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2. 3D MODELING AND DIGITALIZATION IN HERITAGE

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2.1. Fundamentals of Cartography and Photogrammetry

Cartographic products in digital public environment can be seen more than ever before. An interactive map product embedded in many digital cartographic systems become ubiquitous. A map is a visual representation of an entire earth area or a part of an area where 3D space, usually is presented on a horizontal plane/ flat 2D surface.

There are several types of surface models: two-dimensional, three-dimensional, four-dimensional, dynamic and even web. The maps show various objects: physical features, roads, topography, population, climate changes, natural resources, economic activities, small architectural monuments, political boundaries, etc.

Cartography is the art and science of graphically representing a geographical area, usually on a map or chart. It may involve the superimposition of political, cultural or other nongeographical objects onto the representation of a geographical area. Modern cartography largely involves the use of aerial and satellite photographs as a base for any desired map or chart. The procedures for translating photographic data into maps are governed by the principles of photogrammetry and yield a degree of accuracy previously unattainable. The remarkable improvements in satellite photography since the late 20th century and the general availability on the Internet of satellite images have made possible the creation of *Google Earth* and other databases that are widely available online (WEB-1). In addition, the use of geographic information system (GIS) has been indispensable in expanding the scope of cartographic subjects. Cartography is related to three assumptions: 1. Cartography is relevant assuring the quality of geospatial information; 2. Cartography is attractive constructing interactive, collaborative maps; 3. Cartography is modern generating 3D and 4D real-time models (WEB-2). Fig. 2.1 shows example of modern cartography application.

FIG. 2.1. Modern cartography: 2D, 3D images and photograph of sculptures – park in Klaipeda city (Source: WEB-3)

Photogrammetry is the science of making reliable measurements by the use of photographs and especially aerial photographs (as in surveying). The definition of photogrammetry can be extended: photogrammetry is the art, science and technology of obtaining reliable information about physical objects and the environment through the process of recording, measuring and interpreting photographic images and patterns of electromagnetic radiant imagery and other phenomena. The main product created by the use of photogrammetry science is the orthophoto map. An orthophoto (also known as an orthophotograph) is an aerial image that has been geometrically corrected (ortho rectified) so that the image is uniform from edge to edge. Orthophotos are corrected to remove terrain effects (what happens when you convert a 3D real surface into a 2D product) and distortions that result from the camera's lens and the angle the photo was taken from the plane.

FIG. 2.2. Fragment of orthophoto map: Klaipeda city (Source: WEB-5)

The goal of ortho rectification is to create an image where distance measurements are the same across the entire image. A digital orthophoto map typically has a geographic reference to the Earth, such as a UTM or State Plane coordinates, so each pixel in the photo can be accurately located (Manual, 2004; Linder, 2009; WEB-4). Many of the digital aerial photographs available through GIS are orthophotos. Fig. 2.2 shows rectified aerial photography: fragment of orthophoto map of Klaipeda city.

2.2. Generation of spatial models of small architectural objects located in public space

The mapping of protected cultural heritage objects is relevant today and in the future. The idea is to commemorate cultural heritage objects, protecting them from degradation, to ensure the preservation of information, to increase the relevance and visibility, and to realize more convenient access to geoinformation. Various institutions are involved with the common goal of promoting cultural heritage to Lithuanian and foreign residents by using information technologies.

Digital maps, constructed by the use of various technologies (e.g., TLS) are becoming public and accessible at the website to anyone who is interested. Terrestrial laser scanning (TLS) is referred to terrestrial Light Detection and Ranging (LiDAR) technology, acquiring XYZ coordinates of numerous points on surfaces by emitting laser pulses toward these points and measuring the distance from the device to the target. Software packages are generally required for managing and analyzing the data because of the large amount of data stored in a TLS point cloud. A point cloud may be converted into a grid DEM to facilitate topographic mapping and spatial analyses. TLS instruments are commonly of three categories based on the distance the laser light can travel to record a point in a field-of-view: short, medium and long-range scanners. A potential limitation to TLS approaches is the weight of the instrument (>20 kg including the battery) length (Ruzgienė, Berteška *et al.* 2015, Kraus, 2007).

