of in the same factory for further use of resources. Factories for the production of items that cannot be produced in such factories must be located in a degraded area, near sources of resources, and transported by air using airships as the cheapest air transport, requiring minimal infrastructure in the module. Such an airship can moor to its top and perform loading and unloading. In this case, the same circulation principle is used – the used product is returned to the manufacturer. Finally, since the cluster is self-sufficient in terms of providing people with resources, work, rest and entertainment, movements between clusters are minimized and can be covered by a light bridge above the ground capable of transporting people and small loads, as well as air transport located at the top module, for example, a vertiport can be located there.

2 METHODOLOGY

This paper proposes a new design for the organization of urban space, as well as some changes in urban life and the provision of the city with necessary resources caused by the changed design. The elements of the new city structure are described as a response to the challenges described above. A comparative analysis with existing cities is carried out to test the viability of this urban scenario. Quantitative assessments are carried out, based on available methodologies for assessing provision. For example, using the available estimates for vertical farms, the number of such farms is calculated to fully supply the city's residents with food without using agricultural land.

3 CLUSTERS

As mentioned above, modules and clusters become the main elements of city formation. A module is a high-rise building in the form of a tower that combines many functions, such as residential, office, industrial, educational, entertainment and agricultural. Clast is the combination of several modules into a stable structure, ensuring the exchange of people and resources between modules above ground. The clusters, in turn, are connected to each other through light bridges and air transport. On the Fig. 2 shows how modules and clusters help reduce land use in the city. In this case we are talking about its strict, constant use. Of course, residents can use nature for their walks. This approach is in harmony with the works of Iley [8], Roggema [9], Roggema et al. [10]. 'This requires a shift in our mindset. We need to go beyond just a 'human-centric' view of the future to set a wider 'life-centric' mission that recognises how our systems are nested and interdependent. Healthy human societies cannot exist on a dying planet' [8]. The author focuses on changing the thinking in the field of ecology, while in this work, an architectural solution is proposed as a response to the need to coexist with nature, which in turn entails changing the behavioural model in relation to nature. It is proposed to reduce as much as possible the single use of land as one of the most valuable resources and to share the freed up free land with nature with joint access to it by both nature and man. 'If we want to use the design of the city to deal with future disruptions resulting from climate impacts, migration, economic change, or any other threat, this design should allow the city to transform and adapt to changes. Looking at the city as a complex adaptive system, the capability to adapt to sudden, unprecedented changes and to deal with uncertainty is therefore essential' [9]. He also formulates the basic principles of designing a sustainable city: close cycles at the lowest possible scale; build redundancy in the design; create anti-fragility; see citizens as (design) experts; use the landscape as the basis for urban growth; develop innovative, rule-breaking designs. These principles largely coincide with the theme of the research, but if the author says that the landscape should become the basis for urban development, then in this paper the basis for development is the rethinking of the role of the street and its place. In this way, the city as if detaches itself from the landscape, proposing to divide it between man and nature. Agreeing with Roggema et al. [10] that: ‘There is a direct relationship between the way cities are developed and the negative influence this has on the ecological quality of the environment. Current practice is hard to alter and, where existing urban planning focuses on the developments, trends, and habits applied in the recent past, it seems to be repeating how policies responded to former experiences, thus formulating copies of policies for novel or unknown problems of the future’, it is proposed to radically change the design of the city and the organization of life in it. Not to look for ways to improve the existing structure, but to propose a new reality that would eliminate existing problems all at once. Perhaps this would lead to the emergence of new problems, which is a promising area of research.

