GEOVISUALISATION OF A NON-EXISTENT BUILDING

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Abstract
The aim of the paper is to present the research on reproduction a non-existent building with use of archives and
geoinformation solutions. The subject of research was the Warsaw-Vienna Railway Station, which was one of the most
beautiful train stations in pre-war Warsaw. It was destroyed during the 2nd World War and it has never been rebuilt.
There is almost no documentation regarding the architecture of this building in the archives.

The paper presents the idea of virtual reconstruction of the building. 2D and 3D visualizations of the building have
been created and presented with use of geoinformation tools. The 2D visualization includes an online map of the station
premises created in ArcGIS Online, while the 3D visualization was created in SketchUp Pro. The integrated
application, combining the 2D and 3D models, was created in ArcGIS Story Map. Finally, a mobile application based
on Augmented Reality has been developed.

Keywords: 3D model, visualisation, interactive map

INTRODUCTION
The Warsaw-Vienna Railway Station was located in the centre of Warsaw, at the intersection of Marszałkowska Street
and Aleje Jerozolimskie, which are the most important communication roads in the city (Krajewski, 1971). This
railway station served as a head-end station and was the beginning of a railway route called the Warsaw-Vienna Iron
Road. The designer of the station in the classicist style was the well-respected architect Henryk Marconi, who came to
Warsaw in 1822 on request of General Ludwik Pac (Paszke, 2015). The cornerstone for the Railway Station construction
was laid on July 14, 1844. On June 14, 1845, the first train departed solemnly, and the station was completely put into use
on November 27 of the same year. The station became the pride of Warsaw, not only because of its representative
appearance. During the defence of Warsaw during World War II, the Railway Station suffered considerable damage and
until the first post-war days only its ruins survived. After the end of hostilities, early in the morning on May 30, 1947, the
remains of the eastern tower of the station were demolished (Paszke, 1986).

The significance of the Warsaw-Vienna Railway Station is emphasized by the works of literature, art and drawing,
devoted to it, as well as a rich collection of articles from the contemporary press, which scrupulously followed all
changes taking place inside and outside the building. Until today, no architectural materials have survived that would
enable the reconstruction of the Railway Station. Archival materials provide views and descriptions of the Railway
Station, but they contain quite limited metric information that could be the basis for the development of the station
model. The only information of this kind is a brief reference to the horizontal dimensions of the Train Station. In the
publication "History of the Main Railway Station in Warsaw", M. Krajewski states that in the plan view, the building
had 280 cubits of Warsaw measure (approximately 160,3 m) in length and 24 cubits (approximately 13,8 m) in the
widest place (Krajewski, 1971). A. Paszke, in his work "Railway stations of Warsaw-Vienna Iron Road. Branch I, Warsaw-
Skiermiewice (1845-1912) ", gives the dimensions of the station as 288 cubits (about 166 m) in length and 31 cubits (about
18 m) in the widest part (Paszke, 2015). These dimensions come from the author's own measurement on the plan. The
Author also remarked that the dimensions given in the literature seemed less accurate or were approximate.

Therefore, the aim of this work was to visualize the Warsaw-Vienna Railway Station using modern geoinformation
solutions and available archival materials. During the analysis, two research questions were posed. The first question
was whether (and how) a 3D model of the Railway Station could be developed, having very limited archival source
materials. The key question here is whether it is even possible to develop such a model at all with such a small amount of metric data about the object. The second research question concerns the way in which modern technologies can be used to visualize a 3D model of a non-existent object and how its location can be shown in the contemporary geographical space. There are a lot of solutions dealing with the issues of geovisualization described in the literature (Baranowski, 2006), including the use of geoinformation solutions to facilitate access to historical knowledge (Mościcka, 2009) as well as joining historical and technical knowledge (Mościcka, Wyszyński, 2016). However, they refer to data and objects about which we have extensive knowledge. Therefore, the solutions proposed in the work are proprietary solutions.