2.2.1. The instruments and technologies

The new multi-station *Leica Nova MS60* enables surveying with one instrument, combines fast 3D laser-scanning capabilities, GPS/ GNSS connectivity and digital imaging (WEB-6). The *Nova MS60* features includes a fast laser speed of up to 30,000 points per second, optimized scan area definitions, adapted scan managements, and an improved scanning path for zenith scans. Measurement professionals can make decisions directly in the field, performing point-cloud analysis such as flatness analysis, etc. Scan data of the *Nova MS60* can graphically show in real time, collecting the points positions in the field.

Laser scanner *Stonex X300* made in Italy is a 3D scanner designed to deliver effective results every day, on any project. This scanner has a dedicated line of accessories to work better, scanning process is controlled by smartphone or tablet, allows to work where others fail, regardless of dust, humidity, heat or bumps (WEB-7).

3D Reshaper is a scanner software dedicated to surveyors and can execute processing of point cloud (manual and automatic filters, merge, color), 3D meshing (smoothing, holes filling, borders improvement), 3D inspection of data, polylines, CAD surfaces, to compute a digital surface model, longitudinal profiles, classify points, etc. terrestrial scanning (WEB-8).

JRC 3D Reconstructor is the multi-platform powerful software to handle LiDAR point cloud: import, process and manage terrestrial scanning data, handheld, mobile, airborne laser scanner and easily integrate UAV and 3D imaging data in a single platform.

For realization of 3D modelling of architectural small objects located in cities/ public space, apply up-to-date mapping/ geoinformation technologies:

- Remote Sensing (RS) – imagery from satellites in *Google Earth* (simultaneously *Street View*) application usable for overview general situation of study object (WEB-3).
- Terrestrial Lidar Scanning (TLS) – the scanning sculptures with laser scanners (*Nova MS60*, *Stonex X300*), 3D modelling by the use of software (*3D Reshaper, JRC 3D Reconstructor*). Laser scanning speeds up workflows by combining technologies (imaging, scanning capabilities and GNSS connectivity) in this all-in-one instrument. With the use of specialized software, all measurement and scanning data can be visualized in 3D environment for quality and completeness corrections (WEB-9).
- Geoinformation Systems (GIS) – the use of software application (*ArcGIS*) for thematic map construction, classification of topographic elements and coordinates from other data sources, e.g., city municipality.
- Aerial Photogrammetry – the use of orthophoto map for presentation of sculptures positions and infrastructure of cities parks for public needs.

2.2.2. The results of sculptures mapping

The sculptures park located in Klaipeda city, Lithuania is the open-air art gallery with 116 works of art of various thematic and 6 historical objects, situated on area of 10 ha. This object was selected because of great significance as nature and art monument combining historical memorial legacy, modern decorative sculptures and the use of public space for cultural events. The mapping of sculpture park objects is important activity for obtaining information that can be used for construction state-of-the-art data base, disseminating for everyone's needs by the use of smart devices.

Data acquisition and processing. 116 sculptures and 6 historical objects were scanned by the use of terrestrial scanning technology (TLS) with laser scanner *Leica Nova MS60*. The photographs of all sculptures by the use of high-resolution camera were gained from four stations (at the sides, front, rear of the sculpture) and sometimes from additional stations depending on the complexity of the sculpture. These photographs were used for 3D modelling. Software *3D Reshaper* was applied for 3D modelling of all sculptures in a virtual environment (WEB-8). The virtual geoinformation data base can be taken from the platforms of http://www. mlimuziejus.lt/park (WEB-10) and can be used by everyone. 3D modelling was fulfilled step by step: importation of points cloud gained from laser scanning of sculptures; TIN creation, filling of gaps; creating real image; shading of invisible areas, generation of three-dimension model. The example of 3D modelled sculpture named "Bangpūtys" by software *3D Reshaper* is presented in Figures 2.3 and 2.4.

FIG. 2.3. **Extraction of a real image model: orientation of sculpture "Bangpūtys" model, used 4 photographs (Source: own elaboration, 2020)**

FIG. 2.4. **3D model of sculpture „Bangpūtys" generated from TLS data (Source: own elaboration, 2020)**

Thematic map construction. The spatial data set was created with software application *ArcGIS*. The orthophoto map of study area and topographic survey with sculptures planimetric coordinates was provided by Klaipeda city municipality. These data were imported in *ArcGIS* overlaying positions of sculptures onto the orthophoto map and constructed map (Fig. 2.5).

