# 2D and 3D modelling in landscape architecture

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**Abstract. In architecture, urbanism, city planning, as well as in landscape architecture we come across efforts to work with complex 3D models, which were created from geometrical 2D and 3D data and semantic data originating from different databases. Concepts of data systems for architectural and urbanistic 2D and 3D models have been already developed, but landscape architecture models still miss clear structure of used input and output data. In our work we decided to study 3D models of privaty gardens, as we understand this type of space as a significant city making constituent, which can influence its environmental qualities. For the purpose of research 55 private gardens around city Bratislava were chosen. These gardens directly reflect trends in urbanisation of city, transformation of land and the country in the city hinterland. At the beginning we summarized all of the input data landscape architects work with. Studying the output data we tried to point at the use of 3D models of landscape architectonic works not only for presentation of architectonic solution, but mainly for the purpose of planning of urban zones, as all of the models have significant task of data holder. Subsequently simple analyses aimed at environmental qualities of proposals were elaborated. In conclusion of our work we propose the concept of structure of 3D informational landscape model with the particular focus on usage in processes of urban planning. Defined structure of landscape models may be incorporated into existing 2D GIS databases and thus influence the quality of landscape architects work. These complex 3D landscape models can also serve as layouts for updating already existing data in databases and accuracy improvements to 2D models.**

**Keywords: 3D model, landscape architecure, data structure, private garden.**

## Introduction

In landscape architecture and planning, as well as in architecture and urbanism, implementing of digital tools and models revolutionized project - making on all levels. New digital tools enabled architects to analyse problems, create their solutions and at the same time better express their ideas [3]. Gradually, digital tools have been developed from 2D into 3D level, while today it is quite common to capture in models time dimension as well [12]. It is common praxis to visualize changes in landscape architectonic works during different seasons of year. Since landscape architecture works with living material, there have not been made perfect systems, which would enable unification of data and easier work with them in the future yet. In our work we aimed at 2D and 3D models which we use in landscape architecture now. In the team of landscape architects, urban planners and designers we studied 3D models of private gardens, which were made between February 2014 and October 2015, as we consider them to be a significant city making constituent. These constituents in large scale effect ecological quality of urban environment. Private garden space is still the least researched and understood habitat in our towns [9], whereas on the level of zone it captures all important information in detail. Therefore we decided to study to which extent existing 2D databases are linked to created 3D models, what the common process of its creation is and what data models can provide for landscape architectonic and planning praxis. This way we tried to point at the use of 3D models of landscape architectonic works not only for presentation of architectonic solutions, but mainly for the purpose of planning of urban zones. This need originates from the fact that in majority of works an emphasis is not put on space such as private gardens, and in urban plans or 3D city models they are only presented as a blank space with vegetation. At the end of research we performed basic analyses of studied models, whereas discovered results point mainly at the need of using 2D databases already on planning stage of urban zones as well as on importance of 3D data in planning and landscape architectonic work. Correct use of 2D and 3D models is one of the conditions for increasing quality of urban environment. This is largely conditioned by creation of structure of input and output data, with which these models work.

## Model area

2D and 3D models of gardens, which we evaluated in our research, can be found in broader surrounding of Bratislava. Bratislava is the capital city of the Slovak Republic and it is situated at the border with Austria and Hungary. Thanks to its strategic location it is the city with the greatest number of working opportunities and it is still growing. The particular functional area of Bratislava has gone through a lot of changes in characteristics of its structure in last 10 decades [5]. The development of the area of Bratislava has been effected by intensive house building development. Now urbanization is not characterized only by city and population growth, and dynamism of housing capacities, but as well as by the processes which influence surrounding of agricultural and natural landscape. As the city is from the northern part surrounded by the massive of The Carpathians, which limit its further development, the city is pushing on rural zones, where new housing zones are being built almost on a green field. The development of build up area is being performed mainly at the expense of agricultural land and on a smaller scale at the expense of natural landscape [10]. This fact is related to the present state of legislative protection of these areas. Bratislava is surrounded by large-area protected localities (CHKO Malé Karpaty, CHKO Dunajské luhy, CHKO Záhorie) and the development of city towards these areas is very complicated for investors. Takeover of agricultural soil on the other side is not secured form legislative point of view to such an extent, so the urban development is understandably being headed this direction [2]. Building up new residential localities in the hinterland of Bratislava is one of the most visible features of suburbanization. Newly build family houses and blocks of flats are not only enlarging villages by new streets, but they are significantly affecting functional and residential structures and are radically changing rural character of villages. On the territory of Bratislava we can distinguish between two main types of agricultural land: large-area arable land and vineyards, mainly on the boundary of the mountain range Small Carpathians and the Danube Lowland. The vineyards situated on the slopes of the Small Carpathians are attractive for building of housing complexes or individual houses with higher standards. With the development of individual housing construction is closely related formation of new gardens and the change in reclassification of arable land into garden lands. 3D models of gardens thus directly reflect trends in urbanisation of town, transformation of land and the country in the city hinterland. This fact intensifies the need to solve the question of quality of the proposal not only from the view of private investor, but mainly to understand private gardens as a significant city making constituent, which can influence its environmental qualities.

