

Generalization of settlements on Czechoslovak topographic maps

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Abstract: The cartographic generalization of settlements has always been a key issue in the technology of creating derived topographic maps. Czechoslovak topographic maps of 1:25 000 (1:25K), 1:50K, 1:100K and 1:200K scales were part of the most extensive unified topographic work of the Eastern Block, which covered the territory from Western Europe to Japan. This paper describes the methodology of survey and the results of generalizing the numbers and shapes of buildings on the derived topographic maps, which were created by experienced map editors in the latter part of the 20th Century. The results can serve as underlying statistical data for automated technology for creating derived maps from a 1:25K scale base topographic map.

Keywords: cartography, cartographic generalization, topographic maps, settlements, buildings

1. Introduction

Closely related to the construction and theory of Geographic Information Systems (GIS) development is the level of accuracy and detail of geographic information contained in GIS databases. Excessive accuracy and detail (exceeding user requirements) leads to higher demands on information retrieval and processing, burdening graphical outputs and making the user's work more difficult. Insufficient detail and accuracy leads to lower information value of outputs and thus to lower quality of all derived (generalised) products, e.g. derived topographic maps (TM) of smaller scales and derived databases. One of the basic prerequisites for displaying topographic maps of different scales is an appropriately chosen generalization. Cartographic generalization in the general sense has been addressed by a number of cartographic experts around the world - see Cebrykow (2017), Chrobak (2010), Kraak, M. and Omeling, F. (2010), Revell, P. (2008), Tyner, A.J. (2005), Dawid (2022).

Generalization of the internal structure of settlements is one of the most complex design-technological stages of creating topographic maps and building geographic information systems – see Gaffuri and Trévisan (2004), Gao et al. (2022), Kronenfeld et al. (2022), Owusu et al. (2023), Raheja et al. (2010), Stojanović et al. (2020). In past periods of topographic map up-dating, derived maps were created on the basis of generalization templates contained in a map project documentation. However, these templates could not, for obvious reasons, ensure the application of a uniform objective procedure for the production of derived maps. Comprehensive automation in the generalization of settlements has not yet reached a significant application in topographic maps, and so most of the procedures at this stage of map production were and

are based mostly on semi-automatic procedures. Thus, the current topographic maps can be evaluated as a certain expression of the experience of the editors and other experts who participated in the creation of this work.

The aim of this paper is to present some results of extensive cartometric and statistical investigations carried out at the Department of Military Geography and Meteorology of the University of Defence, Brno, which were aimed at determining the dependence of the representation of the internal structure of settlements in the creation of derived topographic maps. These statistical investigations were carried out continuously from 1980 to 1999, focusing on the representation of the internal structure of settlements, especially on the representation of buildings, their subdivision (shape) and the internal division of settlements into blocks – see Rybansky (1982, 1994, 1999), Javorský (1992), Miklošik et al. (1995), Talhofer and Rybansky (1997a, 1997b). Statistical measurements were mainly focused on topographic maps of the Czech Republic and selected topographic maps of Slovakia, Hungary, Austria, Germany and Poland. The presented results of the investigation can be a contribution to the assessment of the production of derived topographic maps as well as to conceptual plans in the field of their up-dating. As the topographic map work of the majority of the Central and Eastern European countries was historically created on the basis of the same concept, the results of the survey can to some extent be applied to the assessment of the general principles of the representation of settlements on the topographic maps of these countries.

2. Methodology for determining generalization procedures in the creation of derived topographic maps

The main content elements of the internal structure of settlements in topographic maps (TM) include buildings in settlements represented by a symbolic marker of a point character (marks 200-1a and 200-2a in the marker key

Topo-4-3), buildings depicted at map scale (marker 200-4b), and the actual structure of blocks defined by roads in settlements. The following procedure was established in determining the methodology for establishing mathematical and statistical dependencies in the representation of settlements on derived TMs:

- determination of sample sets of representative settlements for statistical surveys;
- the survey of data on maps (determination of the hierarchy of statistical units in settlements for the survey of the number of listed objects for each TM scale and the actual survey of the number of buildings depicted, the number of building corners and the number of blocks in settlements);
- mathematical-statistical analysis of measured values, determination of functional dependencies for displaying objects of settlements on the derived TMs.

2.1 Determination of sample sets of representative settlements for statistical measurements

The following criteria were considered when selecting a representative set of settlements for the statistical survey:

- economic and administrative importance;
- population;
- the nature of the built-up area and the layout (block, free, villa,...);
- geographical location (φ , λ , h);
- other criteria (historical and urban specificities, availability of measurement data,...).