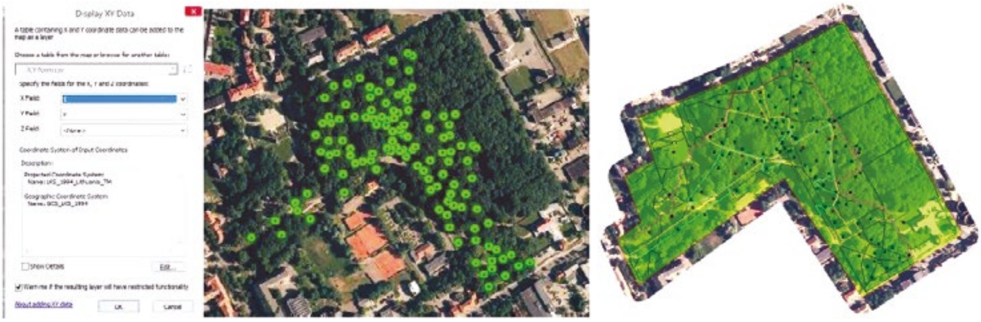

FIG. 2.5. **Sculptures position onto orthophoto map and the map of sculpture park constructed by the use of GIS technology (Source: own elaboration, 2020)**

Another object of study – 3D modelling of architectural heritage objects "Baubliai", located in Dionizo Poskos antiquities field museum, Bijotų village, Lithuania have been performed. Oaks, that are about a thousand years old, are called "Baubliai" (Baubles). The museum shed oak stalk with straw roof, coated by ribbons cementitious foundations; there writer and historian, enlightener of culture D. Poška rested and worked at the end of XIX century. Baubles, has been declared as important historical, cultural, ancient monument of Lithuanian culture with no analogue. Nowadays Baubles are covered by glass roof.

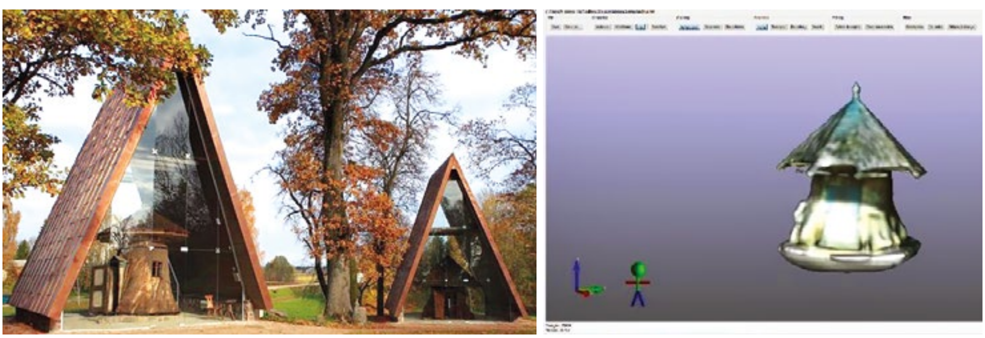

FIG. 2.6. **The field museum with cultural monuments and generated 3D model of Bauble by the use of TLS technology (Source: own elaboration, 2020)**

Two Baubles were scanned with laser scanner *Stonex X300* using TLS technology. Because both Baubles were under a closed glass and enclosure with a roof, the scanning procedure becomes complicated. For both Baubles, due to the trapezoidal roof, it was decided to measure from six different positions outside and also inside with scanning angle 75–90 angles. Measuring conditions were more difficult concerning of the tapering roof, therefore the laser scanner had to be raised higher. Due to the difficult measurement conditions mentioned above, the measurements took five hours. 3D modelling of Baubles was performed by the use of software *JRC 3D Reconstructor* processing, unifying, correcting of the point cloud. Generated 3D model of one Bauble is presented in Figure 2.6.

2.3. Classic methods of 3D modelling

Understandably, new technologies are replacing the old ways of 3D modelling cultural heritage. However, one cannot forget about the classic methods of visualizing objects. When constructing them, we base methods of measurement: traditional (manual meters) and modern (electronic meters). However, when creating them, an equally important or even more important role is played by the "feeling" of the object by the author of the model, his/her knowledge, experience and imagination. The author decides about the hierarchy of importance of the elements included in the object. Some of them are detailed, others are blurred or even deleted. That kind of 3D modelling, unlike digital methods, is heavily influenced by subjectivity and humanity.

