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Analysis and Comparison of Software Supporting Roads Projecting and Designing in Land Surveying

1. Introduction

Poland has experienced dramatic road building increase in the second half of 20th century. While in the seventies we became obsessed by automobiles, it turned out that financially and organizationally we were not able to build highways [3, 9]. As a result, we are far away behind West European countries when it comes to both quality and roads length. Due to that fact, our economy and tourism is negatively affected by the lack of highways. The strong impulse to start realizing new investments in the field of roads designing and building was the European Union access and winning the UEFA EURO 2012 football championship organization [1, 10].

Thanks to present-day technology development and common access to computer equipment road projects are no longer prepared by traditional methods. The most elementary requirement for every road design is nowadays preparation of digital terrain model (DTM) [7]. It is stored in the computer memory as X , Y , Z coordinates of terrain points. On the basis of these points, terrain surface is approximated, what then helps to calculate height of every surface point. On the market we can find a wide range of software both for designers and land surveyors.

One of the most popular application is *Bentley System Inc.* packet. It consists of group of applications used to support designing in the field of civil engineering. At the moment *InRoads Suite V8i* is available on the software market [6, 12]. The newest edition enables its user to load files of competency formats, load and process data downloaded from total stations, levelling instruments, GPS receivers, ground laser scanners, LIDAR aerial laser scanners and every ASCII files with text data. What is more, the newest solution is the common data source for all *InRoads* products. *InRoads* application does not have its own graphic interface and, therefore, it has to work together with *AutoCAD* or *MicroStation* application [13].

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The whole *Bentley* packet is composed of six applications. The first one is *InRoads*. The basic task of this programme is to create road projects. What is more, it enables to create DTM of existing terrain. In order to compile this task it uses one of available methods, namely text file loading, graphic data import or geometry data import. Additionally, a tool to modify existing DTM is available. The next step in road designing is creating road Horizontal Alignment. While designing, the user can take advantage of few methods. One of them is apex method. In this method the user has to define break points of every road section and then fit curves in these breakdowns. The other method is fold elements method, which is used to design roads with integral curvature, i.e. junction ramps, or to modernize roads. In this method every element has a degree of freedom. A fixed element is based on two map points. A floating element is fixed to one map point and is usually connected to previously defined fixed element. Finally, there are free elements, which are not fixed to the map points. The designing process starts from defining and placing of fixed elements, then connecting them with floating elements and lastly fastening free elements [4]. Vertical alignment of road is designed in similar way. Afterwards, regular cross-sections can be created. This application offers the possibility to create many road versions, which can be then edited, modified and displayed. Corridor has to be created for a chosen version. The procedure to compile this task consists of defining spatial alignment and assigning regular cross-section, superelevation with ramps to every section of the road. Thanks to these operations the user can achieve three-dimensional model of designed road and, additionally, is able to calculate area volume. Finally, the project has to be saved, drawing forms need to be defined and road visualization can be created. Moreover, *InRoads* application enables to export stakeout data to numerous total station types of various manufacturers.

The next application of *Bentley* packet is *InRoads Bridge*. It is used to design the geometry and visualize bridge constructions. The next one is *InRoads Site*. It enables the usage of COGO functions (geometry calculations on the basis of points coordinates) to plan groundwork and three-dimensional terrain model. Thanks to *InRoads Survey* the user is able to import geodetic data from land-surveying equipment to *AutoCAD* or *MicroStation*. The fifth application in the packet is *InRoads Storm&Sanitary*, which helps to generate complicated 3D models and, additionally, analyse and design sewerage network. The last programme is *Bentley Rail Track*, which is used on a large scale in railway branch [5].

Winkalk application, released by CODER company, is used to conduct basic geodetic calculations. It uses numerous forms to realize different calculation function. Every form enables to create a calculation report and draft of geodetic construction.

The graphic module built-in the application enables to analyze, extend and edit calculated geodetic constructions. What is more, the application is equipped with

the module to cooperate with geodetic equipment and enables direct data transmission. Furthermore, this application contains some optional modules that is: *Road Design, Register, Adjustment, Levelling, Coordinates System Transformation*.

