Journal scientific and applied research, vol. 27, 2024
International Journal

Original Contribution

ISSN 1314-6289 (Print)
ISSN 2815-4622 (Online)

MAP OF THE EARTH MASSES - ROLE IN THE INVESTMENT PROJECT

Ivan D. Ivanov

DEPARTMENT OF GEODESY, FACULTY OF TECHNICAL SCIENCES, KONSTANTIN PRESLAVSKY UNIVERSITY OF SHUMEN, SHUMEN 9712, 115, UNIVERSITETSKA STR., E-MAIL: i.d.ivanov@shu.bg

ABSTRACT: *Map of the earth masses shows the essence of the vertical planning project by visualizing the anticipated displacement of the land masses within the boundaries of the property. It is the official document through which the designer can determine the amount of land masses for the purpose of their valuation [5]. The article examines the role of the cartogram and modern practices regarding its creation and use in the investment process.*

KEY WORDS: *Geodesy, cartogram, vertical planning, volume, investment project.*

1. Introduction

The cartogram of land masses shows the difference between the natural (existing) terrain and the project terrain of squares, parking lots, facilities, around buildings and other project activities. The cartogram contains a graphic and a textual part. There are different ways and approaches in creating the cartogram. As the main tasks of the cartogram, we can indicate:

- to provide the executor of the investment project with information about the locations of excavation/filling works when modeling the terrain;
- to provide the necessary quantitative data in order to value earthworks;
- to depict the so-called "zero line" or in other words - the dividing line between earthworks - excavation and embankment.

The data on the basis of which the cartogram is made are also heterogeneous in nature. In addition to the availability of the natural (existing) terrain and the design solution, it may be necessary to use data from geological surveys, architectural drawings and details, structural drawings and details, etc. This sometimes requires the knowledge and correct interpretation by the surveying engineer of these different specific data and drawings in order to achieve the most accurate result.

2. Problems and approaches in making a cartogram of the land masses

As mentioned above, this part of the Geodesy investment project can also interact with other engineering disciplines, which gives rise to different problems and approaches in the preparation of the cartogram. Questions that periodically arise around the development of this type of drawings in the investment process are discussed here.

2.1. When is it necessary to make a cartogram of the land masses?

Sometimes the issue of creating the cartogram is not discussed at the start of the investment process. The reasons can be different - high density of construction (for example, in the case of industrial areas) and minimal improvement in the property, construction of prefabricated construction (with it quite often the excavations are only for building the foundation), financial relief, permission from the approving authority, etc. The opinion of the collegium is maintained that this type of drawings are mainly made when designing "objects of large volume and importance", which by its nature and concept does not have a precise definition, so the assessment of the creation of the cartogram remains subjective.

From a normative point of view, in Bulgaria the main normative act, which regulates the scope of the investment project under Geodesy [3], in its art. 108, para. 1, indicates the **mandatory creation** of a cartogram of the land masses. In Art. 110, item 1 of [3] also states "***a bill of quantities*** ***for the execution of types of earthworks and other types of civil engineering***", which "***a bill of quantities***” in itself cannot be prepared without a cartogram of the earth's masses. In Art. 110, item 2 of [3] says "*value account* ***when one is required*** *by the design assignment (design contract)*", which raises the issue of valuation as an optional part of the cartogram.

2.2. What approach to use in calculating the volume of land masses?

This question remains perhaps the most debated, because the study of volume calculation methods and achievable accuracies is a problem that is relevant to a wide variety of applications, including cartogram production. The approaches are mainly divided into classical calculation and computer calculation. In turn, classical cartogram computation can be done in general in several ways:

- through a square grid;
- through figures;
- through profiles.