As a sample we selected 20 models of gardens made in years 2014 and 35 models of gardens from 2015. Researched models of gardens were divided into three categories according to their position towards the city of Bratislava (Fig.1) :

- A – gardens in build up areas of Bratislava
- B – gardens in developing zones and catchment villages in the circle of 30 km from Bratislava
- C – village gardens

The figure shows also the gardens which were created on fields that were used in the past as

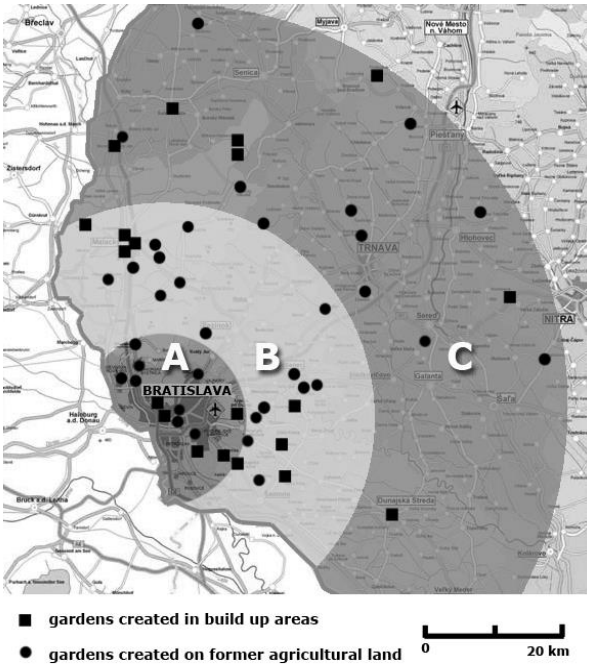



Fig. 1 Locations of gardens related to the capital city of Bratislava - distinguished by colour according to the usage of land on which they were created
[Source: constructed by author, 2015]

agricultural land and gardens which were created on plots classified as gardens in build up areas of towns and villages.

In architecture, urbanism, city planning, planning and researching of landscape we come across efforts to work with complex 3D models, which were created from geometrical 2D and 3D data and semantic data originating from different databases. The same rule applies to landscape architecture. The systematic of models either on 2D or 3D level has not been perfectly worked out yet, as it is for example by BIM modelling [1], therefore we were researching what the best work order of landscape architect during creating 2D and 3D proposals of gardens is. In the first step we were trying to find out the input data landscape architects work with. The second step consisted of analysis of particular 2D and 3D models of gardens with an individual regard to their further use because we assumed that their elaboration will go into details. Subsequently we elaborated simple analyses aimed at environmental qualities of proposals. In conclusion we propose the concept of structure of 3D informational landscape model with particular focus on its usage in processes of urban planning.

**Input data used while creating 2D and 3D landscape models**

2D and 3D models in the great majority are being created on the basis of databases and different types of information, which were made for various purposes. Besides this fact, we expect from them a high degree of complexity and interoperability, because when planning territory on any scale it is important to take into consideration not only architectural requirements, but at the same time economic, sociologic, traffic, environmental and further aspects, too. As complexity is obvious when modelling cities, it has to be introduced into landscape architectonic models if we want them to be compatible, linked with 3D models of cities and they were their equal partners. Information technology and technology of data collection enable faster processing of 2D and 3D models, time; and financial demand has decreased.