The *Road Design* module offers many functions concerning curve and spiral calculations. Moreover, this module enables to calculate stakeout data for indirect points of curves and spirals and cardinal points of curve.

Drogownictwo 2000 application was created in order to facilitate designing and staking out basic road curves and vertical curves [11]. It is a freeware programme. Thanks to this application the user can design curves in the form of curve, spiral, multicenter curve or curve Blossa. For both spirals and horizontal curves parameters needed to stake them out could be calculated. In the curves stakeout function, the user can choose stakeout method and coordinate origin. Additionally, the application gives a possibility to stakeout both road major axis and inner and outside edges. Moreover, it is also possible to allow for road extension on the curve after filling in its width. When it comes to the horizontal curve, it could be easily adjusted to the drainage system. The additional option in the application is the function to select parameter *A* of spiral.

C-Geo application of Softline company is universal and popular programme, which supports land surveyors and designers work. *C-Geo* enables to carry out various geodetic tasks. All the calculations are managed by the project manager and the results are created in the form of reports.

The applications offers following functions:

- co-operations with total stations, code levelling instruments and recorders,
- solving various calculation task in land surveying field,
- execution of specialist engineering calculations,
- coordinates transformations between coordinate systems,
- import and export of CAD/GIS data,
- creating and servicing SQL database connected with map objects.

Application functions can be extended with additional modules: volume calculations, contour lines, cross-sections, *XYZ Road Designer*, three-dimensional transformation, adjustment of horizontal and vertical network, external databases.

2. Analysis and Comparison of Used Applications

2.1. Overall Impression

Drogownictwo 2000 is the easiest to operate and it has the most intuitive interface. The most serious disadvantage of this application is that it does not allow to import any data, all the information have to be filled in manually [8].

Winkalk in the field of road designing is clear and simple.

C-Geo application is much more complicated and therefore it is advisable to familiarize at least with basic rules of the work in this application. In order to achieve proper results, it is necessary to keep required order of actions. What is more, the place to fill in data is not always obvious.

When it comes to *InRoads*, it is worth mentioning that the basic knowledge of *MicroStation* is required. What is more, all the menus are in English and, as a result, it is difficult to carry out tasks in this application without the basic knowledge of English language, especially technical language concerning road designing. Interface of *InRoads* is broadly developed, as shows figure 1, and some work phases are complicated. For this reason, it is practically impossible to realize a proper road design without using help content. What is more, it is often necessary to become acquainted with manual for self-tuition or textbooks. Programme does not dictate the order of design phases. Therefore, it is often unclear for beginners which functions should be chosen in each stage of designing. Every element in the application has double representation – graphic and numeric one. Due to that fact, deletion of the drawing does not delete project data [2].

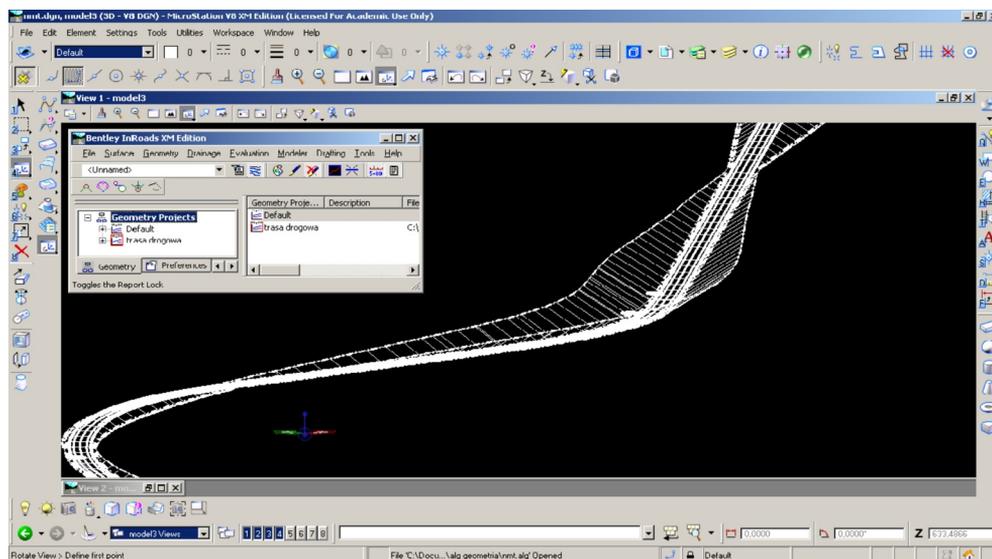


Fig. 1. *InRoads* application interface

2.2. Digital Terrain Model

Drogownictwo 2000 and *Winkalk* applications do not enable to create DTM.