A feature of the classical methods is the subjective assessment of the dimensions of the squares, respectively of the figures, as well as the density of the profiles. Thus, the final accuracy of the volumes depends not only on the precision of the model of the natural (existing) terrain, but also on the refinement of the figures (Fig. 1). On the other hand, this also affects the time required to process the different segments (squares, different shapes or profiles). There are different formulas by which volumes can be calculated using classical methods, but in general the formula looks like this:

$$v = S \cdot h_{cp} \quad (1)$$

where S is the area of the figure in m^2 and h_{cp} is the mean working elevation. Finally, we sum up the volumes separately - excavation and embankment, thus calculating the final balance for the given object.

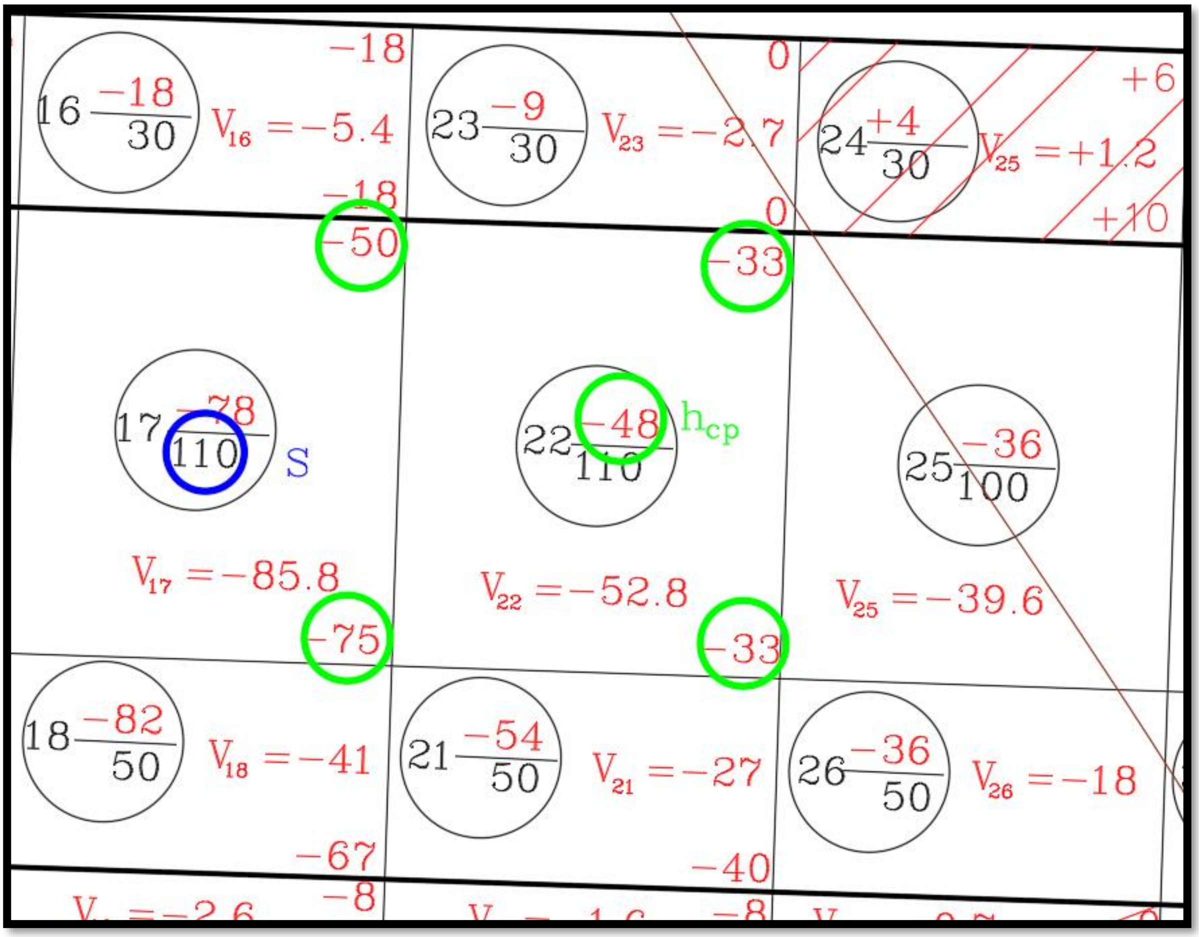

Fig. 1. Cartogram of land masses by means of figures [3]

