Index of Development: Influence of City Plan Limits

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Abstract. The development of modern cities is a complex living organism that includes both main zones of the city – central and peripheral. The most evident development is mainly in the peripheral zones which is caused by the enlargement of the cities. In case of development is important not to forget to the total development, because cities must work as one complex, in which every change is related to everything (for example these all are connected: road and technical infrastructure, residential, commercial and office buildings, industry zone, etc.). Primary tool for city planning is city plan and another city planning documentation, which determines the direction of development of partial city zones. But in case of development of cities exist many elements, which slow down the development. These include bad city plan, which should be appropriate for the development of the city, but often it’s not, and it is not able to react promptly to city situation. This situation is often inappropriate in designed or stabilised city zones. The result of a poor city plan is unusable city zones (land), which are either completely blocked, or there is only conditional use of these zones. These conditional use is not directly in concordance with city plan and expected development. Brno is the second biggest city in the Czech Republic, but there are big problems with city plan, moreover that Brno has old city plan, there are problems with land use and other limits which are created by collision of city plan and other limits set by any authorities. One of the biggest problem is connected to flood limits and collisions with city plan. The aim of this paper is in analysis of Brno designed residential zones and deduce the index of development level for parts of the city. The methodology is based on comparison of actual city zones in city plan and in the detection of blocked zones (plots) by any limits. The result of this paper is in given index of development based on ratio of blocked and no blocked plots by a found limit. This paper is aimed to limits of Brno city plan and possible influence of monitored limits to development index. Main focus of this paper is to residential zones, analysis of land intended for residential buildings and its limits. The outputs of this paper are useful for private/public sector and their decision making in investment and city planning.

1. Introduction
For our society and our progress is important to manage our development as a persons and as some habitants. In case of broader evaluation of human development, there are many things, which we can evaluate. The most often monitored indicators are in the connection with human society. For this were evolved the Index of Human Development, which include Life Expectancy index, Educational Index, Mean Years of Schooling Index, Expected Years of Schooling Index and Gross national income. Focus to the human development provide many of authors, which develop the partial indexation of Human Development Index, for example Niels Lind [1] made an adjustments of indexation. The Human Development Index has published annually by the United Nations Development Program, but it is focused primary to the human society. In case of need any index monitoring the development of human
settlements, on the Second United Nations Conference on Human Settlements (Habitat II), the City Development Index was developed. This index monitoring the level of education, health, waste, infrastructure and city product [2]. However this indexes were oriented primary to the past, and are not independently useful for decision making in the process of development of the cities.

2. Present state references
In the 2014 Péter Gyenizse, Zita Bognár, Szabolcs Czigány and Tibor Elekes published their paper focused on urban development in case of landscape shape index, but still, this were too connected with the past and the already done evolve of the monitored cities in Hungary [3]. Another approach published by a Tomi Deutsch focused on the role of the Housing Price Index as an index of urban (city) development. This methodology includes the ratio of ownership, and transactions in the analysed period. [4] To the problems connected with land sustainability and city development published S. Park, S. Jeon S. Kim and Ch. Choi the paper with approach to urban growth and its suitability. The principle is in comparing the land suitability index, geographic information system, frequency ration, analytical hierarchy process, logistic regression and artificial neural network. The outcome of this paper is in forecasting urban land-use changes. [5] The view to the future of urban development of the paper last mentioned, is the right approach, which is used in this paper and its methodology for indexation of city development.

The objective of this paper is in the focus to the city planning and limits of possible structure development in the cities and the inputs for this paper are in limits of the urban zones in the studied city (case study). The reason for this research came out of need for public sector and effective urban planning, and for private sector and decision making in investments.

3. Methodology
The focus of this paper is to the index of development, and city plan limits in residential zones. For this purpose, we develop an approach including equation (1), with inputs in Index of Development of central zones of the city and Index of Development of peripheral zones of the city.

\[ IoD = IoD_{ce} \times IoD_{pe} \]  

This equation (1) is only the highest calculation. The next level of the equation is in partial calculation of the Index of Development – central and peripheral zones. The best value is 1.00 for every level and part of the equation.