2.3.1. 3D drawings made by hand

This kind of 3D modelling is usually faster and simpler than others, and also can be created always and everywhere.

Two methods are used to create 3D drawings: parallel projections and perspective projections (Ducki, Rokosza, Rylke, Skalski, 2003).

In the first method (simpler), lines are projected in parallel along three different axes (x, y, z) with different angles in conjunction with a horizontal baseline. We distinguish isometric projection, elevation oblique and axonometric projection/plan oblique.

This type of 3D drawing is easily understood even by laypersons and can be constructed at all scales. It is often used both to present urban and planning layouts as well as small architectural spaces (gardens, atriums, etc.) (Fig. 2.7).

Perspective projections are characterized by the parallel lines convergence at the vanishing points usually placed on the horizon line (the viewer's eye level). The most used are one-point and two-point perspectives.

a b

FIG. 2.7. Examples of the use of parallel projection (Source: a – axonometric projection of the center of Bialystok, graphics by Wojciech Matys; b – 3D street – art by Marek Kierklo, Kartuzy, photo by Bartłomiej Gruby, WEB – 11)

These kinds of 3D drawings are usually created in two mains types of perspective: linear perspective and atmospheric perspective.

Linear perspective has all converging lines which seem to move towards a common vanishing point (or points) placed on an eye-level of the viewer's line (horizon line) (Fig. 2.8).

a b

FIG. 2.8. Linear perspective projection – examples (Source: a – graphics by Marta Baum, b – graphics by Wojciech Matys)

The atmospheric perspective projection is based on landscape painting. The space shown is not "constructed" (Wilk, 2014). It is often impossible to determine the location of vanishing points and depth is shown by varying object sizes (larger seem closer, smaller farther) (Fig. 2.9).

a b

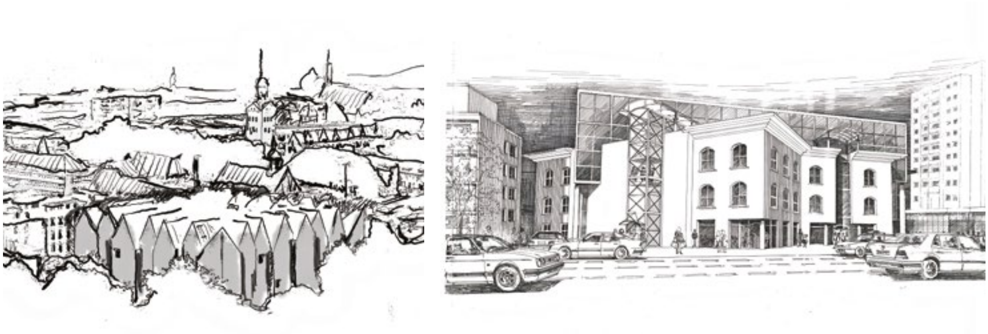

FIG. 2.9. Atmospheric perspective projection – examples (Source: a – graphics by Wojciech Matys b – graphics by Marta Baum)

2.3.2. Manual models

A model is a conventional three-dimensional “image” of space made in a given scale or in appropriate proportions. The conventionality of the model is achieved, among others, thanks to the use of homogeneous materials, the use of non-obvious, undefined elements, or simplification of the presented spaces.

This kind of 3D modelling is often used when creating models of sculptural objects or also tactile models intended mainly for the blind (Fig. 2.10).

a b

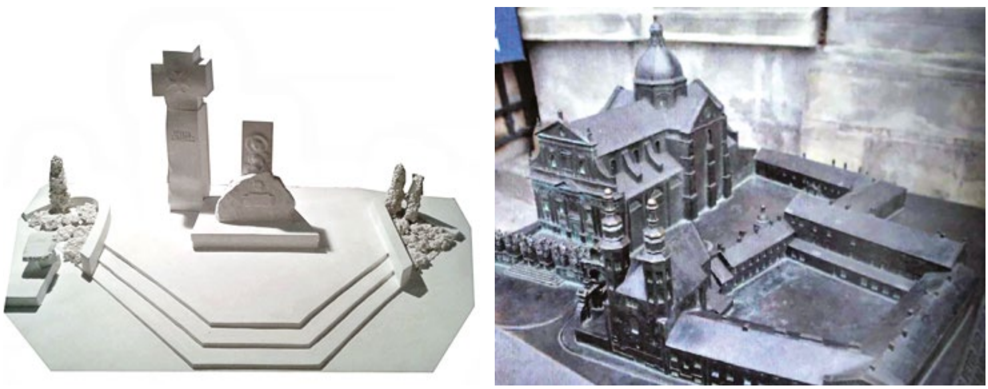

FIG. 2.10. Examples of the manual models (Source: a – Manual model by Jerzy Grygorczuk, photo by W. Matys, b – photo by M. Kłopotowski)