In computing, there is a much wider choice of methods and software for creating the cartogram. Of course, there remains the option of using classical methods in a digital environment, which does not seem like an effective and economically justified approach. For volume calculation, digital surfaces (initial and design) in the form of TIN (triangular irregular networks) or GRID network are most often used. Different software use different calculation methods based on these surfaces, but in general the accuracy is not significantly affected by this. In this connection, a study was also conducted in [1], where when comparing three different methods, a maximum difference in volumes of 0.45%

was obtained, which is a negligible value. Two factors mainly influence computer accuracy:

- the accuracy of the photographed source (existing) terrain;
- the way of modeling the surface (for example, the connections between the points at the vertices of the triangular network – the TIN model).

Computer modeling and calculation completely outperforms classical approaches in this type of activity. In addition, it also enables the solution of some more specific tasks, such as in [2], where map materials are used at different scales. In Bulgaria, most geodetic engineers use this approach when calculating cartograms of the earth's masses, but the main problem lies in the outdated current regulations. According to [3], cartograms are prepared according to one of the classic methods described above, which forces designers to shape the cartogram according to one of the above-listed methods (most often through figures). Usually, the approval authority specifically insists on this type of layout and calculation, which artificially compromises the computer-calculated volume between the two surfaces as a consequence of the detail of the figures.

2.3. What data to use when creating the cartogram?

In the case of investment design, a complete solution is usually given for the construction and improvement of the rest of the property. In the part of vertical planning, the project location in terms of height of the improvement measures is decided. After that, the drawings are usually prepared and the details are the individual landscaping elements such as flooring, retaining walls, steps and others. They themselves occupy a certain volume in the calculation of the cartogram of the land masses. The main problem with their inclusion in the cartogram calculations is the fact that usually the designers of these landscaping elements **work in a local coordinate system**. The process of georeferencing and inserting these details usually takes a considerable amount of time and it is good before starting to make a realistic assessment of whether it will be economically viable. These landscaping elements often also require pre-compaction of the earth masses, which on the other hand compromises the pre-set coefficient of swelling of the earth masses and it may turn out that instead of calculating removed earth masses for laying these elements, we will have to simply compact the earth's mass as such subtracting the volume of the elements will be redundant, even negatively affect the final result.

Here is the time to discuss the quantities for excavation of the building or, respectively, the foundations. Usually, the construction engineer indicates in a separate drawing a plan of the excavation, in which he calculates the volume of the earth masses. These drawings and the quantities of land mass in them must be taken into account when calculating the final quantities. If necessary, the drawing can be compared to the field surface by georeferencing it in advance in order to check the quantities of the design excavation.

Something worth paying attention to is the presence of a humus layer on the soil, which is almost always present in the properties. Usually it varies between 0.3 and 0.5 m [4]. In the presence of a humus layer, it is good to compile either two separate cartograms such that the one for the humus layer of the soil will be completely in the trench, or to edit the volumetric surface according to the thickness of the humus layer. Data on the humus layer can also be obtained from geological surveys.

2.4. How to prepare the cartogram layout?

The final layout of the cartogram should reflect the set goals and conditions. For example, if our goal is to show the movement of the earth's masses, we will indicate which masses should be moved where and at what distance (Fig. 2). In these cases, it is good to determine the coordinates of the centers of gravity of the individual sections [4].