3.1. Index of Development

3.1.1. Central zone (IoD_{ce})
This part of the calculation has a focus to the four parts of the urban planning zones (plots). These zones are: residential, commercial, industrial and multifunction as a combination of the any previous. In the city development are another zones – green zones and traffic, but this Index has a focus to the zones designed for a construction of the buildings.

\[ IoD_{ce} = IoD_r \times IoD_c \times IoD_i \times IoD_m \]  

The equation (2) includes partial indexes focused on residential (index “r”), commercial (index “c”), industrial (index “i”) and multifunction (index “m”). The calculation of every index in the equation is based on the empirical incomes. We have a focus primary to the Index of Development of the residential zones in our paper.
\[ \text{IoD}_r = \frac{A_{rL1}}{A_r} \times (1 - \frac{A_{rL2}}{A_r}) \times (1 - \frac{A_{rL3}}{A_r}) \] (3)

\[ \text{IoD}_c = \frac{A_{cL1}}{A_c} \times (1 - \frac{A_{cL2}}{A_c}) \times (1 - \frac{A_{cL3}}{A_c}) \] (4)

\[ \text{IoD}_i = \frac{A_{iL1}}{A_i} \times (1 - \frac{A_{iL2}}{A_i}) \times (1 - \frac{A_{iL3}}{A_i}) \] (5)

\[ \text{IoD}_m = \frac{A_{mL1}}{A_m} \times (1 - \frac{A_{mL2}}{A_m}) \times (1 - \frac{A_{mL3}}{A_m}) \] (6)

### 3.1.2. Residential zone

The calculation principle of the Index of Development – residential is similar to the others (commercial, industrial and multifunction) and its approach is in the ratio of areas sorted by the level of development limits. The incomes to the index we get empirical from the city plan and its limits (areas). All the areas in the equation must be sort by the level of the zone/area limits (chapter 3.3). The evaluated zones (plots) are connected with the development of the city by its designation in the city plan as a design zones. The other zones, which are already used (mostly) are designated as built. For the city development are the most important the design zones monitored by this methodology.

The inputs for the equation (IoD – residential) are total area residential \([A_r]\) and divided total area residential between the limits \([A_{rL1};A_{rL2};A_{rL3}]\)

Inputs of equations (4), (5) and (6) are based on areas of analysed design zones (commercial, industrial or multifunctional). Partial its total area \([A_r; A_c;A_i;A_m]\)of the function zone and the divided total area between areas limit level \([A_{xyz}]\). For the example, the summarization of the partial limited areas residential \((A_{rL1}+A_{rL2}+A_{rL3}=A_r)\) and they are the same for the other design zones (commercial, industrial and multifunctional).

### 3.2. Index of Development – peripheral zone

The calculation of the Index of Development for peripheral zone of the city is similar to the calculation for the central zone. Only change is in the focus on the city parts.

\[ \text{IoD}_{pe} = \text{IoD}_r \times \text{IoD}_c \times \text{IoD}_i \times \text{IoD}_m \] (7)

The other parts of the equation connected with residential zone (index “r”), commercial zone (index “c”), industrial zone (index “i”) and multifunction (index “m”) are similar to the partial equations for Index of Development – central zone.

### 3.3. Limits of the zones

Zones summed for the purpose of this calculation are rated by the limits which each zone bear in the city plan. Limits are sort by some basic characteristics and to three levels of the limit.

| Table 1. Limit levels |
|-----------------------|
| **Limits** | Flood zone | Contamination zone | Bio-corridors | Regulation | Underground structures | Combination | Without limit |
| Level of limit | 3 | 3 | 3 | 2 | 2 | 3 | 1 |

The limit levels are set by the best-practice bound to project management of construction projects. The individual limits are: Flood zone – areas in the zone marked with a possible flood risk. The Flood risk carry the increased costs bound to preventive measures and there is also some contradiction with the city plan, due to which is not possible to build a residential building in this area. Some zones are affected by contamination due to past use, and some zones are cruised by a bio-corridors or underground structures (like a tunnels). Also there could be some regulation which affect some territory. One of the worst case is the combination.
4. Results and discussion
It can be evaluated in this paper only the Index of Development – residential for the central zone of the city. Our case study coming out from the facts out of city Brno. We focus our research in this first phase to this part of our complex Index of Development, because it is a big deal in Brno.

The evaluation is carried out on the central territory of Brno, this territory includes city parts called: Staré Brno, Štýřice, Stránice, Veveří, Brno-město, Černá pole, Zábrdovice, Trnitá, and Pisárky. The city plan in the central part of the city includes only two types of the design residential zone. The zone signed as BC – Residential only and BO – Residential common, which we count together as one.