In *C-Geo* application DTM is created on the basis of scattered points, which can be filled in manually or imported from text or graphic files.

DTM can be created by two methods: regular network of squares or triangulation. Additionally, the user is able to define breaklines. Along selected broken line it is possible to generate terrain section. Moreover, it is workable to calculate coordinates of intersection of terrain and straight line). Finally, the programme enables to generate contour line map.

InRoads, in comparison to the previously described application, offers much wider possibilities in the field of DTM. Terrain model can be created either from points coordinates or from graphics. Moreover, the user can define breaklines and area excluded from interpolation. What is noteworthy, DTM can be displayed in many ways i.e. outline, contour line map, triangle network, scattered points. The application contains various tools to design and modify DTM. Last, but no least, it is allowed in *InRoads* to create many DTM in one project.

2.3. Road Axis Designing

Drogownictwo 2000 application allows the user to design the whole road axis and, additionally, it calculates numerous geometric parameters of curves. The inconvenient feature of this programme is that it does not allow to achieve any graphic presentation of the road axis.

Winkalk application enables to design only single segments of the road, which are composed of straight lines and inscribed curve with spirals. Moreover, there are no tools to calculate geometric parameters of curves. The result of work is presented in the form of report and road segment draft with indirect points. The most serious disadvantage of the application is that it is impossible to design more complicated road segments i.e. with several curves.

Programme *C-Geo*, like *Drogownictwo 2000*, gives a possibility to design the whole road axis. As a result the user achieves a report with coordinates of breaking points, cardinal points, indirect points and designed boundary. Moreover, the report also presents selected curves parameters. Additionally, a road draft is generated. However, it contains only points without any specifications. These specifications could be added manually, yet it is labour-consuming, as the map edition tools are very limited.

InRoads offers the greatest possibilities in the field of road axis designing as figure 2 shows. Apart from using the most basic apex method to design the road axis, the user can also use fold elements method option. The phase of road axis designing is not complicated task. Furthermore, the programme contains appropriate tools to calculate all the road parameters, even on the basis of limited number of input data. Although the application uses the American standard of road designing, they can be easily adjusted to Polish equivalents. In consequence, it is also possible to check the correctness of chosen road parameters. After designing

the road, the user still has a possibility to modify it without having to start the whole process from the beginning and go through all the phases. Finally, there is no need to add any specifications to the draft manually, as the application offers variety of elements that can be placed in the road axis draft.