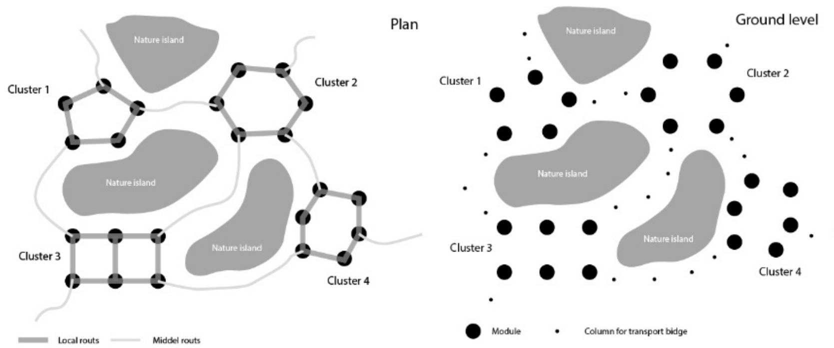

Figure 2: Clusters (developed by the author).

As can be seen in Fig. 2, the occupied area at ground level consists only of the area of the bases of the modules and the supports of the bridges connecting the clusters.

The actual change in displacements at ground level is presented in Fig. 3. Thus, we obtain the first principle of building clusters from modules – this is not interfering with nature, which is illustrated in Fig. 4.

The next important principle of cluster formation is the presence of at least two connections between modules. Otherwise, a violation of the functionality of the bridge will lead to isolation of the module, which has only one connection.

And, of course, it is necessary that the flow of resources across the cluster boundary tends to zero. This means that in an ideal case, the cluster is fully self-sufficient in energy, water, food, and people do not need to go outside the cluster for work, recreation, entertainment, sports and education (at least secondary).

In many ways, this approach requires a change of mindset in the use of nature and allows for the preservation of natural diversity [11], [12].

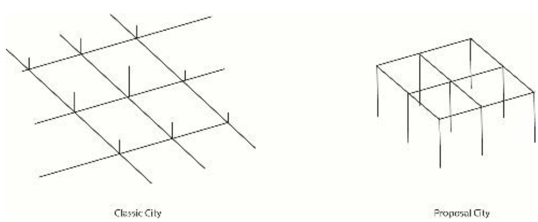

Figure 3: Movements in the city (developed by the author).

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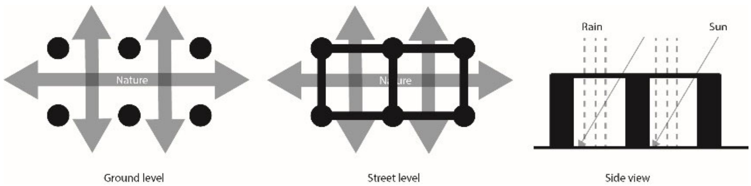

Figure 4: The principle of barrier-free nature (developed by the author).

3.1 Functionality

All necessary infrastructures for normal human habitation are placed in modules, all functions in modules are duplicated, i.e. if a function is represented in a module, it must be represented in at least one more module within the same cluster. At the same time, basic functions such as energy supply, food supply, water supply and sanitation, heating and cooling are present as basic functions in each module.

The mobility of people is graded differently, with local mobility involving movement within the same cluster – within one module via the module's vertical utilities, and between modules via bridges at street level (fast, active movement) high above the ground and at recreational level via footbridges low above the ground (slow, walking). Average movement lengths are movements between clusters carried out over low height bridges. This arrangement of bridges makes them cheaper to build and less expensive to construct as they do not require large spans. The second possibility for travelling medium distances is air transport (helicopters and quadrocopters located on the upper platforms of the modules). Both people and goods can be moved along these routes, but the total volume of movement is minimized. Long-distance movements involve travelling between cities and distant production facilities. They are carried out by air transport, mainly by airships, as the cheapest way from air and not requiring aerodromes, they can be docked to the top of the modules, where their loading and unloading is carried out.

4 MODULE

4.1 Functional structure of the module

In the centre of the module there are vertical communications, and then there is a dark belt, where, depending on the height, there is a reactor for processing food waste into humus, vertical farms with artificial lighting, warehouses and heavy machinery. Further away from the centre is the light belt (receiving light from the sun), which houses living cells, office space and other areas requiring natural light. The outside of the module is surrounded by a shell, which is used to house rails for external lifting devices, solar panels, placed so as not to interfere with the lighting of the interior spaces.