Despite above mentioned we face problems when elaborating models together with spatial analyses, for which it is important to gather information from various sources. In general all information which we use at any stage of territory planning consists of 2D map, 3D model, thematic information, historical data, statistical data, elaborated surveys and studies, effective regulations, etc. [7]. Planners and architects can get to these data individually and combine them manually, thus time and financial demand of elaborated analyses is increasing and therefore they are often abandoned. On the territory of the Slovak Republic the central server with data, which would be available from one website, does not exist yet.

In all architectural models, as well as in landscape models the used input data can be divided into two basic groups:

A. Spatial data – they usually describe physical structure and spatial geometry in 2D and 3D dimension. Spatial data contain geospatial information, digital model of terrain, topographic and altimetric data of buildings in space. These data are mainly limited by 2D and 2.5 D representation. Advanced tools of collecting data enabled collecting of spatial data more effectively and their conversion into 3D formats. In dynamically growing settlements as our area of interest is, it is not always possible to capture all changes in an area, so architects and planners are often made to work with outdated data. It is important to note that for models of gardens are needed detailed spatial data and materials with high level of detail.

In common praxis every landscape architectonic proposal originates from 2D layout supplied by the owner of land. The 2D layout is mainly a copy of a map from Slovakia Land Registry which is made in the scale 1: 500 (Fig 2). The electronic Land Registry has been operating since 2004 and gradually it is being digitalized [4]. In the Registry it is possible to look up parcels according to their numbers, but at the same time according to their owners and the Registry is available for the public. Disadvantage of these layouts are: they are often outdated as the Registry is being updated very slowly, in its database false data are often included. In such layouts landscape architects miss important

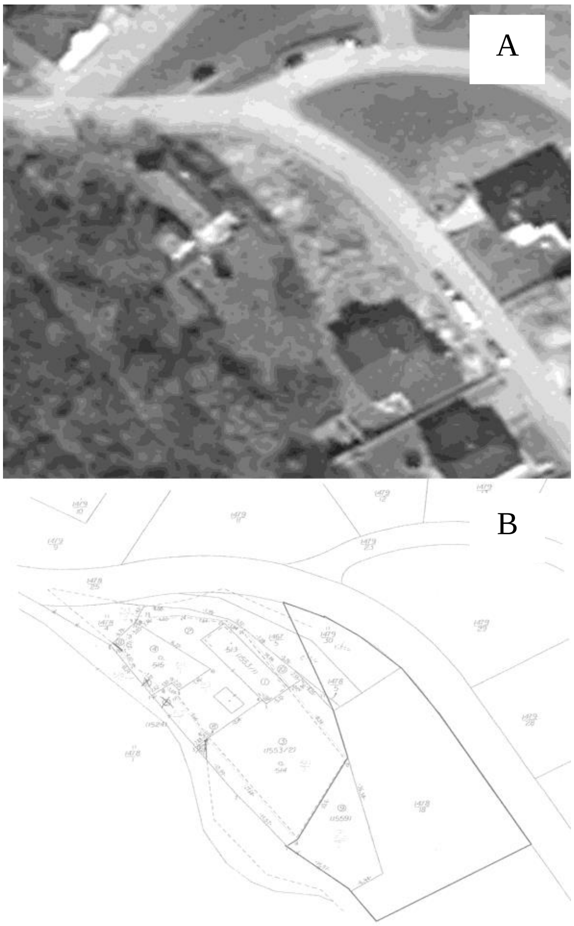



Fig. 2 Combination of Spatial input data used for creation of 3D garden models. A – aerial photoscan with position of important buildings, B – MAP from land registry [Source: geosense and slovakia land registry, 2015]

data about terrain slopes and about small architecture on plots, often we miss also the exact position of important buildings as houses (Fig 2). The problem is often being solved by plot manual re-measuring or by available combined methods. It is mainly combination of methods of aerial photo scanning (Fig. 2) and surveying with a laser distance measurer as photo scans are more updated than cadastre maps and they are available online, too. By combining photo scan, cadastre map and own measuring, a detailed layout is being created, in which all important data are noted. In this way data are being completed. They are captured in a way so it would be possible to work with them – the basis of database is being created to work out any 3D model. Data about altitude are often missing, because DTM – digital model of terrain is for the teritory of Slovakia made only in a scale 1:10 000 and for the level of zone is not usable [11]. Architects have to rely on data provided by clients, alternatively it is needed to carry out own geodetic measurement.