In total, 169 urban and rural settlements were selected and evaluated, 84 of them from the territory of the Czech Republic, and almost 100 000 data were examined. Figures 1-6 show examples of the generalization ways of different types of settlements from the Topo-4-3 marker key, which were used by the editors to create the derived topographic maps. The views of the map sections are ordered from the left starting with the topographic map 1:10K (this map has not been the subject of further research), 1:25K (TM 25), then the map TM 50, TM 100 and the topographic map 1:200K (TM 200) on the right.

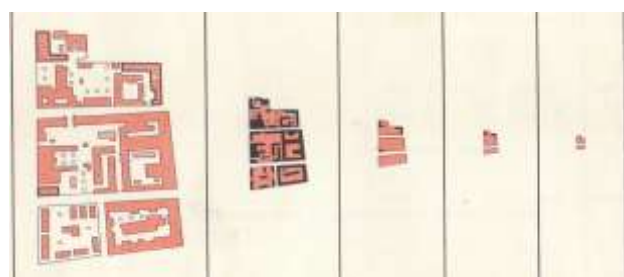


Figure 1. Generalization - large cities over 50 000 inhabitants



Figure 2. Generalization - other cities and urban settlements (up to 50 000 inhabitants) – first type

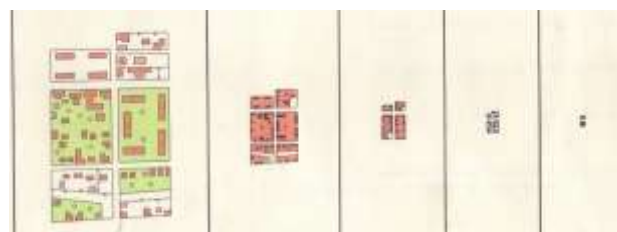


Figure 3. Generalization - other cities and urban settlements (up to 50 000 inhabitants) – second type

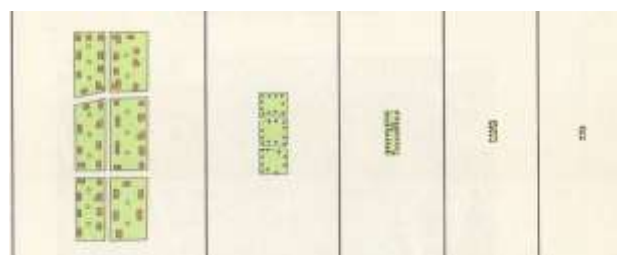


Figure 4. Generalization – villa type settlements

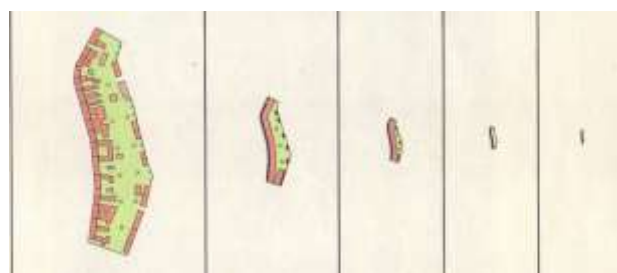


Figure 5. Generalization - settlements of rural type with closed attached housing



Figure 6. Generalization - settlements of rural type with open attached housing

The following figures (7-12) show sample examples for the displaying and generalization of settlements for large cities (over 50,000 inhabitants), other cities and urban-type settlements (under 50,000 inhabitants), villa-type settlements, rural-type settlements with enclosed and open (attached) housing and rural-type settlements with irregular housing.



TM 25

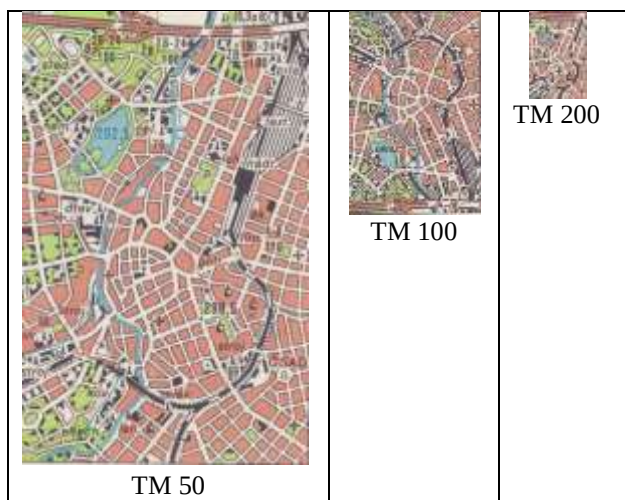


Figure 7. Displaying the generalization of settlements for large cities (over 50,000 inhabitants)