The height of the module is divided into levels, which in turn are divided into underground and aboveground levels (Fig. 5). The uppermost underground level is the water supply level, where groundwater is abstracted, chemically and mechanically treated both after abstraction and after use before returning the water to the ground. Below this is the heat pump level, which provides heating and cooling for the module. Even lower is the geothermal power plant level. This level is the most controversial at this stage and the feasibility of its inclusion requires further investigation.

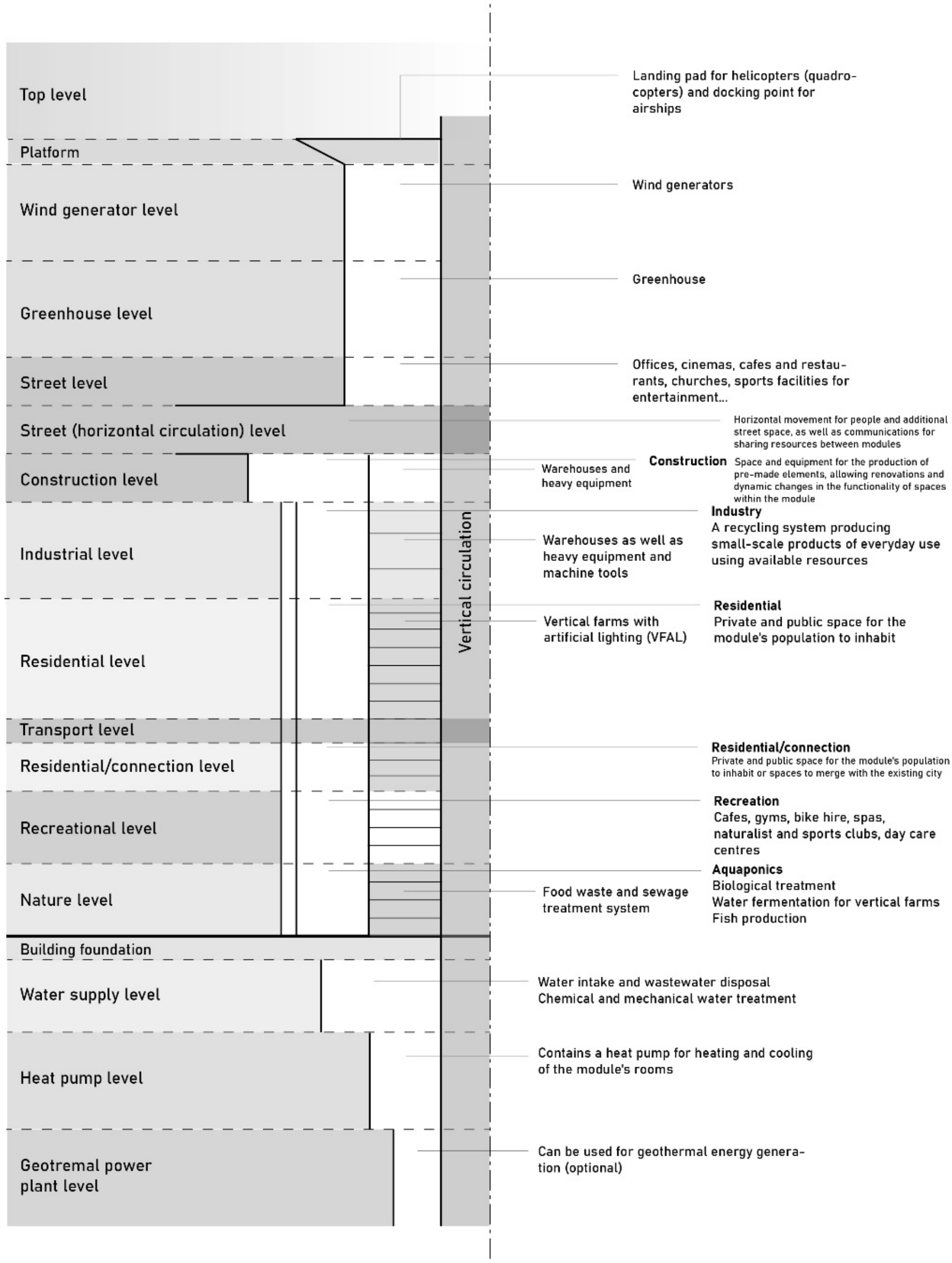

Figure 5: Functional structure of the module (developed by the author).

The above-ground levels are arranged in this order. The lowest is the nature level. Outside the module at ground level is nature, and inside the module in the light belt is aquaponics systems and, in the dark belt, systems for converting food waste into humus. Above this is the recreation level, which is designed to facilitate the recreation of the module's residents.

Even higher is the first residential level, which is where the school and kindergarten should be located. Above it is the transport level, this is where the route connecting the clusters with each other is located. Above it is the main residential level, followed by the industrial level and, finally, the construction level. The street level completes this part. It is at this level that modules are connected to each other into clusters by means of bridges. Further on, the module area is reduced by the dark belt. Immediately above the street is the upper street level, where the street premises continue, but without bridges. Next level is level of greenhouses for growing products that cannot be grown under artificial light, as well as it fulfils the function of a winter garden. Next is the level of wind turbines, above which there is a platform with a vertiport and a docking point for airships.

4.2 Geothermal power plant level

Geothermal power plant level is designed to generate electricity due to temperature differences at different depths. The open method of obtaining energy in this way is not safe for the environment, as salts of heavy metals and mercury compounds get to the surface. The closed method is rather complicated and expensive and most likely depends on geography. This issue requires further research.

4.3 Heat pump level

The underground equipment and heat exchanger are located on this level. This technology is used for heating during cold periods and cooling during hot periods.

