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THE POSSIBILITIES OF SPATIAL DATA INTEGRATION FOR BUILDING CONSTRUCTION IN GIS SOFTWARE

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Abstract

This paper shows possibilities of using GIS packages for creating complete information system about buildings. The building of Faculty of Environmental Engineering and Geodesy was used as an example possibilities of integration data from Department of Geodesy and Cartography with data from architectural stocktaking expanded about attributes and descriptive information. The aim of the work is analysis of possibilities of using this kind of system and available functions for end user.

MOŻLIWOŚĆ INTEGRACJI DANYCH PRZESTRZENNYCH DLA OBIEKTÓW KUBATUROWYCH W SYSTEMACH GIS

Słowa kluczowe: systemy GIS, integracja danych, obiekty kubaturowe

Abstrakt

W pracy przedstawiono możliwość wykorzystania pakietów GIS w tworzeniu systemów informacji o budynkach. Na przykładzie budynku Wydziału Inżynierii Środowiska i Geodezji Uniwersytetu Rolniczego w Krakowie pokazano możliwości wykorzystania i integracji danych przestrzennych pochodzących z Zasobu Geodezyjnego i Kartograficznego z danymi z inwentaryzacji architektoniczno-budowlanej, danymi branżowymi oraz uzupełnienie tych danych atrybutami i informacjami opisowymi. Praca prezentuje analizę możliwości wykorzystania tak budowanego systemu i dostępnych funkcjonalności dla użytkownika końcowego.

1. INTRODUCTION

In the past, Geographic Information Systems (GIS) have been built in 2D systems based on maps, deprived of opportunities to interact with high resolution images. Currently, there is more and more increasing interest in the various institutions and entities to creating Building Information System. As a proof of the interest the project "Building Tactical Information System for Public Safety Officials" was implemented by the U.S. Department Of Commerce in collaboration with the National Institute of Standard and Technology (Holmberg et al 2006). This project included research on technology and standards for the implementation of the vision of creating Building Information System operating in real time, available to emergency services to enable safer and more effective response in an emergency. A similar topics concerning Building Information Systems for buildings for the purpose of conducting rescue operations state firefighters were taken also in Poland (Maciak T and others, 2001). This topic also was taken into consideration by authors from Germany (Blankenbach and others, 2012) noting that the existing systems of Computer Aided Building Management (CAFM) use geometric and graphics data to space management inside buildings and can be easily extended with additional functionality characteristic for GIS systems. Systems expanded of geoinformation can be used, for instance to improve the management of buildings, mobile pedestrian navigation and emergency services.

Building Information System (BIS) is not only apply to management or to serve rescue. S. Günay in his publication (S. Günay, 2007) shows the possibility of Building Information Systems for the preservation of historical buildings. It now appears that the Building Information Systems (BIS) may have many uses, depending on the recipient of such a system. There are two basic concepts for work related to the creation of Building Information Systems . The first is the creation of a knowledge base for the design and construction of the building, which leads to the exploitation building with information system, which is available for external partners. The second is the creation of systems primarily for the emergency services to enable real-time access, for existing buildings (Holmberg et al 2006).

In this article, as a example, the building of the Faculty of Environmental Engineering and Geodesy, University of Agriculture in Krakow, was used. Analyzed the possibility of integration of the underlying data coming from different sources in terms of their use in the construction of Building Information System. Additionally, consistency of the data analyzed from different materials.

2. BUILDING INFORMATION SYSTEM

Geographic Information Systems are tools to acquiring, storage, management and visualization of spatial data. "*Spatial Information System is called a system of acquiring, processing and sharing of data containing spatial information and the accompanying descriptive information about the objects featured in the portion of the space covered by the operation of the system.*" [Gaździcki 1990]

"Spatial information system, against the other information systems are characterized by the presence in them of spatial information. Spatial information is information about the location (coordinates in the adopted reference system), geometric properties, spatial relationships of objects that are of interest to the system and can be identified in relation to the Earth". [Izdebski 2009]

In addition, spatial data can be verified, evaluated the quality or simulated in real-time. Typically, Geographic Information System data are used in urban planning. Buildings and installations are also spatial objects and their information may be stored and processed in GIS. To manage and share data about the buildings (spatial and attributes) can be used Buildings Information System (BIS). There already exist advanced systems Computer Aided Building Management (CAFM) which have features of GIS systems. In particular, they are used for space management, rent, lease, etc. In most cases they use 2D data such as dimetric view of building and other 2D CAD drawings. The user interface of these systems is usually available from your computer desktop or via web browser.