DATA AND METHODS

Source data

To recreate the defunct building of the Warsaw-Vienna Railway Station and the surrounding space, different archival sources were used. They were divided into two categories: cartographic and descriptive sources. The source materials, due to their historical character, provide less precise information, which affected the accuracy of the final result (Szady, 2008).

The only cartographic source that could be used in the work was the part of Warsaw Plan from 1896, prepared by the English engineer William Heerlein Lindley (Lindley, 1896). Lindley's Warsaw plans are a collection of over 7,000 sheets of maps made at various scales for the needs of the construction of Warsaw waterworks. The plans were developed in the local rectangular coordinate system, for which the main point (geodetic zero) was assumed on a cross on the cupola of the Evangelical church in Małachowski Square in Warsaw. There are no data on the parameters of this system, such as ellipsoid, projection, orientation of the "X" axis with respect to the north. The Lindley collection contains, among others, a city plan in a scale of 1:250, which was made in form of 577 sections, in 95x70 cm format, with a network of squares every 25 Russian fathoms (about 53.34 m) (Witecki, 1990). The building of the station includes two of them. The scanned sheets with numbers 356, 336 were used in the work. They were received from the Office of Geodesy and Cadastre of the City of Warsaw (The Office of the City of Warsaw, 2018). Figure 1 presents a part of sheet number 336.

![Figure 1. The part of sheet number 336 of the Lindley plan of Warsaw in scale 1:250 (source: The Office of the City of Warsaw, 2018)](source: The Office of the City of Warsaw, 2018)

Because of the lack of other archival materials, the Authors also used:

1. Reproduction of the architectural plan of the Warsaw-Vienna Railway Station by Henryk Marconi. The Central Archives of Historical Records in Warsaw (The Central Archives of Historical Records, 2018) have a rich collection of original architectural designs by Henryk Marconi. Unfortunately, the design of the station has not survived to this day. Only its reproduction is preserved in the Great Illustrated Encyclopedia of 1896 (Pietkiewicz ed., 1896). There is a drawing of the facade (Fig. 2), a horizontal (Fig. 3) and a vertical projection. The illustration of the station facade provides information on its exact appearance. It is the only archive source faithfully showing the Warsaw-Vienna Railway Station. The reproduction determines the location of openings (doors, windows) and other details of the
facade, as well as the height of the building. The vertical section of the building provides information on the height of individual storeys and the roof. The projection also shows the distribution of decorative elements of the facade and window niches.

Figure 2. Warsaw-Vienna Railway Station facade (source: Pietkiewicz ed., 1896)

The figures taken from the Great Illustrated Encyclopaedia have linear scale. However, due to their relatively small size, their units are impossible to read. Consequently, the reproductions included in the Great Illustrated Encyclopaedia do not provide information about the actual dimensions of individual building elements, but only serve to reproduce the proportions of the building's elements.

2. Design of the Tyszkiewicz family palace in Waka and documentation of the building of the House of the Credit Society in Radom. The Tyszkiewicz family palace in Waka and House of the Credit Society in Radom (also designed by Marconi) has deceptively similar architectural elements, like those visible on the archival views of the Railway Station. Therefore, it was decided to use the architectural design of the Tyszkiewicz Palace in Waka (Marconi, 1880), available in the Central Archives of Historical Records in Warsaw, to recreate the architectural elements of the Railway Station. Unfortunately, it was impossible to collect the original architectural designs of the building of the House of the Credit Society in Radom. The present owner of the historic building is Partner Dom Development Sp. z o.o. (Partner Dom Development Sp. z o.o., 2018 b) with its registered office in Radom, which made available documentation for the building inventory (Partner Dom Development Sp. z o.o., 2018 a) for research purposes. The documentation includes, among others, a front elevation projection, which provided information on the exact appearance of the window facade and the dimensions of its individual elements.

3. Archival photographs, paintings, postcards - The collected illustrations are an invaluable source of information about the appearance of the station. Although they usually do not show the building in full splendour, they still provide supplementary information about individual elements of the facade.