We evaluated the selected sample of models from quality point of view and complexity of input spatial data. The results are shown in Table 1.

TABLE 1

Input data used in 3D landscape model creation [Source: construction by author]

| | Data characteristics | | Usage by garden category | | | Problems of usage of data |
|---|---|---|---|---|---|---|
| Type of input information | Scale | Source | A | B | C | |
| A. SPATIAL INPUT DATA | | | | | | |
| 2D layout | 1:500 | Land Registry | 85% | 67% | 42% | Out of date information |
| Complete topographic data | 1:200<br>1:500 | Manual measurings | 70% | 42% | 41% | Manual and time consuming |
| Complete altitude data | - | Manual measurings | 65% | 57% | 23% | Expensive in difficult terrain conditions |
| DTM | 1 :10 000 | May vary | 0 | 0 | 0 | Unsuitable scale |
| Photoscan | 1: 10 000<br>1: 5000 | GoogleEarth Geosense | 25% | 51% | 74% | Sometimes out of date information, in rural areas missing information |
| 3D models of buildings | - | Architectural studios | 56% | 45% | 12% | Compatibility problems, protected by author´s rights |
| B. THEMATIC INPUT DATA | | | | | | |
| Semantic data in text form (vegetation, soil types, weather conditions, etc.) | - | May vary | 16% | 36% | 55% | Difficult accessibility |
| Soil and bedrock maps | 1: 10000<br>1:5000 | Registry of soils | 0 | 0 | 0 | Difficult accessibility |
| Water maps | | | 0 | 0 | 0 | Poor accessibility |
| Potentional natural vegetation map | 1: 50 000 | Atlas of slovak landscape | 0 | 0 | 0 | Poor accessibility, unsuitable scale |

We can say that most of models were created on the basis of incomplete data and thus inevitably required manual correction. 3D spatial data were more less exception. In general it was a common praxis that gardens of category A, which were being created next to newly- build houses in the centre of Bratislava city, had accurate layouts. They were accompanied by geodetic surveys. This fact is directly linked to natural conditions of these gardens – urbanization is getting into the Carpathian area – area of vineyards. Almost all of them are on slopes. In many cases these used to be recategorized plots so new measurements and updating of databases were necessary. We can stress importance of data vectorization and importance of making out of complex 3D models by architects not only for visualization purposes. On the other hand gardens of category C presented the highest inaccuracy of input layouts; almost in all cases area and altimetric remeasuring was required, many times as a layout an aerial photoscan was used, too. This fact is directly linked to different periods of updating of Land Registry in villages situated further from Bratislava, which is caused by slower pace of territorial development. As the character of these gardens was more rural, in layouts there was also information about natural conditions, though only in text form. 2D models existing in GIS layers were not used in any of the three garden categories of gardens.

B. Thematic data – describe various themes concerning environment, for which 3D model is being worked out. In landscape architectonic models we speak about data about type of soils, waters, geological bedrock, potential natural vegetation and others (Tab.1). This type of data is usually linked to 2D layout in a form of attributes. Some of data are structurized. However, very often a lot of data can only be found in a form of text or raster files.

Selected samples of models were researched from the point of view of taking into consideration all needed information for creation of garden proposal of high quality. Table 1 depicts that in minimum number of gardens it was calculated with available data and thematic data were hardly taken into consideration. Despite the fact that available data have mutual geospatial information, position of data in space is the only bonding between particular data files, with which 3D models work. It is very important to stress that very common reason for not processing and not taking these data into consideration were the problems originating from variability of software or coordinate systems. In data there were used different coordinate systems; they do not overlap and they are not communicating mutually. Therefore for working out analyses, manual reproduction of data is needed. Advantage is that almost all these data and layouts, from which architects can draw on, can be found in various free available databases and they are public. For landscape creation on the territory of region, layers of GIS are used, but for detailed zones downloading of GIS layers from state servers is not practical and time inefficient. Table 1 also shows that if the thematic data were taken into consideration, these were mainly data in text and not in graphical form. Another disadvantage is that a lot of data are being created without clear purpose and that affects their structure and hierarchy. However, territory planning requires simple attitude to all kinds of data, whereas various structuring of each layer often disables creating of complex spatial analyses. Problems are also being created while updating or modifying data. The modification is not enabled to planners, which transfers data into static, not adjustable and many times outdated. We suppose that restriction of input data only to spatial, can lead to misunderstanding of area and to creation of artificial gardens. As we have already mentioned in the previous part, garden as a city forming constituent has to originate from natural conditions and has to try to increase its quality. We can conclude that into 3D models 2D dimensional data without attributes and thematic data are entering, because in current systems they are not mutually linked.