Building Information Systems allow the introduction of a third dimension, and the detailed description and show elements such as fixtures and fittings. Implementation 3D models of building and their visualization allows the user to analyze it without being in that place. Using of mobile devices in conjunction with such a system makes it possible to move around the building and finding the road to the specific points of the building. Additionally, there is the ability to display on the device, the attributes of individual elements of the building.

Building Information Systems can provide answers to questions concerning the property, so it can be used in business applications. Implementation of Building Information System based on 3D models requires proper modeling of geometry, semantics and topology, and sharing these data via a standard web interface. Buildings Information System should provide four basic functions:

- data entry,
- data management,
- data processing,
- data sharing.

For buildings, the source of data can be:

- direct measurement,
- inventory,
- principal map,
- photogrammetric inventory,
- as-built documentation,
- terrestrial laser scanning,
- project documentation,
- documentation of underground utilities attributes.

At the stage of data entry, should carry out a data error detection and editing spatial data in both the formal (formats, limit values, the correctness of the topology) and geometric accuracy. Also, the control of descriptive data should be done.

3. MATERIALS

The object of the study was the ability of integration spatial data for building in GIS system, as well as control of compatibility of the same objects presented in material derived from various sources. The object of research was building of the Faculty of Environmental Engineering and Geodesy, University of Agriculture in Krakow. Analysis of the subject material was presented in Table 1.

4. METHODS

At the first step, the analysis of data import obtained from different sources was done. Discusses potential problems and solutions. The second part examines the consistency of the data, in terms of their content.