4.4 Water supply level

Groundwater is taken in at this level, which is chemically and mechanically treated at this level and then enters the module's water balance system. Excess, wastewater is taken to this level, where it is treated and returned to the groundwater.

4.5 Natural level

Nature is located at this level outside the module. The direct access to this level from the module is closed and comes from the recreation level. This is done so that people going out into nature do not destroy everything near the base of the module. Due to the presence of pedestrian and bicycle paths above the ground, the flows of people are dispersed over a larger area, and access to the land is made over a larger area with a lower density of people. Modern work with landscapes and the creation of park areas is emphasized in the works of Nijhuis and Nijhuis [13], Puplampu and Boafo [14], Steiner et al. [15] and Wong et al. [16].

Inside the module, there is an aquaponics system in the outer light belt and a system for converting food waste into humus in the inner dark belt. The aquaponics system is used for biological water purification as well as fermentation for use in vertical farms. In addition, it acts as a source of fish to diversify the diet of city dwellers.

In addition to all of the above, this system protects the module from flooding, as the entire height of the level is covered with sealed walls that prevent water from penetrating.

4.6 Recreation level

The recreational level is designed to meet people's need for recreation. This level includes cafes, clubs, bicycle rentals and other means of small mobility. Gyms and treadmills are designed for human recreation. This is the quiet level of the module, as opposed to the noisy street level.

At this level (Fig. 6), light pedestrian and bicycle paths above the ground emanate from the module, from which there is a ramp directly to the ground. This is done firstly, as mentioned above, to distribute people over a larger area, and also because for most walks the ground is not necessary, it is enough to walk between trees above nature, to contemplate it, to breathe fresh air. At the same time, the ground under such a path can be used by nature, grass and trees grow on it, and the paths do not prevent animals from running under them. Such paths provide places for nature observation, picnics, etc. Such droves connect the modules on the lower elevated level and can even lead to other clusters, for longer walks.