**Output data of 2D and 3D landscape models**

Primary task of all the 2D and 3D model of gardens, which we researched, was to visually present proposal to a private investor. Our work was aimed at models as potentially usable layouts, which contain certain structure of data and the database of information. For each of researched gardens it was created its own 2D model linked to 3D model of level of detail LOD3 and the database of data [8]. Database of 3D model consists of two basic types of data. These are input data, which were taken over from existing databases and data, which cannot be found in existing databases and were implemented in the area by landscape architectonic activity. Equally as at input, output data can be divided into two types – spatial (geometrical) and thematic (semantic) data. Both types of mentioned data are possible to deduce from 3D model by simple exporting. In the following part we will only deal with output data, which can be deduce from 3D models of gardens. Spatial data involve layout of various areas, shape, size of constructions and complete 3D model of terrain, including terrain changes. Thematic data involve type, kind, size of plants, information about the areas of gardens – area of paved areas, planting, information about intensity of maintaining particular areas, permeability of materials, and amount of trucked soil but equally about the change in soil regime. Combined 2D model/3D models of gardens are layouts for processing of irrigation systems.

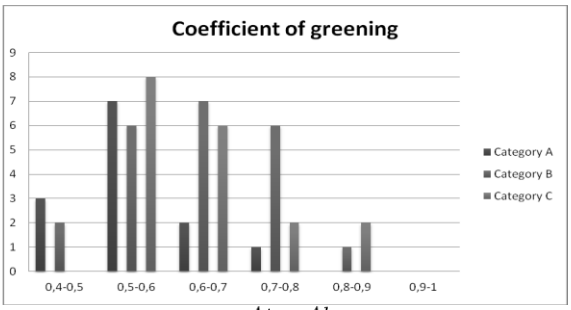
We can say that 3D model of garden has not only presentation function, but it also has a significant task of data holder and is similar to BIM models. The exact structure of input and output data important for landscape architecture is still missing. Creation of accurate structure of these data is important not only for landscape architects and constructers of proposed works, but as well as for urbanists for whom these models are very actual and they are of high informational value. They collect data from several sources and link geometric as well as semantic data within one 3D model. Thus they provide us with accurate data about gardens which have so far been mapped inadequately and in city planning are understood as the green stain on the map.

In works of some authors we often come across an effort to map private gardens with help of aerial photo scanning [9], whereas on the basis of colour of pixels we can identify particular information about constituents of gardens, for example functionality of greenery on the basis of plants connection. Such analyses are very inaccurate and they do not have a big space for further usage, because we work only with raster data. All created models contain several types of information and they have created basic structure of data, based on which we can work further and to create analyses for further degree of landscape architectonic work – by planning new urban zones and by urbanization of rural settlements. 3D dimension enables to analyze changes in environment within a course of years.

**Usability of 3D landscape models for planning of urban zones and elaborating of analyses**

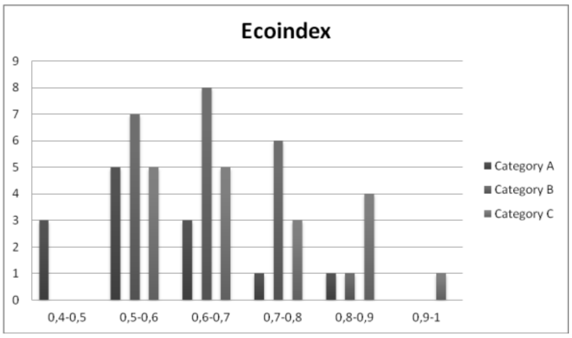
Despite the fact that private gardens significantly contribute to increasing level of biodiversity, in towns they are the least known and the least researched constituents of urban surrounding. The methodology, which would enable to classify and analyse data linked to urban gardens is missing as well. Mapping of parks and public areas of greenery is many times simplier, because they cover large areas and they are publicly available. The latest researches underline individual importance of gardens in urban environment.