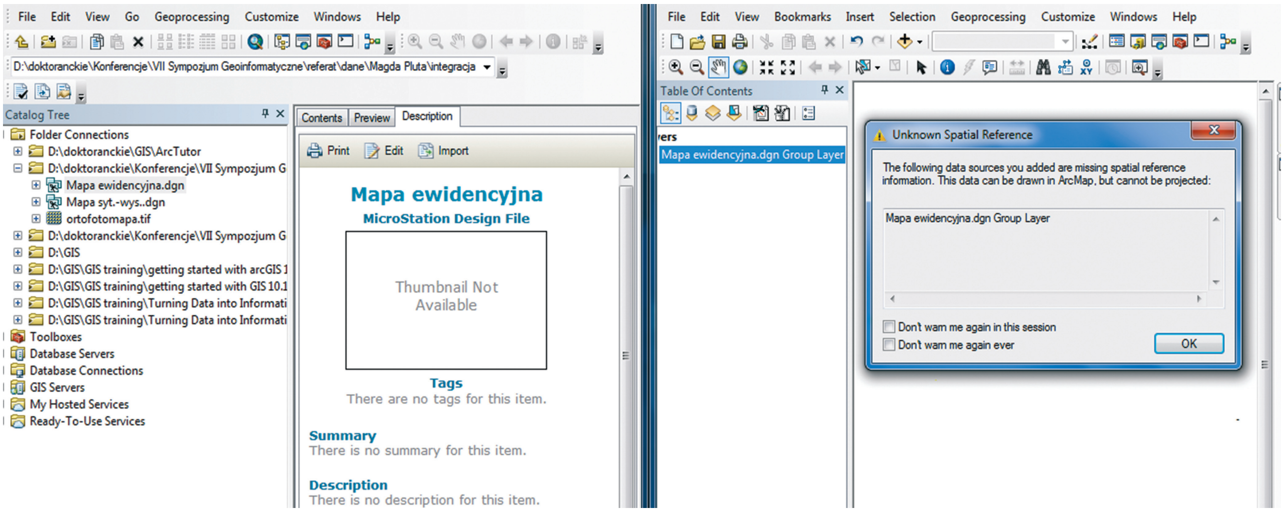
4.1. Vector map

4.1.1. Coordinate system

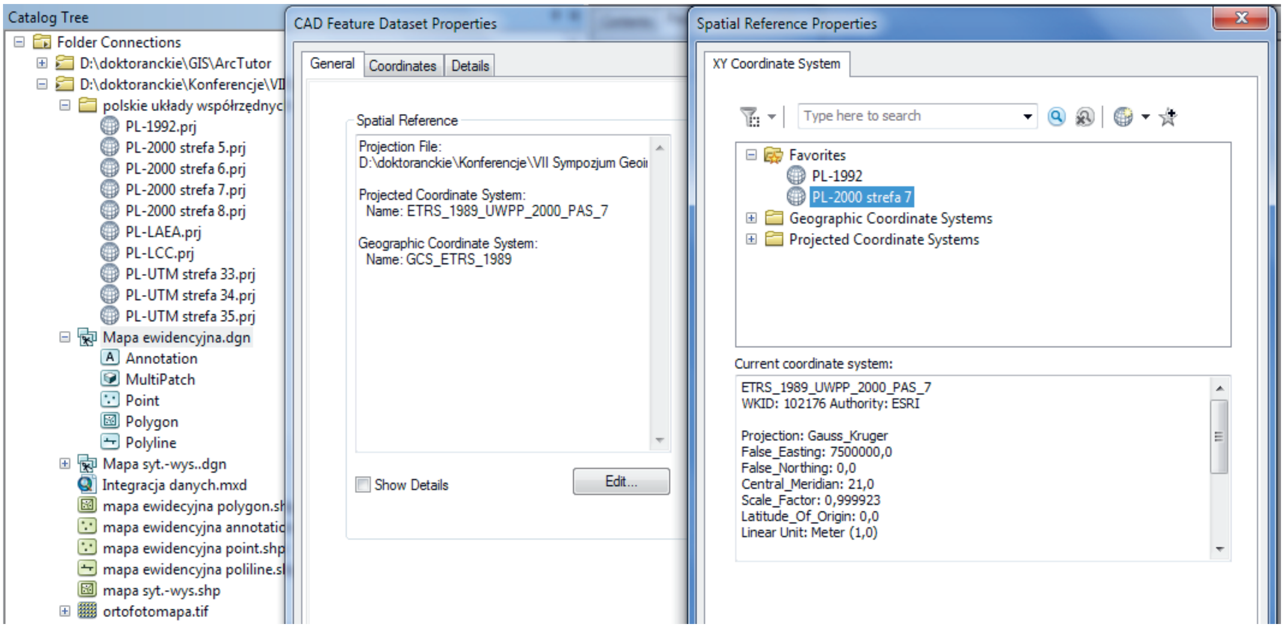
The coordinate system allow to specify the position of geographical objects relative to other objects and define their spatial relationships. Available geographical data can be expressed in different coordinate systems, which raises the necessity of transformation them into

Tab. 1 Reference materials [Own elaboration]
Tab. 1 Materiały źródłowe [Opracowanie własne]

	Cadastral map	Planimetric and contour map	Digital orthophoto-map	Extract of land registry	Dimetric view of building	Terrestrial laser scanning
Source of data	GODGiK w Krakowie	GODGiK w Krakowie	GODGiK w Krakowie	GODGiK w Krakowie	University of Agriculture in Cracow	Own measurement
Type of data	vector	vector	vector	Lack of data	analog	vector
Data format	.dgn	.dgn	.TIFF	_	analog	.zfs
Coordinate system	PUG 2000	PUG 2000	Lack of geo-referencing	–	–	Local coordinate system



Ryc. 1. Data implementation. [Own elaboration]
Ryc. 1. Implementacja danych źródłowych [Opracowanie własne]



Ryc. 2. Setup the correct coordinate system. [Own elaboration]
Ryc. 2. Ustawienie właściwego układu odniesienia [Opracowanie własne]

