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Densification of cities as a method of sustainable development

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Abstract. The way of the Earth's resources are used is one of the basic elements determining the quality of today's economy. Problems related to the urbanization are among the main areas affecting the preservation of development potential for the future generations, which from the start have been taken into account in the doctrine of sustainable development. The growth of the human population and also civilizational transformations require an increase in the volume of buildings and urban areas, which is an inherent part of the development. However, it is important in what way the development of the built environment takes place. The problem of urban sprawl occurs globally not only in regions with high and increasing population density, but also in regions with a declining population, e.g. in Europe. The urban sprawl reflects an inappropriate and unsustainable way of using the environment and its resources, not only depleting the Earth's natural assets and reducing ecosystems, but also adversely affecting people's quality of life and health, and contributing to the social problems. This creates specific requirements for a spatial policy regulating not only the design and implementation of new cities and settlements, but also the management of already urbanised areas, which are also undergoing development and transformation processes affecting on the way they are used on. The article focuses on a strategy of densification of cities, as a method of ensuring their sustainable development allowing better use of the potential of the natural assets which are already being exploited, and to reduce the need for new resources. Four methods of densification the urban areas were distinguished and characterised: - increasing the efficiency of the use of the existing buildings by transforming their functions (changing functions, adapting unused space), - building up on free spaces in the city (construction, extension, infill), - transforming space below and over existing buildings (downward and upward extensions), - replacement of existing buildings (demolition of existing and construction of new buildings). Advantages and disadvantages of the relevant methods were discussed and the determinants for their application were defined. In each case, in order to use the methods of urban densification, it is necessary to perform a proper diagnosis of the initial situation and prediction of a development scenario and also appropriate formal regulations allowing for densification within the limits set by the sustainability criteria. Reasonable densification of cities or their parts is an important and effective way to support sustainable development.

1. Sustainable development in urban planning

Today sustainability is one of the basic ideas defining the criteria and methods for achieving development in most spheres of economy because, in addition to the holistic approach to the related problems, the concept recognises the importance of values which themselves do not constitute a primary motivation or criterion for human operation, yet it is necessary to take them into account to



rationalise the pathways of progress. The main areas affecting the preservation of growth potential for future generations, which from the start have been taken into account in the doctrine of sustainability, include problems related to urbanization.

The growth of human population and also civilizational transformations require an increase in the volume of buildings and urban areas, which is an inherent part of development. However, it is important in what way the development of the built environment takes place. The problem of urban sprawl occurs globally not only in regions with high and increasing population density, but also in regions with a declining population e.g. in Europe in Spain, Portugal, Italy as well as Eastern Germany or in Central Europe in such countries as Poland or the Czech Republic [1].

Observed for decades the uncontrolled expansion of cities reflects an inappropriate and unsustainable way of using the environment and its resources, not only depleting the Earth's natural assets and reducing ecosystems, but also adversely affecting people's quality of life and health, and contributing to social problems. The PLUREL [2] project identified the most important negative impacts as:

- Consumption of land, loss of highly productive agricultural land,
- Destruction of biotopes and habitats with the fragmentation of landscape structure and decline of ecosystem services,
- Less open space, longer distances to attractive recreational areas,
- Increased dependency on private car use, traffic congestion, longer commuting times and distances, climate change emissions, noise and air pollution.

This creates specific requirements for a spatial policy regulating not only for design and implementation of new cities and settlements, but also for the management of already urbanised areas, which are also undergoing development and transformation processes affecting on the way they are used on [3-5].

From the time when G. H. Brundtland proposed the idea of sustainable development which "meets the needs of the present without compromising the ability of future generations to meet their own needs" [6], numerous different concepts, strategies and models for sustainable urban development have been developed. One of the basic postulates defined by most of those concepts is the requirement of prudent management of natural resources, which include non-urbanised areas [7, 8]. Consequences of this and other related ideas include the postulate calling for rational and intensified exploitation of previously developed urban areas, e.g. by increasing density of population and buildings, and such operations as the revitalisation of degraded industrial and residential areas, as well as those located in city centres.

It is believed that a strategy of densification of cities is a method ensuring their sustainable development, to allow better use of the potential of the natural assets which are already being exploited, and to reduce the need for new resources [9-14].

2. Overview and characteristics of urban densification methods

It is possible to distinguish four methods of urban densification, reflecting the specificity of the necessary investment operations and sustainability characteristics:

- increasing the effective use of existing buildings by transforming their functions (changing functions, adapting unused space),
- intensification of existing development by building up on free spaces in the city (construction of free-standing buildings, the horizontal extension of existing buildings, infills the gaps between buildings),
- transforming the spaces below and over the existing buildings (downward and upward extensions),

- replacement of existing buildings (demolition of existing and construction of new buildings).