Gardens represent micro biotopes, each of them in private ownership. This represents an obstacle in any research. They are living organisms which are not easy to research as constituents of urban structure. Equally almost no regulations and restrictions applied to them, which could influence what can be found in the garden and what does not have to be there, except for small exceptions such as protection of old trees and regulations on the level of zone. As the activities in gardens are not limited at all, their effect is hard to predict and it might be positive but negative as well. 3D digital models of researched gardens enabled us to analyse their quality and find out whether similar research and systematics of data for the need of landscape




$$Cg = \frac{At - Ab}{At}$$

Fig. 3. Coefficient of greening of gardens and formula for its computing [Source: constructed by author, 2015]




$$Ei = \frac{Efx.Ax + Efy.Ay + Efy.Az + ....}{At - Ab}$$

Fig. 4. Ecoindex of gardens and formula for its computing [Source: constructed by author, 2015]

architecture is necessary at all. The analyses of gardens were aimed at factors which are decisive in urban zones planning. As this mainly refers to changes of agricultural land into garden areas, we were interested how the building – up of particular lands has changed.

On the basis of database and output data from models we calculated coefficient of greening, which is currently used when calculating urbanistic regulations (Fig.3). It is a coefficient between area of greenery and area of plot. It is being calculated as a ratio of difference of total ($A_t$) and build up area ($A_b$) and total area ($A_t$). Optimal coefficient of greening (Cg) equals 1; plot with 50 % of build up area has Cg of 0.5. Within the Slovak Republic this coefficient is used mainly when proposing zonal plans [6].

Thanks to the database of models it was possible to calculate Cg of all plots very easily (Fig. 3). The results were surprising, as the average Cg was 0.58 and the values ranged from 0.4 to 0.85. Most of gardens reached the Cg between 0.5 to 0.7, whereas the coefficient of greening was higher only in category C. Such values are for the gardens situated mostly in rural environment low and we can assess that gardens have more urban character and build-up area is relatively high. This way urbanisation is being directly projected into creation of gardens, too. For this simple calculation it is sufficient to work with a model only in 2D dimension. It is not necessary to take into consideration 3D data. However, for calculation of coefficient of greening it was not necessary to take into consideration any further thematic and spatial data.

However, we think that already when planning zones it is important to considerate not only area ratio greenery/paved areas. At the same time we have to consider and regulate the type of planting. Therefore we were interested in quality of individual areas. We tried to discover it through calculation of ecoindex (Ei). We chose classic ecoindex [6] as gardens represent coherent areas, without spacious paved areas with solitary greenery. Ecoindex takes into consideration not only quantitative data, but the quality of planting types, too. Higher ecoindex belong to plots with coherent vegetation, plots with specific types of biotopes such as small lakes and areas with extensive type of maintenance. Calculation of ecoindex should have verified relevancy of results, which we found out when calculating coefficient of greening. It is being calculated as a ratio of total sum of different types of areas (paved area, area with extensive type of maintenance, area with intensive maintenance, shrubs and trees, lakes and rivers) multiplied by set coefficient – eco-factor (E) and difference of total ($A_t$) and build up area ($A_b$). Eco-factor of paved areas equals 0, while areas with extensive type of maintenance, lakes and lower vegetation have the eco-factor of value 1. The maximum eco-factor associates with the areas with elderly and grown-up vegetation. Optimal ecoindex of garden equals 1.