Methodology to create the 3D model

Lindley's plan is the only reliable source of knowledge about the Warsaw-Vienna Railway Station building. Therefore, it was assumed that the information obtained from the plan would be the basis for creating a spatial database containing data on the location of the building, its dimensions and the surrounding area. On the basis of the plan, horizontal dimensions of the building were determined. They were used to define the scale for the printout of scans of reproductions of architectural plans originating from the Great Illustrated Encyclopaedia. This scale enabled us to calculate –the real dimensions of rooms located inside the building, based on a horizontal projection drawing. The determined dimensions of the rooms were then used to recreate the plan of the ground floor with the exact arrangement of the rooms. The fixed scale has also enabled the development of dimensions for these elements of the building facade that can be distinguished in the figures included in the Great Illustrated Encyclopaedia, and that have been reproduced in the 3D model.

The development of the 3D model of the Warsaw-Vienna Railway Station was divided into three steps. First, models of
repetitive elements were developed. Based on them, in the next step, models of individual parts of buildings were created. In the final step, parts of the building were joined in a comprehensive model of the Warsaw-Vienna Railway Station building. The adopted repeating architectural elements were the windows, the doors, the cornices, the pillars and the elements of the balustrade were adopted. Based on the analysis of source materials (reproductions of architectural plans from the Great Illustrated Encyclopaedia, materials related to the Tyszkiewicz Palace in Waka and documentation of the inventory of the former House of the Credit Society in Radom), the dimensions of individual architectural elements were restored. The reconstructed elements were modelled using simple spatial solids or ready objects from the free 3D software library. The last stage consisted in texturing the objects.

Decorative elements were recreated on the basis of photographs, paintings and postcards, which were only a visual hint, without providing cartometric information. The dimensions of these elements of the model, which only raise its aesthetic values, but are not readable from the collected materials, were determined during the work.

The 3D model was developed using the SketchUp Pro software (Google Inc., 2018). It is a commercial program designed for 3D modelling. The advantage of the program is a free component library that provides thousands of ready to use models. A one-year educational license was obtained for the implementation of the Warsaw-Vienna Railway Station model.

**Methods of visualisation**

A spatial data base containing vector layers with the location of the railway station, the layout of its premises and the development of the nearest space was developed to take inventory of the station elements. This database was the starting point for connecting all visualized elements of the station, as well as the 2D visualization of the railway station and its surroundings. On its basis, using the ArcGIS Online service (ESRI, 2018a), an interactive map and application were developed, which are an effective tool integrating different sources of data related to the past (Brzezińska-Klusek, Mościcka, Dębowska, 2013). The Story Map application has also been created in ArcGIS Online. It is based on a developed interactive map. Story Map is a journey around the most important issues concerning the Warsaw-Vienna Railway Station. In addition, the application has a reference to the 3D scene with the model of the Railway Station. The 3D scene of the Train Station was developed using the CityEngine software (ESRI, 2018b). The CityEngine program is an independent application, belonging to the ESRI software family (ESRI, 2018c), which provides solutions for effective three-dimensional modelling of buildings and cities for architects, town planners, and GIS specialists.

To visualize the station in the place where it was originally built, augmented reality (AR) (Azuma, 1997), which is widely used in solutions dedicated to learning both space and the past (Węgrzyn, Mościcka, 2017) was used. For this purpose, an application was developed, by means of which the user, using the camera of his mobile device with Android, will scan the appropriate marker, which in turn results in displaying the 3D model. The marker is a part of the Warsaw orthophotomap depicting the contemporary city centre where the station used to be located. The application has been made available and it can be downloaded and installed on mobile device via a link, which is available in the Story Map application. The Unity 2017.2 environment (Unity Technologies SF, 2018) with the Vuforia 6.5 overlay (PTC Inc., 2018a) was used to develop the mobile application. Unity is an integrated development environment for creating three-dimensional and two-dimensional computer games or other interactive materials, such as visualizations or animations. The Unity program has a built-in Vuforia programming tools package that enables creating applications using Augmented Reality technology. The package is used to recognize and track flat images and simple 3D objects (codes) in real time. AR applications developed using Vuforia are compatible with a wide range of mobile devices, including iPhones, iPads, Android phones and tablets.