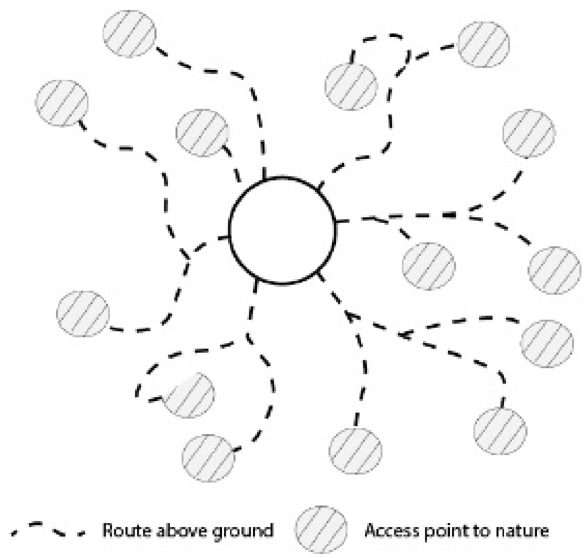

Figure 6: Diagram of the distribution of people on the ground around the module (developed by the author).

4.7 Residential/connection level

This is the first residential level. It is convenient to place schools and kindergartens here, so that children have quick access to the land. It is possible to provide paths from this level leading directly to the paths of the recreational level, bypassing the vertical communications of the module. There can also be housing for elderly people and public spaces. In case the module on the transport level has a connection with the existing classic city, this level can be used for premises and equipment for communication with the city, such as warehouses, a power substation for the exchange of electricity with the city and others.

4.8 Transport level

The transport level is designed to connect the clusters with each other as well as with the existing city. At this level, transport routes are laid out above ground, which can be travelled by vehicles, such as monorails and others. In addition to transport, pedestrian routes and the use of bicycles and other means of small mobility can be envisaged.

4.9 Residential level

Residential level is intended for the population of the module. Public private spaces are placed on this level to ensure comfortable living for the residents. Private flats alternate with public cafes, clubs, co-working spaces, office spaces and parks. This space is divided by large spaces, such as a gymnasium for playing volleyball, and small spaces, such as flats, offices and others. The corridors connecting these spaces act as streets. These streets can be open (outdoors in the form of loggias) and closed (inside buildings, protected from the outdoors).

4.10 Industrial level

The industrial level is designed for the production of goods necessary for everyday human life. It consists of 3D printers and assembly lines, warehouses where resources and parts are stored for reuse. It also provides for disassembly of used products into parts and resources for reuse. To produce a product, it is only necessary to buy a model and produce it in such a factory, instead of producing it in a remote factory and transporting it. All products that cannot be produced in such factories are produced in mega-factories and airlifted by airships. After use, the product must return the same way to the manufacturer’s factory to recycle and reuse parts and materials.

4.11 Construction level

Since the module building is intended for long-term use, the preferences and behavioural patterns of its inhabitants and their needs may change over time, hence the need to reconstruct individual spaces (it is necessary to provide for such a possibility in the building design, which will be discussed below). At this level there are machines and spaces that could recycle the extracted building parts and create new elements that can be assembled on other levels to modify the spaces related to the change of their functions.

4.12 Street level (horizontal circulation)

The street level is designed for the movement of people between modules, for their street activity, for their unexpected and expected encounters, for those surprises and challenges that make people live in the city. Entertainment clubs, concert and exhibition spaces, cafes, restaurants, theatres, etc. are located on this level. Bridges connecting the modules are an additional space of these streets. At the bottom of these bridges are communications that allow the modules to exchange resources for greater stability, such as pipelines for transporting water and media for cooling and heating systems, wires, cables, and roads for transporting containers with cargo. There are also tunnels for transport to allow people to move quickly between modules.

4.13 Street level

This tier complements the previous tier by providing additional spaces in modules above streets. This level does not extend to bridges, being limited to modules.