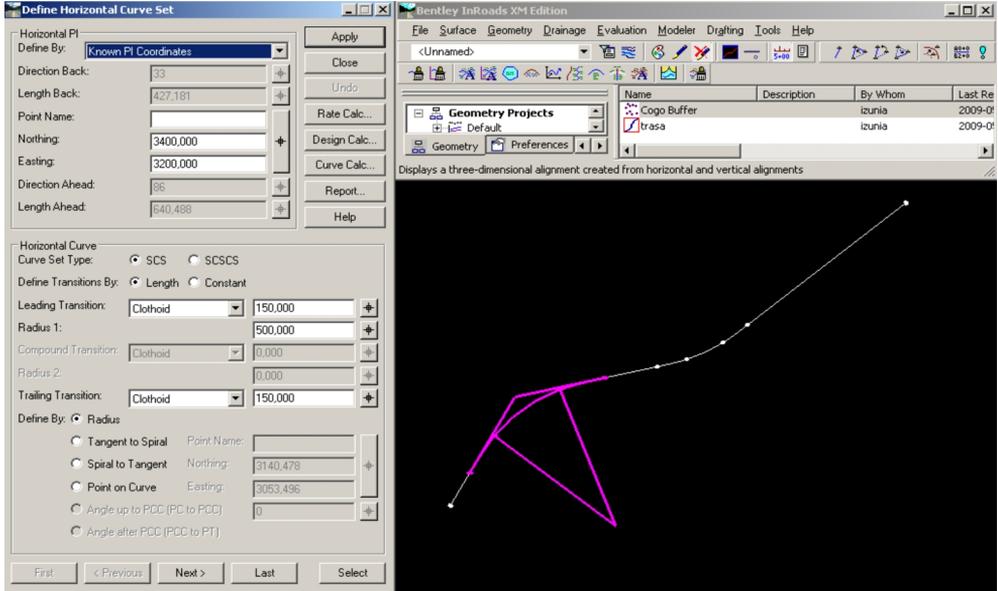


Fig. 2. Road axis designing in InRoads application

2.4. Vertical Alignment

Drogownictwo 2000 application enables to design the whole road vertical alignment and creates clear and precisely described longitudinal section of alignment as shown in figure 3. Additionally, this application allows to calculate geometric parameters of vertical curves. On the other hand, the user does not have an effect on the appearance and content of the vertical alignment description table.

Programme Winkalk does not contain any tool to design vertical road elements.

With the help of C-Geo the user can easily design vertical alignment, yet its graphic representation is generated only in the form of simple graph in the window bottom part. The only mention of parameters of vertical road elements is added to the general report from the road project. In order to achieve the full profile, it is necessary to export assignment to the separate module. Both Road Design and Vertical section module are independent, thus any change made in one of them does not result in changes in the second one. What is more, vertical alignment is created on the basis of coordinates of cardinal and indirect points not on the basis

of straight lines and inscribed vertical curves. As a consequence, in order to create smooth graphic presentation of vertical alignment, it is necessary to set up indirect points densely enough. On the other hand, it deteriorates legibility of the drawing.

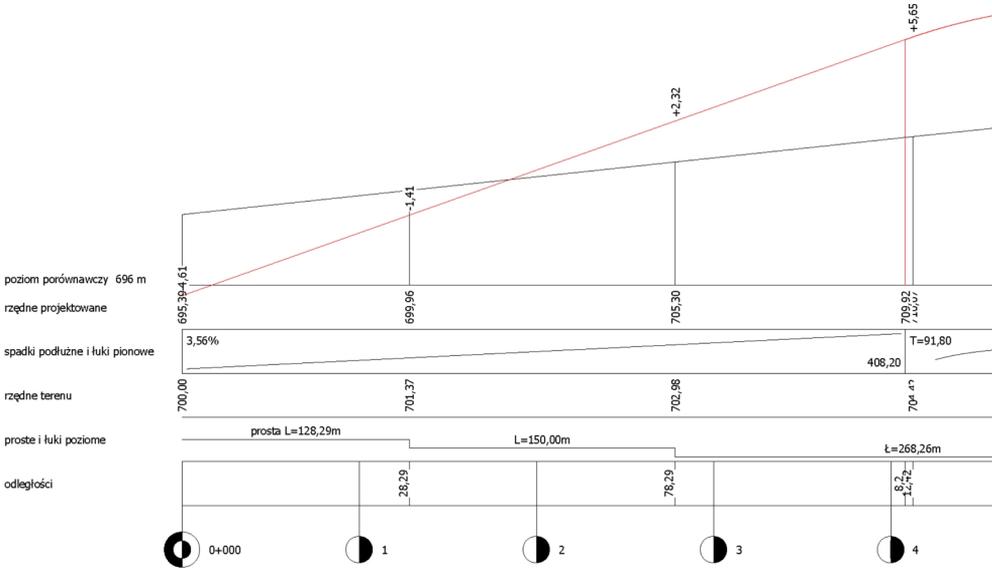


Fig. 3. Fragment of longitudinal section generated in *Drogownictwo 2000* application

In *InRoads* application vertical alignment is designed similarly like road axis: with the use of apex method or fold elements method. On the longitudinal section the user can generate apart from vertical alignment also terrain section. What is more, it is also possible to define point of intersection of road and linear object i.e. wiring system. One of the more difficult tasks is horizontal curves designing, while they are defined not by radius, but by more complicated function i.e. curvature. Similarly like in the case of describing road axis, the application offers many options to describe vertical alignment. However, this functions are so complex that it sometimes becomes problematic to design aesthetic data table under the vertical alignment drawing.