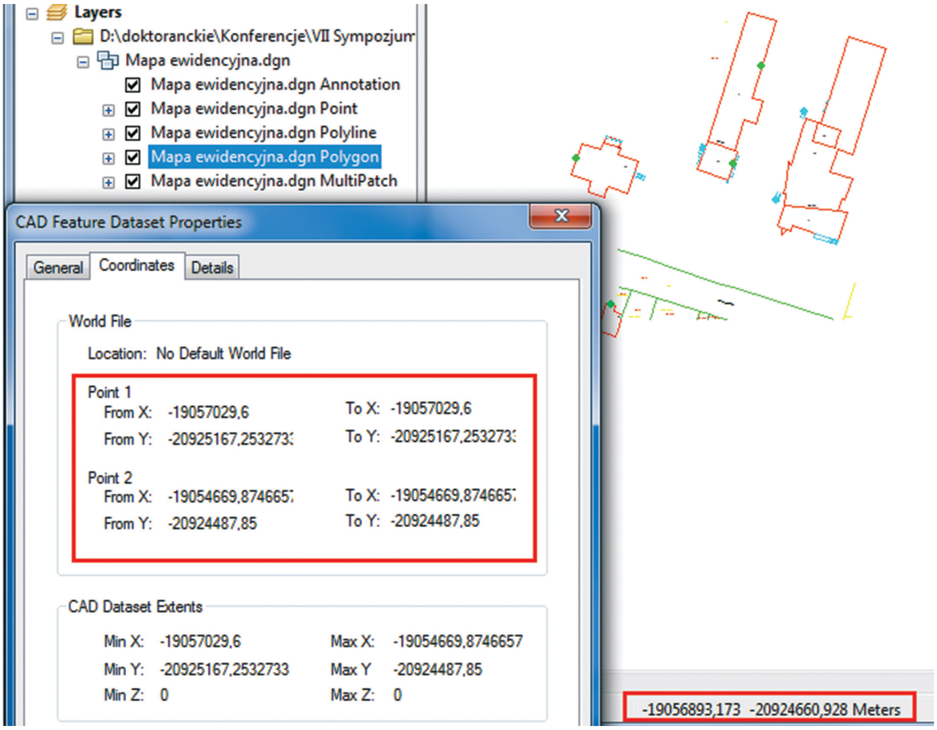
a single coordinate system. After importing the first set of data, the program automatically sets the coordinate system, in which this data was defined. The next sets of data will be transformed "on the fly" to set the coordinate system so that the data are correctly displayed in relation to other map layers. ArcMap application enables the transformation of data on a regular basis if the data are expressed in geographic coordinates (latitude and longitude), which can be identified, or if the data are pre-defined coordinate system.

The dataset *mapa ewidencyjna.dgn*, provided by Grodzki Ośrodek Dokumentacji Geodezyjnej i Kartograficznej in Krakow is run in coordinate system PUW2000 zone 7, after importing the file into ArcMap, it assumes an incorrect position, which means that the program ArcMap does not recognize the coordinate system of the *mapa ewidencyjna.dgn* file.

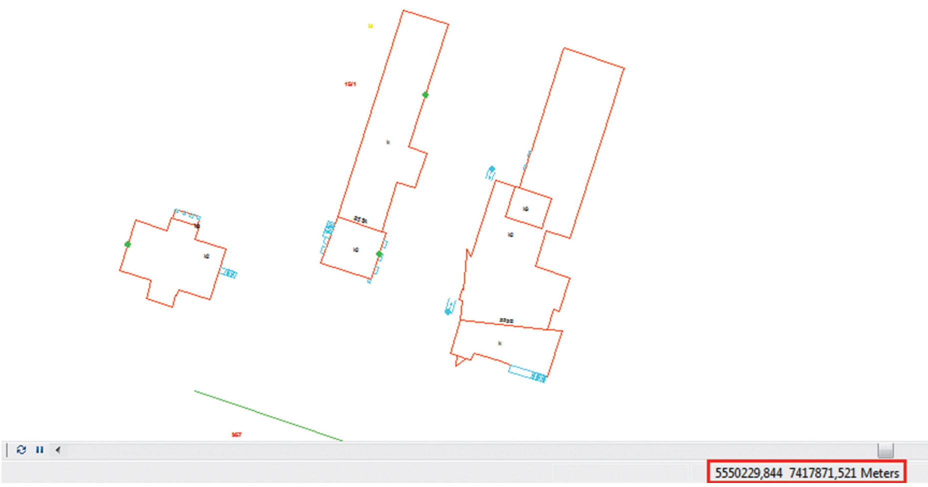
The solution of this problem is importing the files *.prj* with polish coordinate systems into the program, and then take the appropriate coordinate system for the project.

Subsequently, after setting the PUW 2000 Zone 7 for file *map ewidencyjna.dgn*, and set the PUW 2000 Zone 7 to data frame properties in the ArcMap, the file *map ewidencyjna.dgn* can be opened. In this step, it is required to make georeferencing for file *map ewidencyjna.dgn.* Execution georeferencing for each data set, provide browse the content in the form of overlapping layers, expressed in the same coordinate system.