**RESULTS**

**3D model of the Warsaw-Vienna Railway Station**

The building of the Warsaw-Vienna Train Station can be divided into the following parts: the middle part and side parts located on its two sides, connected with the towers crowning the building, roofed courtyards. Due to the symmetrical arrangement of the building, each of the repeating parts has been modelled once. The exception was the development of two models for four-story towers, due to the elements of the highest storeys that distinguish them. The western tower had a telegraph device, while the eastern had a clock dial. Each of the objects has been modelled using repeating elements. For each of them, the method of creating the model was the same.

Modelling of the building required us to prepare a "background". The background layer was a horizontal plan of the building with its dimensions, created at the database development stage. The next step was the development of a layer containing the construction axes of the object, the arrangement of which was based on the reproduction of the
architectural plan of the facade included in the Great Illustrated Encyclopaedia. With the help of simple spatial solids and previously developed models of individual architectural elements, a model of a given part of the Warsaw-Vienna Railway Station was created. The final phase included the creation of textures, stairs and elevations of the zero level. In Figures 4 and 5 some parts of the 3D model are shown.

Figure 4. 3D model of the station: clock tower (source: own work)

Figure 5. 3D model of the station: main entrance (source: own work)

The final step was to "assemble" the developed models of the building's parts into a whole depicting the building of the Warsaw-Vienna Railway Station in all its glory. For this purpose, a background layer with a plan of the building was imported into SketchUp. Then, subsequent models constituting individual parts of the building were loaded and placed on the corresponding places on the plan. The proper spatial reference was given to the models using a part of the Warsaw orthophotomap with the layer containing building location, which clearly indicates its position.
2D and 3D interactive visualisation

The Warsaw-Vienna Train Station and its surroundings are visualised on an interactive map on the ArcGIS Online. The map presents the location of the station in relation to the current development of the area, the arrangement of the rooms inside, the station infrastructure with the buildings and railway tracks, as well as the square and row of trees in front of the station. By clicking on each of the station's facilities or rooms, information about the function of the room can be received. The developed map was saved under the name "Interactive map of the Warsaw-Vienna Railway Station" and made available public at the address: https://arcg.is/1KLiTn. On the basis of an interactive map, an application called "Warsaw-Vienna Railway Station on the 19th Century Plan of Warsaw" was also developed. The application shows an interactive map of the station against the background of the current situation and the Lindley Plan from the 19th century. For this purpose, a ready template called "Story Map Swipe" was used. The selected template uses a "magnifying glass" to display the old map and compare it with present data. The layer of Lindley's Plan was created by importing a previously prepared mosaic consisting of the historical map of the City of Warsaw plan to the account resources on the ArcGIS Online platform. The order in which the layers were displayed was determined using the tools that were available while developing the application. What is important, thanks to the "magnifying glass" function the application users may choose the area that they want to compare (Fig. 6). The application has been made publicly available on ArcGIS Online at the address: http://arcg.is/2CKg3KB.

In order to make the 3D model of the Warsaw-Vienna Railway Station available to a wide audience, 3D scenes were created in the CityEngine Web Viewer application (ESRI, 2018d). In order to improve the data transfer from the SketchUp Pro software in which the 3D model was created, the individual parts of the building were exported separately to the CityEngine program. The *.kml extension was selected as the file format for exporting. This format transfers the geo-referenced data of objects, and also, importantly for the appearance of the model, the texture information prepared in SketchUp Pro. Due to the complexity of models, the export of 7 parts of the building at the same time was impossible due to the size of the model. Therefore, the authors decided to create one test scene for the Eastern Clock Tower. The resulting scene presents a part of the 3D model of the Warsaw-Vienna Railway Station and allows navigating the scene by moving, zooming in and out and changing the perspective, as well as adjusting the lighting conditions according to the user’s own preferences. The scene was shared in the ArcGIS Online service at the address: http://arcg.is/2CEhUAA.