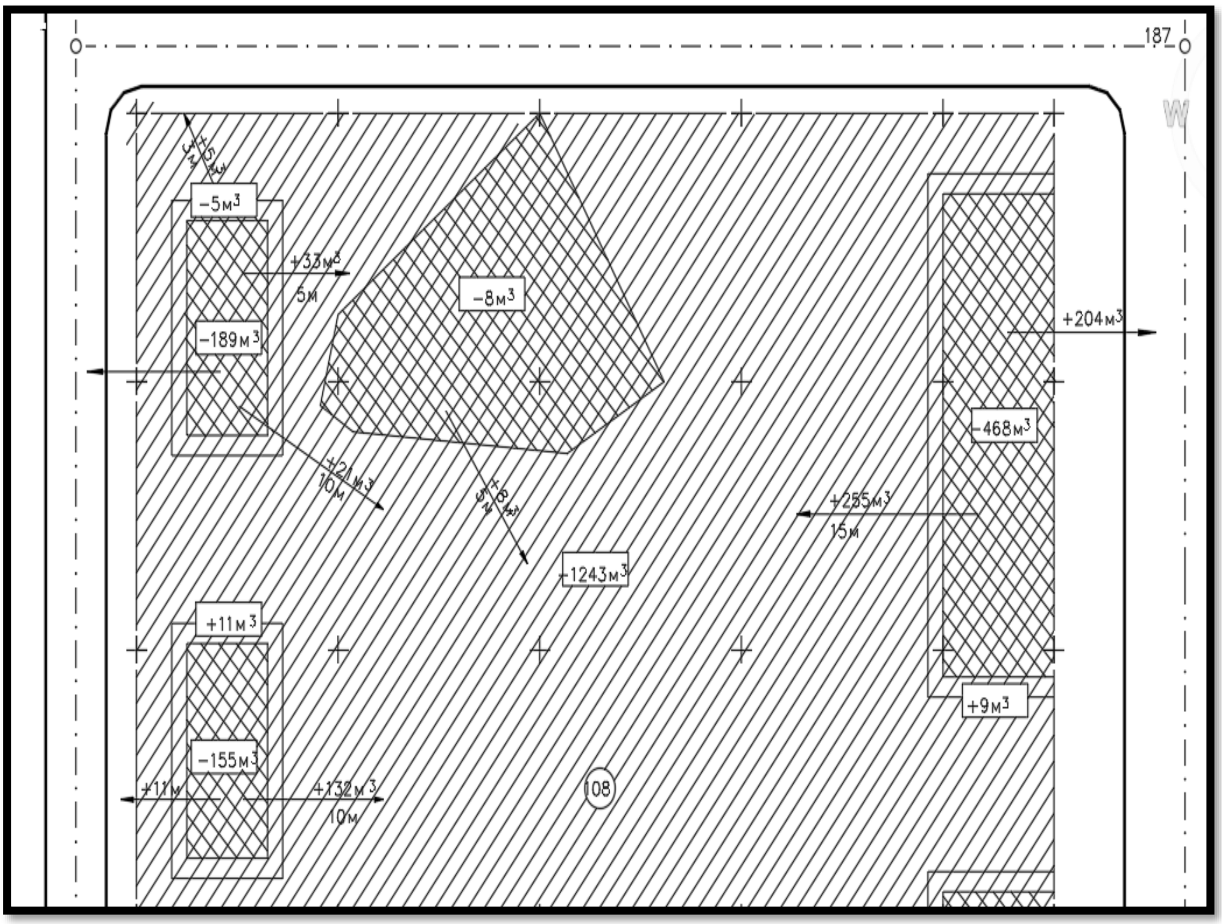

Fig. 2. Scheme of displacement of land masses [3]

The preparation of such a scheme is also related to the construction organization itself, which in most cases is unpredictable in the design process. It is difficult to determine the places for placing temporary objects, technical equipment, construction equipment and others, therefore it is necessary to assess whether it is appropriate and economically justified to invest time in the preparation of such a scheme. The availability of calculated volumes with their location is usually enough information for the technical manager of the site so that he can judge for himself where and how it would be appropriate to move the tables themselves.

Sometimes it may be a condition that the cartogram be prepared in such a way that it can be "easily" verified. Usually, this is the formation of the cartogram in the form of figures (Fig. 1), on which the inspecting authority can calculate each of the figures himself. In practice, however, the most important condition for verifying the reliability of the cartogram is the verification of the natural (existing) terrain, and only if at the time of this verification it has not yet been modified.