In general terms, the urban densification as a way to increase the efficiency of using the natural resources brings the benefits from an increased use of the space occupied by the city. Acquiring new surfaces gives the opportunity not only to meet certain utility needs, but also to enrich urban structure, replenishment, development of diversity and urban functions. This also means the possibility of using existing technical and service infrastructure (within its performance limits).

With the implementation of densification process, also additional possibilities appear for the realization of separate independent of the densification but necessary tasks, related to maintenance, renovation, modernisation of existing urban tissue, like the possibility to revitalise, or to implement advanced energy-efficient technologies. There also can be positive impulses for the development of the existing urban infrastructures and for improving the technical status and aesthetic quality of the existing buildings. The value of existing properties is increased, external sources of funding are activated, occurs economic stimulation.

The densification process is also accompanied by difficulties and risks. First of all, there is a risk of loss of comfort and quality of life, an increase the load in the urban environment (increasing the heat islands, increasing local pollutant emissions and nuisance) and potential social conflicts. In the social and cultural layer, there is a risk of losing local identity, urban heritage. At a larger scale of densification, there is a need for appropriate adaptation measures in the area of the city's technical infrastructure, communication strategy, transport, number of parking spaces.

Detailed characteristics of urban densification methods are presented in Table 1.

Table 1. The characteristics of urban densification

	Advantages	Disadvantages
Transforming functions of existing buildings (changing functions, adapting unused space),	<ul style="list-style-type: none"> • Maintenance of public and private open spaces • Low costs of densification, usually lower than the construction of new buildings • Improved technical status of buildings; possible advancements, including greater energy efficiency and environmental effectiveness • Limited interference with the existing structure of buildings - minor burden to the natural environment • Improved structure of urban functionalities - replacement of unattractive, ineffective functions, the rise of diversity • Preservation of spatial potential for development • Possibility to preserve the historical value of buildings 	<ul style="list-style-type: none"> • Limited space for new functionalities, • Limited possibility for creating functional solutions • Inconvenience of the construction for current co-users of the buildings • Technical difficulties of performing construction works in exploit buildings • With a larger scale of transformations risk of gentrification • Significant formal restrictions with regard to historical buildings
Building up on free spaces in the city (construction, extension, infill)	<ul style="list-style-type: none"> • Use of neglected, poorly exploited areas • Increase of usable area within the same property or in its immediate proximity 	<ul style="list-style-type: none"> • Reduction in public and private open spaces • Potential reduction of green areas and available recreational areas at ground level • Higher costs of engineering and

	<ul style="list-style-type: none"> • Good effectiveness of densification • Possibility of preserve or support for the urban landscape 	<ul style="list-style-type: none"> • construction of the facilities • Necessity to ensure static safety of the adjacent buildings • Reduced exposure to sunlight, increased shading of the adjacent areas and buildings • Necessity to preserve functionalities of the adjacent buildings • Inconvenience of the construction for current co-users of the buildings • Decreased liberty in designing the functionalities, compared to suburban areas
Advantages		Disadvantages
		<ul style="list-style-type: none"> • Potentially greater number of collisions with existing infrastructures and greater limitations related to its reconstruction, compared to projects carried out in suburban areas • Potential reduction of water absorbing surface • Potential reduction of available recreational areas
Transforming the spaces below and over the existing buildings: - upward extension:	<ul style="list-style-type: none"> • Preserving free Terrain • Preservation of existing resources of the built environment/buildings, technical infrastructure/ • Significant formal restrictions for valuable historic buildings • High densification efficiency at a relatively low cost • Good access to daylight and sun • High flexibility in shaping functional and formal solutions • Improving the technical condition of buildings, possible upgrades including improving the energy and environmental performance of buildings 	<ul style="list-style-type: none"> • Inconvenience of the construction for current co-users of the buildings • Reduced sunlight, increased shading for neighbouring areas and buildings • Significant formal restrictions for valuable historic buildings • Risk of loss of local identity, urban heritage • The potential need for urban infrastructure expansion • Transformation of cityscape
	- downward extension:	<ul style="list-style-type: none"> • Maintenance of public and private open spaces • Preservation of local identity and urban heritage • Maintenance of the existing assets of built environment /buildings, technical infrastructure/ • Maintenance access to daylight and sunlight for adjacent buildings, • Preservation of green surfaces
Replacement of existing buildings (demolition of	<ul style="list-style-type: none"> • High effectiveness of densification • Large flexibility in designing functional and formal solutions 	<ul style="list-style-type: none"> • Reduction of the existing assets of built environment /buildings, technical infrastructure/

existing and construction of new buildings)	<ul style="list-style-type: none"> • Possibility to introduce buildings of high quality and technical effectiveness • Improved structure of urban functionalities – replacement of unattractive, ineffective functions, • Potential of the rise the urban diversity • Possibility to revitalise and support the urban landscape 	<ul style="list-style-type: none"> • Large investment costs • Increased burden for the natural environment related to effects of demolition /energy, transport, waste management/ • Risk of overburdening of the urban tissue • Risk of loss of local identity and urban heritage • Risk of gentrification • Risk of loss the functional diversity
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3. Determinants for using the identified methods