TM 25

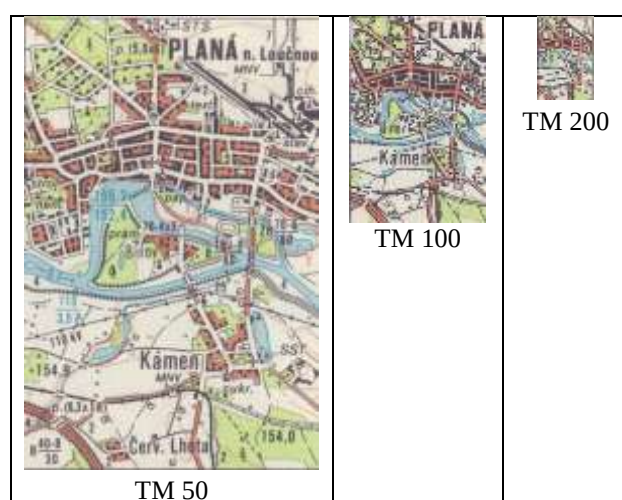


Figure 8. Displaying the generalization of settlements for other cities and urban-type settlements (under 50,000 inhabitants)

For the assessment of the level of generalization of settlements with villa development, settlements with the area of family houses over 50% were selected – see Fig. 9.



TM 25



TM 25

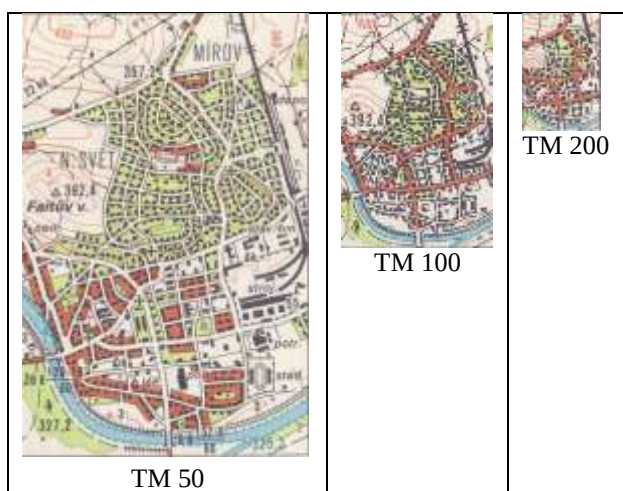


Figure 9. Displaying the generalization of villa type settlements

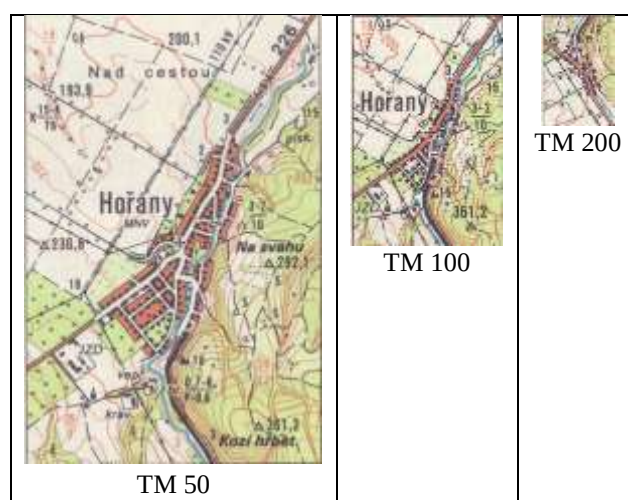
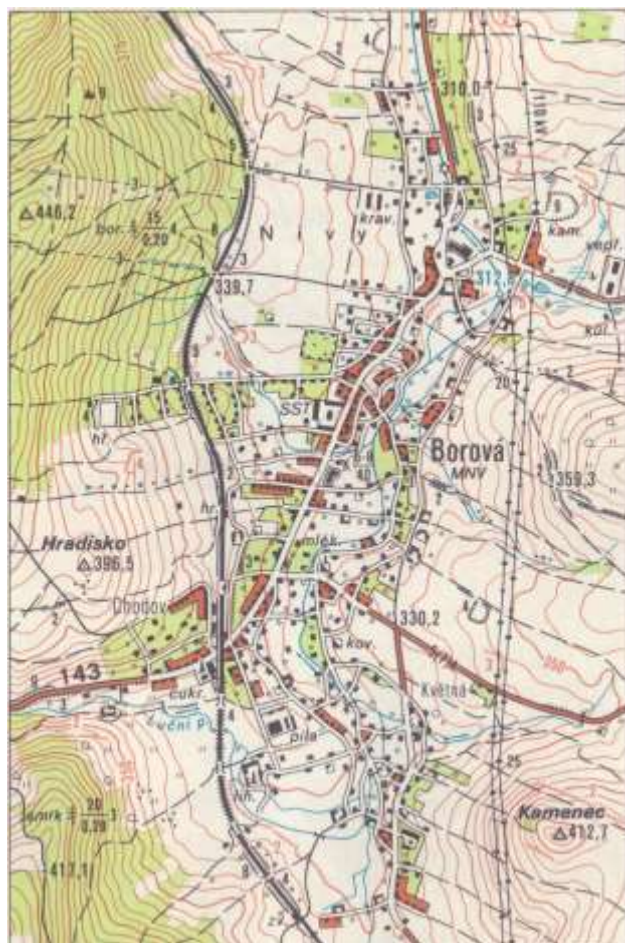