The first step is the gathering of the data, which we empirical get out of the Brno city plan and other plans which describe the limits (flood, contamination, bio-corridors, underground structures) and from the other urban planning documentation. By this we get the total amount of the residential design areas in the Brno central zone – 406,376,43 sqm. By the empirical analysis we can split the total area between individual limits.

For the final evaluation is needed the total of partial limited areas sort by the limit level. These areas are in the table 3. Beneath of this we can say, that in the table 2 we can see partial limits and problems. In the parts Staré Brno and Trnitá is the biggest problem with flood limits, and in the Pisárky with a lesser impact. The part Štýřice has a problem with contamination of the old dumps. The part of city Trnitá has also problems with regulation and combined problems (regulation + bio-corridors). In the Pisárky there is a small amount of the plots with underground structures limits (tunnel).
Table 2. Limited areas for every parts of central Brno [in percentages]

| Limits         | Flood zone | Contamination zone | Bio-corridors | Regulation | Underground structures | Combination | Without limit |
|----------------|------------|--------------------|---------------|------------|------------------------|-------------|---------------|
| Staré Brno     | 43%        | 0%                 | 0%            | 0%         | 0%                     | 0%          | 57%           |
| Štýřice        | 0%         | 64%                | 0%            | 0%         | 0%                     | 0%          | 36%           |
| Stránice       | 0%         | 0%                 | 0%            | 0%         | 0%                     | 0%          | 100%          |
| Veveří         | 0%         | 0%                 | 0%            | 0%         | 0%                     | 0%          | 100%          |
| Brno-město     | 0%         | 0%                 | 0%            | 0%         | 0%                     | 0%          | 0%            |
| Černá pole     | 0%         | 0%                 | 0%            | 0%         | 0%                     | 0%          | 100%          |
| Zábrdovice     | 0%         | 0%                 | 0%            | 0%         | 0%                     | 0%          | 0%            |
| Trnitá         | 45%        | 0%                 | 0%            | 36%        | 0%                     | 0%          | 20%           |
| Pisárky        | 10%        | 0%                 | 0%            | 0%         | 0%                     | 0%          | 82%           |

Table 3. Limited areas – total for Brno central

| Limits         | Flood zone | Contamination zone | Bio-corridors | Regulation | Underground structures | Combination | Without limit |
|----------------|------------|--------------------|---------------|------------|------------------------|-------------|---------------|
| sqm            | 109,061,50 | 55,592,10          | 0             | 9500,80    | 5,565,50               | 5,225,10    | 221,431,43    |
| %              | 27%        | 14%                | 0%            | 2%         | 1%                     | 1%          | 54%           |

The penultimate step is in the calculating the area of a limit levels (1 – 3). The sort of the limited area is in the table 3.

Table 4. Limited areas – sort by limit levels

| Limit level | 1           | 2            | 3            |
|-------------|-------------|--------------|--------------|
| Sqm         | 221,431,43  | 15,066,30    | 169,878,70   |
| %           | 54%         | 4%           | 42%          |

The last step of this partial research is in the final calculating of the Index of Development – residential for Brno central. The Index of Development – residential for Brno central is set to value 0.305. This value is predicted as a below average.

5. Conclusion

This paper is focused on the new methodology for assessment of city development zones. In this case the main focus is to the residential zones. Out of our calculations, we get the value for Brno central residential design zones – 0.305 out of maximum (best) value 1,000. Our predictions are, that this value is unacceptable for the city like a Brno. The 46 % of design residential zone in central part of the city are under the inflict of limits and 42 % are inflicted by high level of limit.

As an experiment, we tried to sort out (computationally) the flood limit and move it to the limit level 2. This is solvable, because there are some legislation changes at a city level and this limit can be mitigated. With this experiment, we get Index of Development – residential for city central with value 0.322 and limit level 3 has diminished to 15% from 42%.

In our future research, we will try to calculate the complete Index of Development and also we will try to implement the impact of free sites built-up land, which could be more testifying for private sector and its decision making. For the public sector is important the fact, which amount of design zones are appropriate for the future construction without any limits. It will be also tested the different ratios of limit levels and we want to find out correct value of Index of Development for the future use.
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