2.5. Cross-Sections

Both programmes *Drogownictwo 2000* and *Winkalk* do not enable to create road cross-sections.

In *C-Geo* application cross-sections are created in the separate module and, unfortunately, they are not correlated with *Road Design* module. Thanks to DTM it is possible to generate terrain cross-section, yet all the other data to create road cross-sections have to be calculated manually.

In *InRoads* it is necessary to create spatial model of roadway, which is composed of road axis, vertical alignment, corridor and cross-section templates in conjunction with defined superelevations on curves and spirals. Creating cross-sections in this application is complicated and complex task. Especially definitions of end condition requires high spatial imagination and experience of the user. What is more, the user has to define changes of the road cross-section template on the particular elements of road axis. Nevertheless, in the final effect this effort guarantees the universality of created model and the possibility to generate cross-sections in every point of the road. Furthermore, the application offers attractive graphic presentation of elements of spatial model of roadway, i.e. attribution of different colours to individual cross-section fragments with different slope, colour distinction between fill and cut, as figure 4 presents. Similarly like for road axis and vertical alignment, the programme has broad menu to generate cross-section descriptions. Yet, realization of aesthetic descriptions considerably extends the time of work.

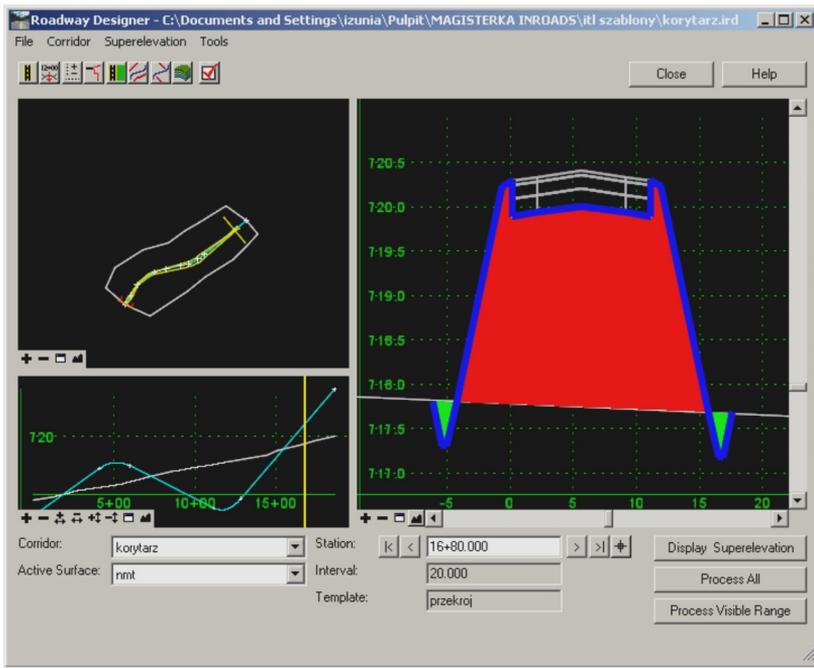


Fig. 4. Cross-section designing in *InRoads* application

2.6. Stakeout

Thanks to the tools of *Drogownictwo 2000* application, it is possible to calculate data to stakeout only horizontal curve and vertical curves. On the other hand,

the programme contains tools to calculate data to stakeout not only road axis, but also edge with defined offset length and curve widening. One of the biggest inconvenience in the application is incapacity to choose stakeout station, as the programme dictate the choice of coordinate origin. Moreover, it is impossible to generate stakeout sketch.

In order to calculate stakeout data in *Winkalk* application, first of all the road has to be designed and all its points have to be saved in the database. All the calculations of stakeout data are realized in separate module, different from *Road Design* module. Although *Road Design* module allows to calculate some stakeout data, they are not connected with previously designed road. When it comes to stakeout of vertical road elements, the application enables to generate stakeout data only for vertical curves and segments with homogeneous slope. What is more, all input data have to be filled in manually on the basis of the road project.