After setting proper coordinate system for the project, the imported file *mapa ewidencyjna.dgn* file is in the wrong position relative to the reference coordinate system. At this stage, should make transformation of the location using the features of the ArcMap – georeferencing. If the data set is composed of several layers, a referencing is being made for the one selected layer, and the program automatically performs for others. As a result, all the layers included in the data set, have the new, correct location. ArcGIS software allows you to perform georeferencing in several ways. The available options are shifting, rotation, scaling, creating checkpoints by using the point whose position you want to chang, and then specify the location where the selected point is to be found. With this option, you can also enter the coordinate values of X, Y for the desired location. To complete the transformation of *control points method* are required two points on the specified coordinates. Another way of georeferencing, is the *function link table*. When you select this option, a dialog box appears in which you must specify the coordinates of two points before the transformation and the corresponding coordinates that we want to get to these points after the transformation.



Ryc. 3. Wrong georeferencing for data set. [Own elaboration]
Ryc. 3. Niewłaściwa georeferencja danych źródłowych [Opracowanie własne]



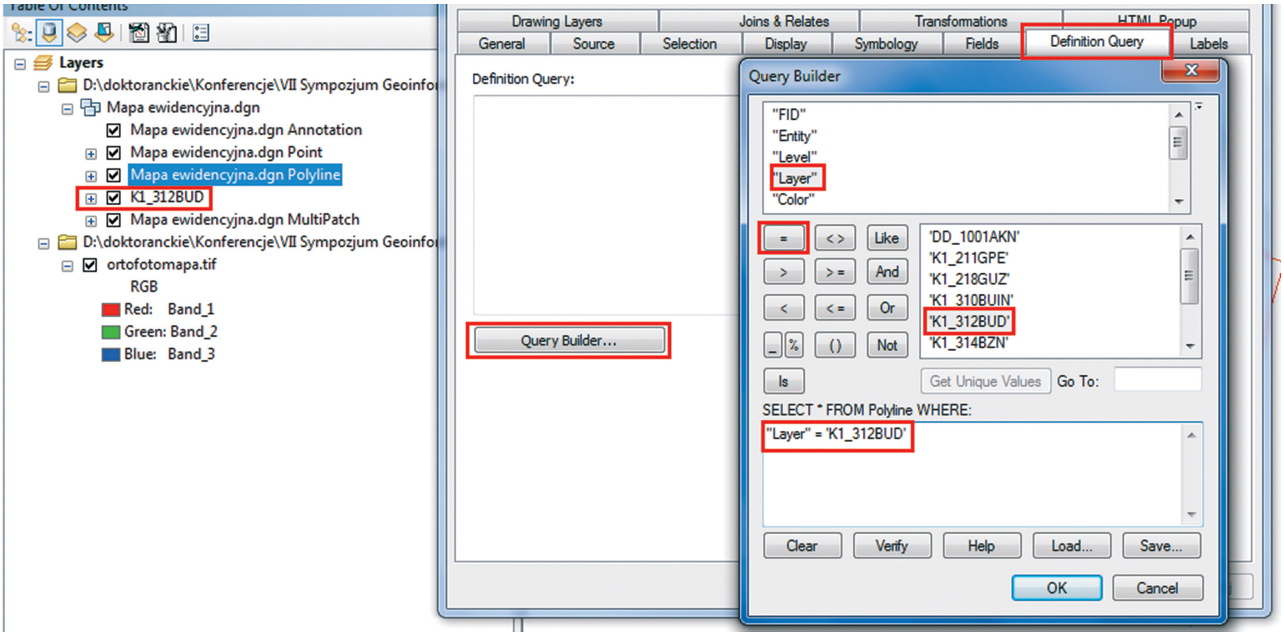
Ryc. 4. Data set with georeferencing. [Own elaboration]
Ryc. 4. Dane źródłowe z właściwą georeferencją [Opracowanie własne]

In the research the checkpoints function was used. Coordinates of the corners of the building were read in the Microstation V8i, and then georeferencing was made.

The same actions were done for *mapa syt. – wys. dgn* file.

4.1.2. Layers

In the reference material *mapa ewidencyjna.dgn*, and *mapa syt.-wys.dgn* derived from Grodzki Ośrodek Dokumentacji Geodezyjnej I Kartograficznej in Krakow, data are collected on the layers in accordance with the technical manual *K1 Mapa Zasadnicza, 1998*.