Model views are digitized by photos. The same is true of hand-drawn drawings that are also scanned (also by large-format scanners). Digitized objects can be used in visualizations using photo processing software.

2.4. Drawing by computer is a different way to draw

The importance of Architectural Drawing as a means of communication between professionals is unquestionable. That is why one of the essential objectives of technical schools in the Plan of Study, is to provide students with a means of communication that is essential for their future professional activities. What is clear is that virtually no important architect has dispensed with the intermediate language that is the graphical representation. Therefore, it is safe to say that the graphic medium, architectural drawing, really offers the greatest potential for the study of the entire set of issues related to the architectural discipline. At the same time it is taught, or at least that has been the focus throughout our years of teaching at this school, the precise rules to master the different techniques, both conventional and newest, those have been used or are used in Architectural Drawing execution and knowledge necessary for their restructuring.

Nowadays not only conventional techniques are taught, but attempting, at least experimentally, to show each student more innovative ways in Architectural Representation. This is the case of the use of computers, and the new language BIM.

New ways of drawing the BIM (Building Information Modelling – modelling building information). For BIM applications, with programs such as Revit, architecture is more than a three-dimensional model with different representations; it is not enough to represent the building in a realistic way, it is a simulator of buildings under real conditions. Many words have been spent in comparing AutoCAD – AutoCAD Architecture – Revit, but if we do, we will always fall into the simplistic comparison as tools to represent reality, forgetting the most important thing of Revit, which is to simulate reality. Simulating reality can make better choices in the design phase, as well as provide many of the problems that arise in the life cycle of the building.

The computer drawing was projected in 2D and 3D, but with BIM new concepts were incorporated:

- 4D-BIM: incorporation of the time factor in the project
- 5D-BIM: construction costs related to time and durability of the building
- 6D-BIM: building maintenance throughout its lifetime.

The BIM (Building Information Modeling – modeling building information), is a new revolution as with the advent of computer drawing.

2.4.1. 3D print introduction

A 3D printer is a machine capable of generating print designs in three dimensions and in different materials ranging from mud, dust, some plastics and even metals. The result is being able to create volumetric parts previously designed on a computer.

3D printers use multiple manufacturing technologies and we will try to explain simply how they work. With 3D printers what you do is create an object with its 3 dimensions and this becomes built on layers until the finished desired object.

What a 3D printer really does is to produce a 3D computer design created with a physical 3D model. In other words, if we have designed on your computer, for example a simple cup of coffee (by any CAD program – Computer Aided Design) we can print it in reality through the 3D printer and produce a physical product that would be our own cup of coffee. With this we can generate through physical documents electronic documents. Generally, the materials used to manufacture metal objects can be, nylon, and about 100 different types of materials.

2.4.2. 3D print uses of 3D printers at different sectors: research in the UPM

The models are made with a 3D printer model MARKETBOT REPLICATOR TM 2 DESKTOP 3D PRINTER Fig. 2.11. In the images you can see some examples. In Fig. 2.12. and Fig. 2.13. you can see the models.

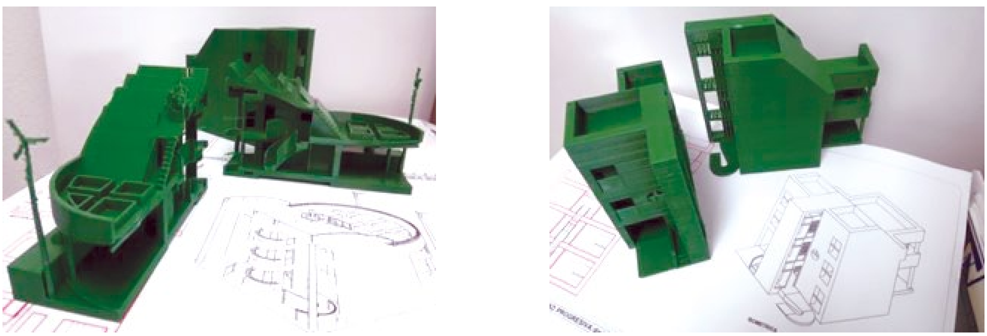

FIG. 2.11. Models were made with a 3D PRINTER MARKETBOT REPLICATOR TM 2 DESKTOP 3D PRINTER (Source: own elaboration, 2020)