Instead of noting characteristic working differences in the corners of the figures, the original and project terrain can be directly marked on one drawing through horizontals, and the cartogram can be imposed under them with some transparency in the form of a thematic map (Fig. 3). This, in addition to saving time, also gives much more detailed information than the classical approach of drawing a cartogram using figures

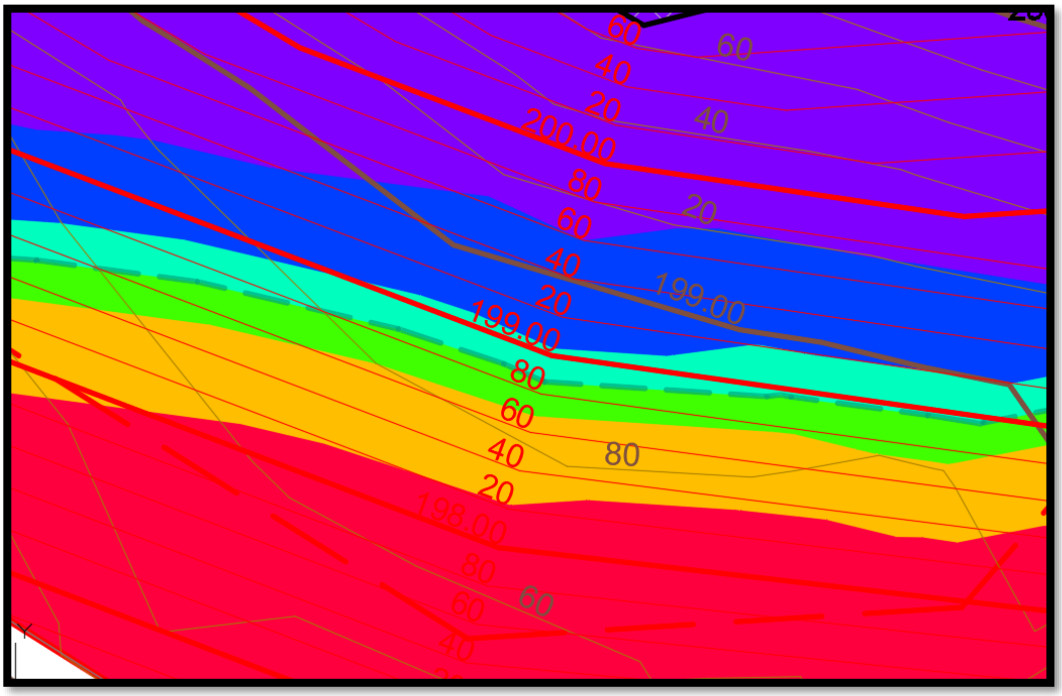

Fig. 3. Cartogram in the form of a thematic map containing the existing and project terrain

A legend and explanatory table can be prepared for the cartogram. In Fig. 4 and 5 shows an example header and table of quantities to the graph of Fig.3.