The AR application was developed using the Vuforia Developer Portal (PTC Inc., 2018b) and the Unity environment. For the correct location of the 3D model a test picture was used. It was a part of an orthophotomap from the map service of the Capital City of Warsaw. The target image, which acts as a code, influences the correct functioning of the AR application. On the Vuforia Developer Portal, after adding the image in the Vuforia Target Manager tab, it is analysed and evaluated in terms of quality. Target images are assigned a certain number of stars (on a scale of 0 to 5), depending on their quality. Higher scores are better because the image provides easier detection and more stable tracking, and it
depends on the number of detectable features. The added fragment of the orthophotomap was given 5 stars, which means that it will be very well detectable by the camera of the tracking device. The developed model was loaded into the Unity program and placed on the plane of the test image, thus making the orientation of the model relative to the orthophotomap (Fig. 7).

![3D model orientation on the present ortophotomap](source: own work)

It was assumed that the application would be dedicated for devices equipped with the Android system from version 4.4 upwards. After determining the necessary parameters, the application was tested. For this purpose, it has been saved on a mobile device running Android 6.0. The camera of the mobile device tracks the position and orientation of the reference image (code) in real time, and when the perspective of the viewer on the camera corresponds to the perspective that was created in the program, a virtual object is displayed, which looks as a part of the real world. When the camera of the device detected in its field of view a fragment of the printed orthophotomap of Warsaw, the model of the Station appeared on the device's screen in the place of its location (Fig. 8).

![3D model view in mobile application](source: own work)

The application was also checked by directing the camera of the device to the laptop screen, on which the target fragment of the Warsaw orthophotomap was displayed on a scale of 1:2000 in the map service of the City of Warsaw. The test was carried out with a satisfactory effect. When the laptop screen appeared in the field of view, the model of the Warsaw-Vienna Railway Station appeared on the screen of the phone. The operation of the application was also checked for the
size of the orthophotomap recorded by the camera of the device by changing the scale on the map service and changing the scale of the printout. Changing the print scale to a larger scale yields satisfactory results. If the scale is decreased a lot, it depends on the camera's distance from the marker, so here the results are not synonymous with both print tests and using the map service on the laptop screen. When a distance of 10 cm between the mobile device and the marker was kept, the application worked when using the scale 1:4000 and larger, both by registering the marker on the printout and on the map service. The "DworzecWiedenski3D" application has been made available on the web at: https://drive.google.com/file/d/1SN-KCYwAQB36ZsgBM_QMjkD3n4X_hB31/view.

On the basis of previously developed products, a coherent integrated application was created in the form of Story Map. From among the ready-made templates, the "Map Journal" project was selected. 9 scrolling sections have been developed in the application. Each of them refers to a different issue concerning a station. Each section consists of a main window and a panel. The main window is the place where the illustrations, the interactive map and the application are displayed, while the pivotable panel contains text that refers to the content of the main window, as well as the story map control tools - buttons for section switching.