FIG. 2.12. Models were made with a 3D printer MARKETBOT REPLICATOR TM 2 DESKTOP 3D PRINTER PALLADIO HOUSES VILLA CHIERICATI (Source: own elaboration, 2020)

FIG. 2.13. MakerBot Replicator 3D printer (Source: own elaboration, 2020)

For a long time 3D printers have been one of the greatest inventions that has reached its peak in this 21st century, due to a lot of companies that are innovating in their production and in application uses that can be given. The marketplace in 3D printers reveals many different purposes, sizes and prices, opening millions of possibilities for easy production even allows trial and error without excessive costs.

References

1. Ducki, J., Rokosza, J., Rylke, J., Skalski, J. (2003) *Hand Drawing for Landscape Architects (in Polish)*, Warsaw, Publishing House SGGW
2. Kraus, K. 2007. Photogrammetry: Geometry from Images and Laser Scans. Berlin: Walter de Gruyter. 459
3. Linder, W. (2009) *Digital Photogrammetry. A practical Course*, Springer – Verlag, Berlin, Heidelberg, 33–73, 121–131
4. *Manual of Photogrammetry* (Edited by J. Chris McGlone), (2004) American Society for Photogrammetry and Remote Sensing, Maryland, USA, 959–963
5. Ruzgienė, B.; Berteška, T.; Gečytė, S.; Jakubauskienė, E.; Aksamitauskas, V, Č. 2015. The surface modelling based on UAV Photogrammetry and qualitative estimation. Measurement. Oxford: Elsevier Ltd. Vol. 73, p. 619–627
6. WEB-1:*Cartography*, (2020), [Online] Available from: https://www.britannica.com/science/cartography [Accessed: 18.02.2020]
7. WEB-2: *Modern Cartography*, (2020), [Online] Available from: http://www.gsdi. org/ docs 2004/ Cookbook/cookbookV2.0.pdf [Accessed: 18.02.2020]
8. WEB-3: Google Earth, Street View application (2020), [Online] Available from: https:// earth.google.com /web/@55.69191266,21.17681752,11.67728544a,6495.67834488d,35y,0 .00000121h,0t,0r / [Accessed: 20.10.2020]
9. WEB-4: *Geospatial technology*, (2020), [Online] Available from https://mapasyst. extension.org/what-is-an-orthophoto/ [Accessed: 18.02.2020]
10. WEB-5: Maps.lt (2020), [Online] Available from: https://beta.maps.lt/?c=2362412.9% 2C7500077. 6&r=0&s=72223.819286&b=orto / [Accessed: 20.10.2020]
11. WEB-6: Smart Office, (2020), [Online] Available from: https://www.soffice.lt/ produktas/ technine-iranga /tacheometrai/daugiafunkciniai/MS60.html [Accessed: 10.03.2020]

12. WEB-7: Stonex (2020), [Online] Available from: https://www.stonex.it/ project/x300-laser-scanner/ [Accessed: 15.03.2020]
13. WEB-8: Reshapter 3D, (2020), [Online] Available from: https://www.3dreshaper. com/en/software-en/download-software/current- release-software [Accessed: 22.03.2020]
14. WEB-9: Terrestrial Laser Scanning, (2020), [Online] Available from: https://www. sciencedirect. com/ topics/earth-and-planetary-sciences/terres- trial-laser-scanning [Accessed: 20.01.2020]
15. WEB-10: Mažosios Lietuvos istorijos muziejus (2020), [Online] Available from: http:// www. mlimuziejus.lt/park/ / [Accessed: 20.10.2020]
16. WEB-11: Kartuzy (2020), [Online] Available from: https://kartuzy.info/zdjecie/3631957 [Accessed: 20.10.2020]
17. Wilk, S. (2014) *Construction and Design Manual Drawing for Landscape Architects,* Dom Publisher, Berlin