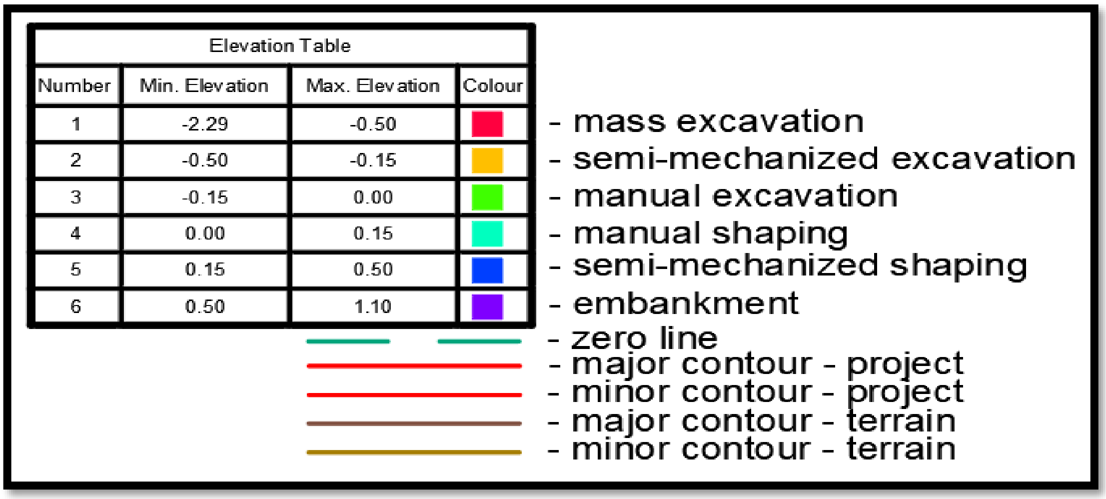

Fig. 4 – Legend and markings to the thematic cartogram

Earth works	**m3**
1. Excavation	***399.62***
1.1 Manual excavation - <0.15m	7.62
1.2 Semi-mechanized excavation - 0.15m - 0.50m	49.76
1.3 Mass excavation - >0.50m	342.24
2. Embankment	***334.84***
2.1 Manual shaping - <0.15m	19.20
2.2 Semi-mechanized shaping - 0.15m - 0.50m	82.73
2.3 Embankment >0.50m	232.91
3. Balance	***-64.78***

Fig. 5. Table with calculated amounts of land masses

Thus, in practice, a maximally generalized picture is obtained with the necessary quantities concerning the most common types of earthworks in order to be able to be valued. The thematic map visually shows the locations of the types of earthworks, and the visualization of the field and design surface in the form of horizontals provides control over individual thicknesses.

2.5. Are additional explanations and preparation of a map implementation plan necessary?

For more complex construction sites, staged construction is sometimes planned. In these investment projects, the construction is divided into successive phases, and this is also associated with implementation in a certain sequence. For example, in one large property, several buildings can be built, as in the first stage, one part of the buildings is excavated, and then the rest. If removal of the earth masses is not foreseen, this means that a certain amount of earth masses will be excavated and deposited on the construction site once, and then the same will have to be moved or removed again. If the contracting authority expressly wants a preliminary valuation of the earthworks, this may require the preparation of several cartograms, consistent with the planned phased construction.

In most cases, for the smaller objects, explanations about earthworks are not presented in the cartogram. It is enough to correctly calculate the quantities of land masses. However, practice shows that it would be useful to compile trace data for the zero line and trace it to the object accordingly. Thus, when making an excavation or when modeling the existing terrain, seized earth masses will not be placed on places where excavations are planned.

3. Conclusion

This article examines a part of the complex investment project, which is prepared by the surveying engineer, presenting some problems, guidelines and exemplary solutions regarding the preparation of the cartogram of the land masses. The emphasis placed in the article can serve as a guide in the preparation of this type of specific activity in order to achieve optimal and economically justified results in the preparation of the cartogram.

References:

[1] Blistan, Peter. (2012). Modeling and calculation of the irregular bodies volume - principles. Egrse. 19. 13-25.

[2] Fys, Mykhailo & Yurkiv, Mariana & Lozynskyi, Viktor. (2021). Modeling of 3-D objects using geodetic and cartographic data and determining their volumes with an accuracy assessment. Remote Sensing Applications: Society and Environment. 22. 100506. 10.1016/j.rsase.2021.100506.

[3] Instructions for the development, implementation and maintenance of the plans for vertical planning (MRRB - General Directorate "Geodesy and Cadastre", 1998).

[4] Milev, G., Milev, I. Applied Geodesy Part 1, Engineering Geodesy. Book 2. Design and application of development and master plans. Union of Surveyors and Land Planners in Bulgaria, Sofia 2017, ISBN 978-619-90732-0-9.

[5] https://precizinjenering.com/new/10/картограма-на-земните-маси.html.