The first section contains a short introduction to the topic and the presentation of a historical object, and the next is a short calendar of the most important events in the history of the Railway Station. The third section contains a developed interactive map that displays the vector layer "Station Building" on the background of the base map. In this way, the location of the object was shown in relation to the current surrounding. The user navigating in the main window has the ability to change the scale, move the map, view the content of the database in the pop-up window, and access the legend. In the next section there is a reference to the layer showing the layout of the premises of the Railway Station and the building itself against the background of the base map. The fifth section in the main window contains layers referring to the nearest station space against the background of the base map, while the sixth is a reference to the application "Warsaw-Vienna Railway Station on the 19th Century Plan of Warsaw". The next section is a reference to the developed 3D model of the Vienna Railway Station (Fig. 9). The panel contains a link that will allow the user to open the Clock Tower model in the CityEngine Web Viewer application. The 3D scene was not placed in the main window due to the long initialization time. After clicking on the link, the scene is loaded in a separate window, and the user can still browse the Story Map application, waiting for the selected 3D model to be displayed. In addition, there are references to illustrations that show selected elements of the Warsaw-Vienna Railway Station model. The next Story Map section was devoted to the developed AR application. The user can look through the reference to the video showing how the application works. In addition, there are references to links, through which the application "DworzecWiedenski3D" and instructions for its installation can be downloaded. The section also contains a reference to the target image, which is a fragment of the orthophotomap of Warsaw. The application is publicly available on ArcGIS Online at the address: https://arcg.is/0zXPSL.

![Figure 9. Scene with 3D station model in Story Map (source: own work)](image)
DISCUSSION AND CONCLUSION

The main question that can arise when developing the 3D model in the way described above is to ask about its accuracy. The accuracy of the vector layers developed was undoubtedly affected by the calibration error of the Lindley plan and the vectorization process. The accuracy of the polygon layers, which show the building of the Railway Station with the division into parts and the arrangement of rooms inside it, is additionally influenced by measurement error and error resulting from the method of rounding up the results. All these factors make it impossible to calculate a numerical value, which would explicitly indicate the degree of compatibility of the developed database with the source material. For this purpose, the law of error propagation in relation to the calibration process can be used, but it should be noted that the overall error is additionally burdened with a number of errors referring to archival material that we do not know, such as the error of map deformation or error of map scanning.

The criterion for the accuracy of the 3D model development determines the degree of compliance of the dimensions of the building and its individual elements between the actual object and its model. The degree of compliance in the case of a non-existent object can be estimated based on the analysis of source materials. It should be noted that only the dimensions of the horizontal plane of the Warsaw-Vienna Railway Station come from a cartometrical source, i.e. from the Lindley plan. The remaining dimensions, which were developed on the basis of figures included in the Great Illustrated Encyclopaedia, are subject to errors in scanning, printing, measuring and estimating the scale. The adopted dimensions very often did not result unambiguously from the measurement, but only constituted the author's interpretation. The dimensions of the smallest decorative elements also constituted a subjective interpretation of the authors based on materials that do not refer directly to the object being reproduced; however, they were adopted in order to improve the aesthetic values of the modelled elements. It is therefore reasonable to assume that the accuracy analysis could only be carried out on the dimensions of the horizontal plane of the model, which are the length and width of the building. Other dimensions of the model, including the height of the station, the dimensions of the window recesses, cavities of the entrance doors, balustrades, pillars, cornices and those decorative elements whose only purpose is to raise the aesthetic value of the model should not be subject to analysis of accuracy because their dimensions were obtained by estimation and interpretation in the course of the author's own work.

This work attempted to reconstruct the 3D model of the Warsaw-Vienna Railway Station. Many elements were unknown, due to the fact that the existing source materials made it impossible to unequivocally estimate the dimensions of façade elements and their exact appearance. Nevertheless, it should be stated that it was possible to develop a 3D model of the Railway Station, even with such limited source materials. It should be noted that the developed 3D model contains a lot of decorative elements: pillars, balustrades, and window façade. The complexity of the model undoubtedly influenced the size of the processed files, which encountered certain problems during processing formats, importing into CityEngine software, creating 3D Scenes and creating AR applications, which can be eliminated through the use of commercial, more efficient solutions.

The paper also proposes a method of geovisualization of historical objects using AR technology. The AR application is not devoid of errors. The quality of the displayed simplified 3D model should be improved, which would improve its visual values. The advantage of the created application is the fact that it shows a non-existent object in relation to the current space, which stimulates the user's imagination and can increase the interest in the issue.

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BIOGRAPHY

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