Ryc. 5. Definition query – *Queyu builder* [Own elaboration]
Ryc. 5. Zapytanie logiczne [Opracowanie własne]

Each layer holds a specific object from a set of objects allowed by the technical instructions. Naming the layers clearly indicates the type of object, for example, the contours of buildings storing layer is denoted *K1_312BUD*. The content of the cadastral map is created by points, lines, polylines, polygons, descriptive attributes. Each of them will be placed on different layers, such as the function of the building was placed on a layer of *K1_312BFN*, while the number of the plot of land on the layer *K1_211GNE*. In addition, the layers have characteristics such as color, font, line thickness.

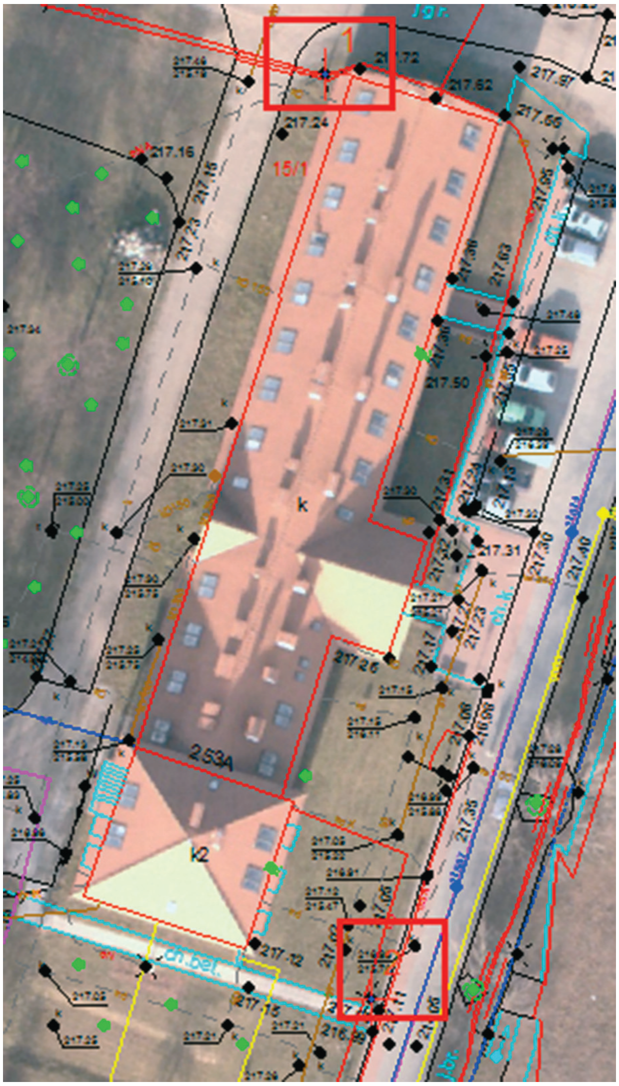
Working with data based on the layers, so it is important to maintain their consistency with the source data . In ArcGIS data is stored on the 5 basic layers: annotation, point, polyline, polygon, multipatch. When you import a CAD file, then is making a generalization of the display layers, all descriptive elements, stored on different layers in the file *.dgn*, when imported into ArcMap will be on the annotation layer, preserving the symbolism of the file *.dgn*. The problem is therefore different layers for the file *.mxd* and file *.dgn.*

ArcMap allows layer division within each of the five basic layers, layers corresponding file *.dgn*. This operation can perform separately for each layer of the file *.dgn*, retaining the ability to select individual layers. For this purpose, we use the properties for the basic functions of the program ArcMap layers. Consecutively in the tab *definition query*, we construct a query that will provide them with only the data that belong to the desired layer file *.dgn*. In the *Query Builder* dialog box, select the field "layer" sequence "-" sign and assign the appropriate value. In the case of building footprint will be *"K1_312BUD"*.

As a result a K1_312BUD layer, which contains the content corresponding to the content of the same layer in the file .dgn was created.

4.2. Orthophotomap

ArcGIS allows to work on models of raster data depicting the phenomenon as a surface consisting of a regular grid of cells. Each cell contains a value that represents the membership of a class or category, or the expanded measurement value. If the raster has been georeferenced, has a well-defined position in geographical space, through the knowledge of X, Y coordinates of one of the corners. For the purpose of the project, the orthophotomap is a material comp for the rest of data. The Ortophotomap is shared by Grodzki Ośrodek Dokumentacji Geodezyjnej i Kartograficzej in TIFF format without georeferencing. For the purpose of integration with other materials, georeferencing using the coordinates of control points should be done. Georeferencing was made in accordance with the rules given in the ArcGIS help 10.2. As the control points selected lanterns with *mapa syt.- wys.dgn* file, as objects clearly identifiable both on the orthofotomap and *mapa syt. – wys.dgn* file.