We can say that ecoindex for all plots turned out more positive thanks to ratio of high vegetation (Fig.4). It is important to say, that ecoindex is used mainly when assessing areas in urban environment. The average ecoindex of gardens ranged from 0.4-1. The values were thus significantly higher than by Cg. It applied also here that gardens in zone C had higher ecoindex than gardens in zones A and B. Ecoindex is taking into consideration not only areas, but as well as the data which are observable only in 3D dimension. It refers to the size of treetops, value of connection of plants, area of greenery on the roofs and constructions. Equally for calculation of ecoindex it is important to know data about permeability of paved areas and about character and management of planting. Ecoindex does not work with database of woody plants and does not compare database of woody plants to input data about potential natural vegetation, which is not reflected in results. Usage of 3D model for calculation of ecoindex is significant, as we can simulate state of vegetation after passing of certain period of time. Evaluation of similar results is important for planning of city zones and for determination of

TABLE 2

Proposed data structure of 3D landscape model [Source: construction by author]

| | | Type of data | | | | | |
|---|---|---|---|---|---|---|---|
| | | Geometric | | | Semantic | | |
| | Item | | Input | Output | | Input | Output |
| Adminisstrative Boundary - Parcel – wtih number and outline from Land Registry | 00 Terrain | G1 Outline<br>G2 Height<br>G3 Location | x<br>x<br>x | X<br>x<br>x | S1 Change time<br>S2 Volume change data | | x<br>x |
| | 01 Buildings | G1 Outline<br>G2 Height<br>G3 Location<br>G4 Roof type | x<br>x<br>x<br>x | X<br>x<br>x<br>x | S1 Erection time<br>S2 Change time<br>S3 Number of floors<br>S4 Type of use | x<br>x | x<br>x<br>x<br>x |
| | 02 Technical infrastracture | G1 Position<br>G2 Outline | x<br>x | X<br>x | S1 Type of infrastructure<br>S2 Protection zone<br>S3Specifications | x<br>x | x<br>x<br>x |
| | 03 Pavements | G1 Outline<br>G2 Height<br>G3 Location<br>G4 Area | x<br>x<br>x | X<br>x<br>x<br>x | S1 Material<br>S1 Rate of permeability | | x<br>x |
| | 04 Vegetation | G1 Position<br>G2 Current height<br>G3 Habitus | | X<br>x<br>x | S1 Latin name<br>S2 Mature height<br>S3 Current age<br>S4 Mature age | | x<br>x<br>x<br>x |
| | 05 Mulch | G1 Outline<br>G2 Area<br>G3 Depth | x | X<br>x | S1 Type of material<br>S2 Intensity of maintenance<br>S3 Rate of permeability | | x<br>x<br>x |
| | 06 Water sources | G1 Position<br>G2 Area | x<br>x | X<br>x | S1 Quality of water<br>S2 Richness | x<br>x | x<br>x |
| | 07 Soil | G1 Position of erodic soils | x | X | S1 Type of soil<br>S2 Erosion | x<br>x | x<br>x |
| | 08 Another data | G1 Historic development | x | X | S1 Potential natural vegetation<br>S2 Wind intensity<br>S3 Weather conditions<br>S4 Rain intensity | x | x |
| | 09 Regulation | G1 Position | x | X | S1 Specification | x | x |

regulatives. When calculating ecoindex we come across direct need of linking 3D spatial data with thematic data. Thematic data shown in attribute tables of 3D models of gardens, point at factors, which does not take into consideration more complex ecoindex either. Another factor, which we could research thanks to complex models of gardens, was the type of planting and conformity with natural types of vegetation of gardens. In majority of gardens there was high percentage of introduced species of woody plants and herbs. Natural conditions were mostly taken into consideration in zone C gardens, which is directly related to inputs with which 3D models worked. In almost all gardens the soil conditions and water regime were enriched by trucking new soil – top soil for new plants, which are not in the territory natural and for their maintenance there were in 85 % cases proposed artificial irrigation system. Gardens are thus proposed in majority of cases as artificial ecosystems, which have lower precondition to become adequate biotope for organisms. We can say that despite high ecoindex, functionality and significance of these areas do not have to respond to it.