In *C-Geo* application stakeout data are calculated similarly like in *Winkalk*. It is possible to generate a report, which contains besides data tables with reference points and stations also simple stakeout sketch shown in figure 5. However, this draft is not always legible due to the lack of tools to draft edition. What is more, the application does not offer tools to calculate data to stakeout vertical road elements.

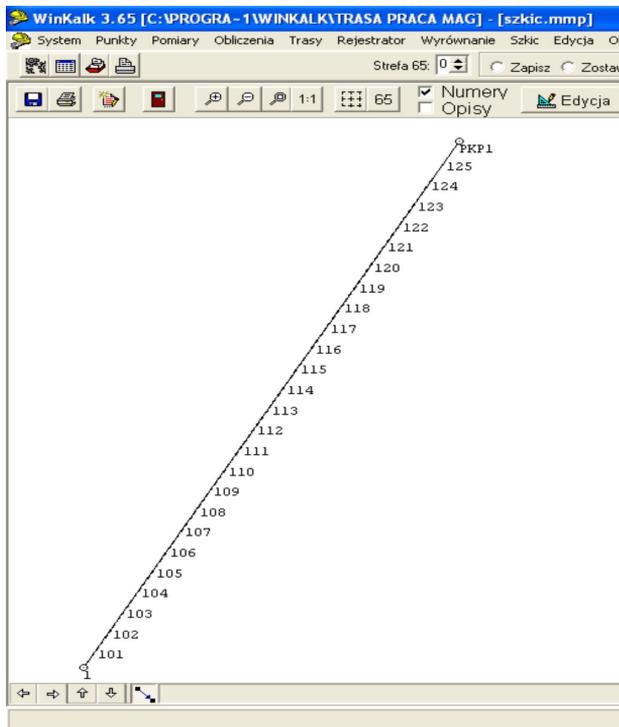


Fig. 5. Stakeout sketch form *Winkalk* application

InRoads programme offers tools to create a report to stakeout road elements polar method as figure 6 shows. Apart from road points, the user can also achieve data to stakeout any point with defined coordinates or surface elements. Furthermore, it is also obtainable to generate stakeout data files for particular types of geodetic equipment of various manufacturers. Unfortunately, there is no tool to create stakeout sketch in this programme.

Centerline Alignment: trasa						
Offset From Centerline	BS	OC	FS Station	Angle Right	Distance	
0,000	1001	1000	0+000,000	242,5092	75,124	
0,000	1001	1000	0+010,000	246,6704	66,250	
0,000	1001	1000	0+020,000	252,0866	57,746	
0,000	1001	1000	0+030,000	259,2986	49,800	
0,000	1001	1000	0+040,000	269,0633	42,726	
0,000	1001	1000	0+050,000	282,2388	37,027	
0,000	1001	1000	0+060,000	299,1650	33,414	
0,000	1001	1000	0+070,000	318,4654	32,588	
0,000	1001	1000	0+080,000	337,0024	34,748	
0,000	1001	1000	0+090,000	352,2616	39,407	
0,000	1001	1000	0+100,000	363,7889	45,808	
0,000	1001	1000	0+110,000	372,2859	53,328	
0,000	1001	1000	0+120,000	378,6005	61,558	
0,000	1001	1000	0+130,000	383,3908	70,249	
0,000	1001	1000	0+140,000	387,1125	79,247	
0,000	1001	1000	0+150,000	390,0769	88,456	
0,000	1001	1000	0+160,000	392,4953	97,811	

Fig. 6. Fragment of report with stakeout data from *InRoads* application

2.7. Reports and Results

From every work phase in *Drogownictwo 2000* application the user is able to generate a clear report and save it to text file. When it comes to graphic results, it is only possible to achieve longitudinal section of alignment.

Winkalk programme gives a possibility to generate a report and, additionally, a draft from every work stage. One of the biggest disadvantages of *Winkalk* is that the user is not allowed to choose points, which are to be depicted with numbers on the sketch. As a result, a drawing might be unreadable, when points are located too densely.

In *C-Geo* application all reports are generated to the separate module and they are stored there. This module contains many useful functions to edit and print re-

ports. On the other hand, there is no tool to generate reports from particular phases of designing. What is more, a draft created by the application is rather indigent. Similarly like in *Winkalk*, the user can not choose points to describe. It can result in an unreadable sketch.