4.14 Greenhouse level

Plants that require sunlight are grown on this level. This level also serves as a winter garden for the residents to walk and relax in, as well as for their possible hobby of growing plants.

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4.15 Wind generator level

This level is used to generate wind energy. In order not to interfere with air transport, it is separated from the upper level by a wide platform, and instead of the blades of modern wind turbines, slotted air intake and turbines inside are used. By means of deflectable flaps, the flow of air inwards and the direction of its exit can be controlled. Horizontally, this level is divided into several floors to avoid a unidirectional thrust vector by controlling the flaps.

4.16 Top level

This level is separated from the lower level by a wide platform, which is used to place the vertiport and also allows docking and unloading and loading of airships. If such a neighbourhood is dangerous for any reason, then on the tops of some modules in the cluster it is possible to place vertiport, and on other tops of the same cluster equipment for docking airships, and the received cargoes can be distributed among other modules through the street level.

5 FUNCTIONAL MODELS

5.1 Transport model

The module distinguishes three types of mobility depending on distance (Fig. 7).

- Local routes are movements between modules. Characterized by high intensity of people and cargo. They are carried out at street level on foot or using transport, for example, a horizontal elevator. Cargo and resources move across bridges in containers, pipes or wires. An alternative route for people, but not cargo, may be at the recreational level. Travel is carried out on foot or with the help of bicycles or other means of low mobility.
- The middle route is movement between clusters or an existing city. It is carried out at the transport level using shuttles that move on rails, on a monorail or in another way. Both people and goods are moved. Characterized by low intensity. An alternative way is to move using helicopters and quad-copters on the upper level. Mostly people move. The movement can also be carried out to various natural locations.
- Long-distance route is movement between cities and mega-factories located in degraded areas. Carried out by air using airships. Characterized by low intensity for people and medium/high intensity for cargo.

5.2 Structural model

Structurally, the module is built around the vertical communications shaft, which is the main rigidity core. From the foundation to the street level, a coaxial shaft of a dark belt is formed, combining with the main one, horizontal rigid connections. This creates reliable support for the bridges and allows warehouses and heavy equipment to be placed in the space between them. Below the foundation, the water intake ring, heat pump ring and geothermal power plant ring create a special clamped support in the ground, which allows the tall module to stand securely.

The light belt space is connected to the rigid core in a hinged manner at both the lower part (below street level) and the upper part (above the street), which, like a Japanese pagoda, can effectively withstand earthquakes.

Hinged elements form a coarse-cell structure, which allows you to create large spaces (Fig. 8). This structure is permanent. But the space inside a large cell can be divided into smaller ones, such as apartments, by elements manufactured at the construction level. This padding can change over time, providing greater flexibility in the functionality of the module (Fig. 9). The issues of modern materials with reaction are described by Menges and Reichert [17].

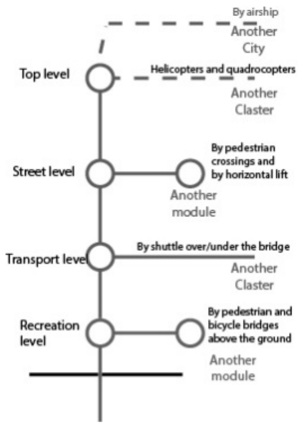

Figure 7: Transport concept (developed by the author).

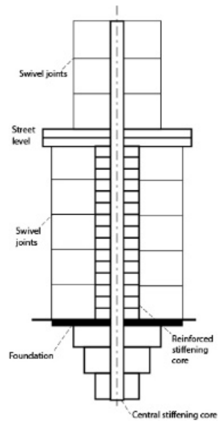

Figure 8: Structural concept (developed by the author).