Ryc. 6. Orthophotomap and mapa syt. – wys.dgn file join together. [Own elaboration]
Ryc. 6. Integracja ortofotomapy oraz mapy syt.-wys. Zapisanej w pliku .dgn [Opracowanie własne]

4.3. Terrestrial laser scanning

Terrestrial laser scanning of building of Faculty of Environmental Engineering and Geodesy, University of Agriculture in Krakow, was made by laser scanner Z + F Imager 5006. Data files are saved in the format scanner *.zfs*, and then imported into Leica Cyclone, where was made orientation of point clouds. In next step made the unification of data to give a point cloud containing the entire object with an average density of points at 0,003m. Data registered in the local coordinate system of the scanner. One advantage of data from terrestrial laser scanning is that they retain the full geometry of an object, acting by a reliable source of information on the exact dimensions and construction of the object.

The project assumes integration of data obtained from different sources including terrestrial laser scanning. Registration of point clouds in the local coordinate system, without reference to the approved coordinate system *PUW2000 Zone 7*, prevents integration with other data in the form of *las dataset*. To solve this problem, should give the coordinate system using matching point. Coordinates of matching points can get, for example, from GNSS measurement or *.dgn* files provided by Grodzki Ośrodek Dokumentacji Geodezyjnej i Kartograficznej. While importing a point cloud files in the *las dataset* form, there may be a problem with large size of file, resulting from the high density of point clouds from terrestrial laser scanning. 3D Analyst Extension is dedicated to point clouds originating from airborne laser scanning. In the presented work, point cloud was used as a control material in the field of 2D dimensions of the building in relation to other materials.

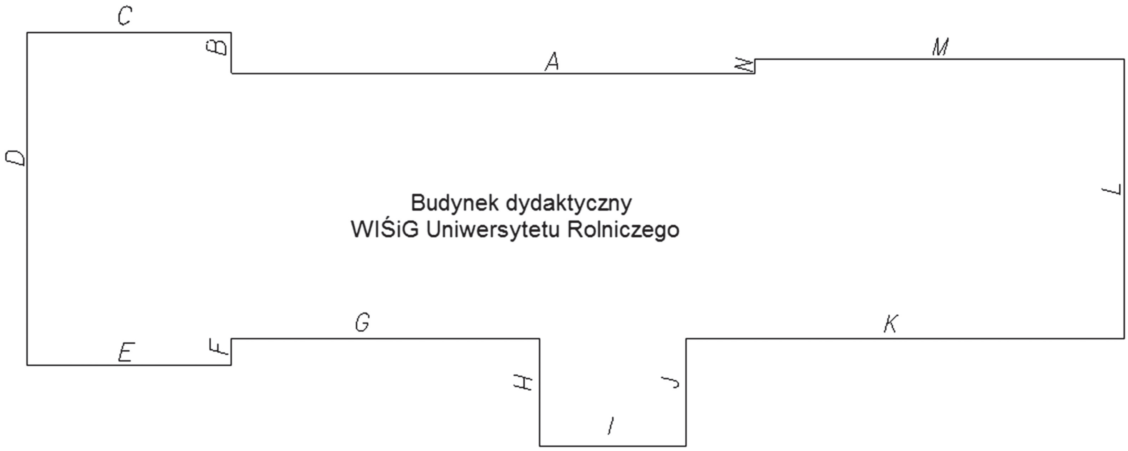
5. CONTROL OF DATA INTEGRITY

Control of data integrity, concerned 2D dimension, measured along the contour of the outer for different base materials. To this aim, a drawing with designations of each wall was attached.

The measurement for *mapa ewidencyjna.dgn* and *mapa syt. – wys.dgn* files were done in ArcMap, the data from terrestrial laser scanning in the Leica Cyclone software, design data read from the dimetric view of building provided by the Department of Agricultural Geodesy, Cadastre and Photogrammetry. In addition, direct measurement was performed in the field using geodetic roulette in direct measurement. The measurement results shows tab. 2.