For each work stage in *InRoads* application the user is able to generate a report. What is more, the programme offers wide menu in the field of creating graphics as a result of calculation and design work. There are also many options for drawing content, its appearance and descriptions. Huge advantage of *InRoads* applications is its potentiality to generate spatial model of roadway. Additionally, thanks to the *MicroStation* tools, the designed road may be presented in the form of rendered pictures shown in figure 7, visualizations or animations.



Fig. 7. Visualization of designed road created with the use of *MicroStation* application tools

2.8. Cooperation with Other Applications and Import/Export Possibilities

In this field *Drogownictwo 2000* application is rather limited, the only possibility is to save data to text file or to print longitudinal section of alignment.

Thanks to Import/Export function in *Winkalk* programme the user has a possibility to cooperate with such applications as: *EwMapa*, *C-Geo*, *Geo-Info* and CAD applications. What is noteworthy, all these operations can be executed only on points coordinates. Moreover, *Winkalk* does not offer data transmission to total stations or GPS receivers.

C-Geo possesses much broader menu concerning import and export. Yet, similarly like in *Winkalk*, all these functions apply to the content of working table, namely points coordinates. It is particularly important for land surveyors to be able to create stakeout input data for geodetic equipment and this application has this function. What is more, the programme contains an option of exporting data to *InRoads* application.

Import and export capability of *InRoads* application is tightly connected with *MicroStation* options. Graphic elements from *InRoads* can be exported to such file formats like: dgn, dwg, dxf, IGES, Parasolids, ACIS SAT, CGM, VRML World, STL, SketchUp, Google Earth, Collada, U3D. Moreover, thanks to this application it is possible to import and export data from geodetic equipment of various manufacturers.

2.9. Additional Functions

The most useful additional tools in *Drogownictwo 2000* are: function to select parameter A of spiral, function to adjust vertical curve to the drainage system, horizontal curve inventory.

C-Geo contains such additional tools like: calculations of edge, which does not have to be parallel to the whole road axis, calculations of differences between designed and measured road.

InRoads programme is such an extended application that it is practically impossible to describe all built-in functions. Options that mostly deserve credit are: calculations of area volume, material separation, exclusion of area volume between given stations from calculations, search of area volume balance point, mass-haul diagram, technical infrastructure designing, intersection designing.

3. Conclusions

The most functional and with biggest potential programme is *InRoads*. It contains tools necessary to create a complete road design on the basis of digital terrain model together with vertical alignment and cross-sections. Additionally, it is possible to take advantage of this application in order to modernize or design intersections and interchanges or even technical infrastructure. What is more, only this programme does not dictate descriptions appearance, their number and layout and it allows to design unlimitedly complicated roads. For land surveyors it is extremely important that it is possible to generate and export stakeout data to geodetic equipment. On the other hand, this universality results in high price,

which now comes to 30 thousand zlotys. What is more, it is necessary to purchase *MicroStation* or *AutoCAD* application to be able to use *InRoads* programme.

Against a background of expensive *InRoads*, freeware *Drogownictwo 2000* appears surprisingly favourable. Thanks to its simple interface the user can quickly and completely calculate road axis, vertical points and stakeout data. The only disadvantage of this programme is the lack of tools to generate drawings or drafts of road axis and cross-sections.

Winkalk and *C-Geo* are typical geodetic applications. Although they contain *Road Design* modules, their functionality leaves a lot to be desired. Especially, when it is judged by the user of *Bentley* packet programmes. The fundamental task of calculation modules in above-mentioned applications is to calculate data for land surveyors to stakeout road elements in the terrain. The authors of this software did not pay attention to the tools needed to generate full graphic presentation of the road project. What is surprising, apart from coordinates of cardinal points and indirect points the user can not achieve any additional geometric parameters of designed road. Unless *Road Design* modules in *Winkalk* and *C-Geo* applications were improved, these programmes would not be able to compete in the future with *InRoads* application, even though they are competitively priced. At the moment *C-Geo* is 10 times cheaper and *Winkalk* is 100 times cheaper than *InRoads* application.

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