A short overview of the features of possible densification methods, presented in Table 1, shows that transformation is the most efficient method in terms of sustainability.

The most effective approach includes the transformation of unused parts of buildings, e.g. attics, superstructures, basements or complete buildings whose functionalities lost their original value. Transformations largely take advantage of the existing urban infrastructures, which most effectively complies with the principles of sustainable development, such as the 3R principle - Reduce, Reuse, Recycle.

The second most beneficial method is based on upward extensions, which as a rule can take advantage of the existing infrastructure with no need for significant enhancements, allowing to create another layer of the city. One or two-storey upward extensions take up unoccupied space and do not have to reduce access to daylight and sunlight in the urban environment, at the same time benefitting from excellent availability of these resources.

Downward extensions of buildings and urban areas, on the one hand, may pose significant engineering and economic challenges [15], yet on the other hand offer considerable opportunities for creating another layer, important for the functioning of a city, without affecting the character and landscape of the urban area. They practically do not cover any free spaces in the primary functional layer of the city, they do not reduce the accessibility of daylight and sunlight, and do not affect the green areas. Owing to downward extensions it is possible not only to gain new functional spaces supplementing and enhancing the city's functional program, but also to establish technical spaces enabling other densification operations, e.g. upward extensions by creating underground car parks and passages, foundation reinforcements, or possibility to introduce new technical infrastructures for a building or the city.

Construction of buildings in available areas will be the next method, which similarly to upward and downward extensions, introduces brand new spatial structures into the urban tissue but this is linked with exploitation of unoccupied terrains – a limited resource. A risk of public costs is visibly greater, particularly if the construction projects were to affect green areas or recreational areas. As shown by research, including simulations of heating processes, in urban environments green areas are necessary for reducing the effect of urban heat island [16]. Furthermore, contact with green areas is indispensable for people, and radically reduced opportunities for this are one of the reasons why residents of city centres move to suburbs. Postulated in the framework of sustainable development, efforts to create highly attractive public spaces [10] may be only partly successful as a response to a lack of green areas and recreational grounds. Exaggeration in reducing green areas may lead to effects which are contrary to the intended objectives, like in some cases of rigid implementation of the

strategy of the green ring around cities, accompanied with “egress” of urbanisation beyond the ring, resulting in worse effects than the expansion of suburbs [17, 18].

It seems that, given the relative suitability of the functional structure of adjacent buildings and surrounding, the least problematic method is that of in-fills added to rows of buildings, where a new structure is a natural supplement to the existing urban tissue. Greater problems for the neighbourhood may be posed by extensions reaching into the internal structures or inner yards of the existing buildings.

Replacement of buildings is the most expensive method of urban densification, also constituting the greatest burden for the environment. At the same time, it allows for the implementation of solutions which are most effective in functional, formal and spatial terms. To maintain adequate proportions of investment projects and to properly consider the context of the place, particularly the existing system of communication, services and social relations, it is necessary to apply the responsible approach to programming and implementation of an investment.

4. Conclusions

The urban densification is a method of increasing the efficiency of management of environmental resources, but it is not an easy task. The characteristics of the densification methods show that in addition to the obvious benefits that can and should provide densification there are also many risks to the urban environment. Some of these hazards can be overcome by appropriate technical solutions, some of them require a proper programming of densification development.

The urban densification cannot be a simple increase of the intensity of its construction and population. In order for this action to have the characteristics of durability, it must also result in maintaining or increasing the quality of life offered, which means, above all, that it cannot aggravate these conditions.

It should be emphasised that density of buildings in urban areas should be adequate to the size and character of a given city, as well as the type and condition of the existing technical infrastructure; it should also take into account the population's needs and expectations.

In order to use the specific methods of urban densification, it is necessary in each case to perform a proper diagnosis of the initial situation and projection of a development scenario, and to apply appropriate formal regulations allowing for densification within the limits set by the sustainability criteria. Reasonable ways to densify cities or their parts is an important and effective strategy supporting sustainable development.

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