All of these results point not only at the need of creating 3D models because of implementing of third dimension but mainly they point at importance of interlinking the models and databases with 3D models, whereas creating complex landscape architectonic 3D model. Current urbanistic analyses work with greenery only in 2D level and thus important information are disappearing and emphasis is left on quantity, not on the quality of areas of greenery. These simple analyses point at the need of noticing more detailed proposal of gardens and to understand them equally with architectonic works. Thanks to calculated coefficient of greening we can see that proposals of gardens can in a large scale influence important factors, which effect complex quality of environment. Private gardens can be considered to be the least researched constituents of urban environment, which significantly influence environmental problems of cities. The answer to tackling problems connected with proposals of private gardens is 3D model, in which there is incorporated 2D database. From this landscape architectonic model we can select needed data, to generalize and simplify them in order they were compatible with 3D models of cities. 3D model of city provides unique possibility of changing of scale and increase in detail from the level of zone to the level of city. On the level of zone it is needed high level of detail, which is typical for landscape architectonic models. By linking landscape architectonic 3D models data are being updated. Urban/town models do not have them very often because it is complicated to process detailed models of terrain and paved areas on the basis of existing layouts.

We assume that equally as it is when creating 3D models of cities; it is needed to create a specific framework for working with data for 3D models of landscape architecture (Table 2). Within this framework the basic constituent is an administrative boundary which is understood either as a plot or alternatively as a boundary of zone being solved, or town. The proposed structure was designed according to study of input and output data and models of gardens itself. The structure works also with need to calculate basic urbanistic parameters. To the plot are consecutively linked all important data, which enter into architectonic creation of 3D city models. Data are divided into two basic groups – geometic and semantic. Such defined structure of landscape models may be incorporated into existing 2D GIS databases and thus influence the quality of landscape architect work. On the basis of proposed structure it is possible to take into consideration more aspects when creating regulations and proposals of city zones. Thus private gardens may increase their importance and become a significant city making constituent. The quality of layout and clear structure of data might significantly influence the quality of proposals, too.

## Conclusion

From the above mentioned is clear that proposing of landscape architectonic works is now being made in fully automated computer level in 2D and 3D dimension. However, proposals do not often take in consideration conditions in which works are being proposed either because of unavailability of information or complexity and demand of time. Partial solution can be creation of system of input data for landscape architects, which will be linked to a plot as to a basic unit. Complex 3D models of gardens are layouts for updating already existing data in databases, accuracy improvements to 2D models.

This way created complex 3D models of gardens do not have to serve only for presentation purposes, but they are also a source of wide-range information. Final model enables to calculate percentile of grown-up vegetation, to evaluate number of domestic and introduced species of woody plants, to compare them with potentially natural vegetation, to calculate the amount of greenery on constructions, green roofs. Together with linking to existing databases and semantic information already at their creation stage, the model is able to evaluate possibilities of construction on specific type of bedrock and land, it is able to calculate simply sun exposition of particular facades during a year and a day, shadowing of houses through greenery and their incorporation into 3D models of towns can help when proposing town functional zones, biocorridors and biocentres. They may be used for analyses of energetic efficiency of houses, calculation of coefficients of greenery and ecological coefficients in transforming zones. Equally they serve as important layouts for updating of spatial data thanks to their particularity and verification and vectorisation of already existing data by a specialist.

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**Kopsavilkums.** Arhitektūrā, urbānismā, pilsētplānošanā un arī ainavu arhitektūrā mēs sastopamies ar to, ka tiek strādāts ar apjomīgiem 3D modeļiem, kuri tikuši radīti no ģeometriskiem 2D un 3D datiem. Uzsvars šajā pētījumā ir likts uz skadrības trūkumu tajā, kādus datus izmanto un rada veidojot 3D modeļus ainavu arhitektūrā. Kā pētījuma objekts tika izvēlēts privāto dārzu 3D modeļi 55 teritorijām Bratislavā tās rajonā. Pēc pētījumā iegūtajiem rezultātiem kļuva skaidrs, ka ainavu arhitekta priekšlikuma izstrāde norisinās pilnībā datorizēti 2D un 3D dimensijās. Ne vienmēr priekšlikumu izstrādē tiek ņemti vērā visi faktori, vai nu informācijas trūkuma dēļ, vai sarežģītības un laika limita ietekmē. Jo pilnīgāks ir izveidotais modelis, jo vairāk informācijas un datu tas sniedz, līdz ar to šādu pilnīgu modeli ir iespējams visai plaši pielietot pētījumos, piemēram, analizējot vietējo un introducēto sugu proporciju esošajā un arī projektētajā situācijā.