Tab. 2. Results of measurement
Tab. 2. Wyniki pomiarów [Opracowanie własne]

Wall	Dimension of wall [m]													
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Cadastral map	35,722	brak danych	11,974	12,947	11,789	0,990	12,672	4,549	9,038	4,612	31,782	11,547	17,548	0,233
Planimetric and contour map	35,722	brak danych	11,974	12,947	11,789	0,990	12,672	4,549	9,038	4,612	31,782	11,547	17,548	0,233
Terrestrial Laser Scanning	36,222	0,307	11,501	13,028	11,510	1,200	13,005	4,454	9,049	4,581	31,817	11,603	17,661	0,198
Dimetric view of building	34,100	0,300	10,800	12,300	10,850	1,150	12,300	4,200	8,400	4,200	29,700	11,000	16,950	0,200
Direct measurement	36,200	0,320	11,800	12,985	11,490	1,190	12,980	4,500	9,040	4,570	31,800	11,600	17,670	0,200
Wall	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**
Cadastral map – Planimetric and Contour map	0,000	lack of data	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Cadastral map – Terrestrial Laser Scanning	0,500	lack of data	0,473	0,081	0,279	0,210	0,333	0,095	0,011	0,031	0,035	0,056	0,113	0,035
Cadastral map – direct measurement	0,478	lack of data	0,174	0,038	0,299	0,200	0,308	0,049	0,002	0,042	0,018	0,053	0,122	0,033
Terrestrial Laser Scanning – direct measurement	0,022	0,013	–	0,043	0,020	0,010	0,025	–	0,009	0,011	0,017	0,003	0,009	0,002



Ryc. 7. Draft of building of Faculty of Environmental Engineering and Geodesy. [Own elaboration]
Ryc. 7. Rzut budynku dydaktycznego WIŚiG [Opracowanie własne]

6. DISCUSSION

The analysis of consistency of content data revealed significant differences in the dimensions of the building, and the resulting erroneous content of the materials provided by the public authorities. At the same time, it can be concluded that the documentation: the building from the *mapa ewidencyjna.dgn*, the building from the *mapa syt. – wys.dgn*., the building from point cloud is not consistent with the as-built documentation. In addition, there are variations in the shape of the building is marked on the *mapa ewidencyjna.dgn* and *mapa syt. – wys.dgn.* In these materials, the wall B is skipped, resulting in significant differences in the dimensions of the walls in relation to the dimensions determined on the basis of the data from terrestrial laser scanning. At the same time it can be concluded that the as-built documentation is not consistent with the real state. Due to the fact that the terrestrial laser scanning measurement provides a precise geometry of the building, the data, can be a credible supplementary material for control the data from a Grodzki Ośrodek Dokumentacji Geodezyjnej i Kartograficznej. However, should be aware of the possible difficulties to estimate the edge from point clouds, such a situation was observed for the walls C and H.

7. CONCLUSIONS

The aim of this study was to examine the possibility of integrating the data from various source and control the consistency of the data in terms of geometry. Data integration requires above all the transformation of coordinate systems to one adopted in the project. Materials stored in various resource are stored in different coordinate systems, and in addition to not always possible to recognize by ArcMap software. It is a serious impediment to display all the data in the form of compatible layers. Another problem is that the materials are made available in different formats, what raises the necessity of select the appropriate software for importing each format. In addition, during the import, is necessity to pay particular attention to data conversion and ultimately how they are displayed. Some of the materials needed to create Building Information System like as-built documentation is kept by private individuals, what significantly limited acquisition. In addition, these materials are usually available in analog form, which requires extra processing, and it can be time-consuming. The analysis focused on the consistency of the data in terms of 2D geometry of the building. The results indicate a very large discrepancy of data from different resources, for this reason, they are not sufficient to create a Building Information System for the test object. Data from Grodzki Ośrodek Dokumentacji Geodezyjnej i Kartograficznej has been entered on the basis of vectorization, what caused generalization of building shape. At the same time it can be concluded that data from terrestrial laser scanning are valuable research material, providing precise information on the 3D geometry of the building. Therefore, they may complement geodetic measurements, especially for objects with complicated geometry or for inaccessible objects.

During the analysis of data from terrestrial laser scanning should pay special attention to the course of the edge, because sometimes their position may be ambiguous. The work done in the field of data integration and the consistency of these data clearly indicate that exist huge necessity of alignment and complement the data, to ensure their continued use in implementing the Building Information System.

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