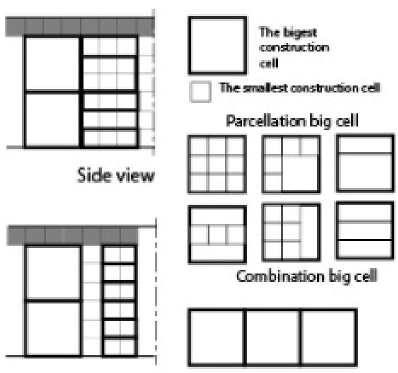

Figure 9: Concept of large and small modules (developed by the author).

5.3 Energy model

The balance of electricity is maintained through three factors: production, consumption and balancing. The production of electricity in the module is carried out in several renewable ways, namely, a wind generator located at the top of the module, solar panels located along the shell of the module, especially in its upper part, a geothermal power plant and the combustion of biogas generated as a result of processing food waste. As for consumption, it is, of course, necessary to pursue policies aimed at rational use of energy and reducing its consumption. Balancing implies both the possibility of storing energy inside the module and then consuming it, as well as connecting it to the energy system in an existing city to sell surpluses and purchase electricity in case of shortage.

Electricity consumption consists of the provision of household needs of the inhabitants, operation of offices and other establishments, provision of industry, transport costs for both vertical movements and horizontal movements in the form of horizontal lifts at street level and shuttles at transport level, charging of airports and airships, lighting of premises. The same high-power consumption will be in vertical trusses with artificial lighting.

5.4 Water supply model

Ensuring the water balance in the module is carried out through the intake of groundwater for mechanical, chemical and biological treatment, through the processing of wastewater, as well as the collection of rainwater. Excess water is returned to the soil after purification.

The water demand is calculated based on the needs of the residents of the module both at home and outside, for example, at work, plus the water demand for all establishments in the module, providing industry, aquaponics and vertical farms with artificial light and greenhouses. At the same time, it is proposed to use aeroponics as the least expensive in terms of water use.

5.5 Food supply model

Food supply is provided by products grown on vertical farms with artificial light and greenhouses in the upper part of the module, where products that cannot do without sunlight are grown. The problem of obtaining food of animal origin is deliberately avoided here. This problem requires a separate study. For the time being, it is envisaged to obtain such food from outside the existing city in exchange for plant products.

5.6 Interaction model

Realizing that such a module or even a cluster cannot exist autonomously, although this is the goal, except of course for the freedom of movement of people, it is necessary to ensure interaction with the existing city. Such interaction is carried out by the module at the transport level, and in the city a special railway station is created or the existing one, capable of receiving transport used in clusters for medium-sized movements for the exchange of people and goods, is equipped. Through this artery, people can get in and out of the module, as well as exchange resources and goods. At first, until a balance is reached in the cluster, this link can cover the lack of resources within the cluster (module), and the excess can be sold to the existing city. It is possible that within the module it will be profitable to produce expensive products, for example, lettuce leaves, and sell them to the city, and buy cheap ones in the city, which will contribute to a faster payback of the project. At first, it is possible to replace delivery of goods not produced inside the module by air from remote factories with their purchase in the existing city, necessarily providing for the return of waste products back to the city for processing, as well as their return to remote factories. In addition, electricity can be exchanged with the existing city through this channel.

6 CONCLUSIONS

The proposals made in the paper make it possible to answer many of the challenges indicated at the beginning of the paper. For example, the vast open areas obtained in this project favour the natural filtration of water into the ground and contribute to the reduction of heat stress, which is also favoured by the processing of food waste inside the module. The presence of streets above ground and a sealed ground level with aquaponics, makes a city based on such modules and clusters resistant to flooding. Growing food inside the modules on vertical farms with artificial lighting, in addition to reducing the need for horizontal movement, contributes to the city's resilience to drought. The land freed from the constant presence of man, without hard surfaces and without the obstacles of roads at ground level, contributes to the biodiversity of nature. Man also does not need to go outside the city to communicate with nature, but only to descend inside the module to the recreation level, where he can walk above the ground between nature, observing it or temporarily descend to the ground.

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