Figure 10. Displaying the generalization of rural-type settlements with enclosed and open (attached) housing

For the generalization of rural type settlements, villages with closed and open built-up type were analysed – see Fig. 10.

For the generalization of rural settlements with irregular buildings, settlements where houses do not have a clear structure were selected – see Fig. 11.



TM 25

For the generalization of rural settlements with scattered housing, settlements where houses are isolated and distant from each other were selected – see Fig. 12.



TM 25

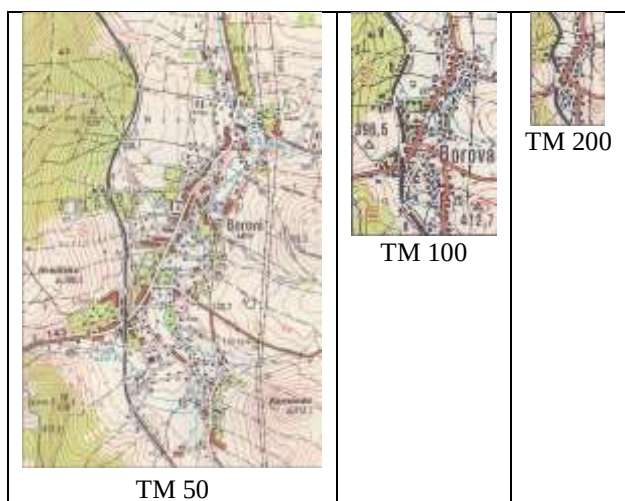


Figure 11. Displaying the generalisation of rural-type settlements with irregular housing

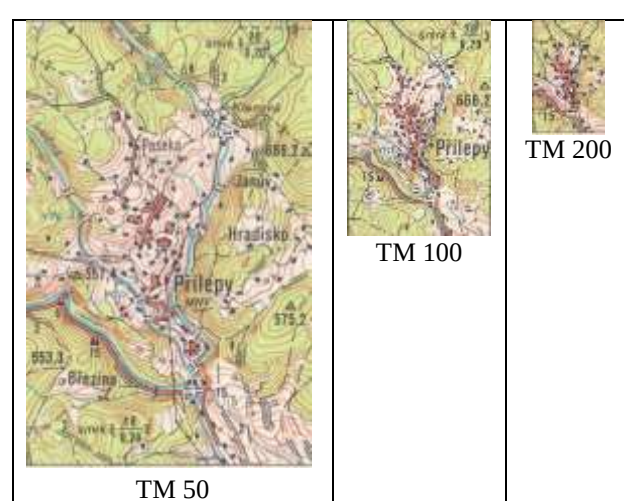


Figure 12. Displaying the generalisation of rural settlements with scattered buildings

2.2 Finding data on maps

In order to accurately determine the number of depicted objects within settlements, it was necessary to divide the settlements into hierarchical parts, starting from the simplest image of the settlement, namely its image on the TM 200 for older measurements and TM 100 for more recent measurements, assuming that TM 200 will not be up-dated.

On these maps the settlements are divided into basic parts A,B,C,... The basic dividing lines were the axes of the thoroughfares in the settlements. On an adjacent larger scale (e.g. 1:100K), the original part of the settlement - e.g. A - was then divided into parts of lower hierarchical level A₁, A₂,...A_i as the crossings were added. Similarly, parts B, C,... On the 1:50K scale map, a part of the settlement from TM 100 - e.g. A₂ - was further subdivided into parts A₂₁, A₂₂,...A_{2j} and for TM 25, e.g. part of the settlement A₂₁ was subdivided into parts A₂₁₁, A₂₁₂, A_{21k}.

For all parts of the settlement and the individual TM scales, the sums of building numbers, building corners and block numbers were then performed.

2.3 Mathematical-statistical analysis of measured values, determination of functional dependencies for display of settlement objects

In general, a polynomial function can be used to calculate the functional relationships necessary to determine the mathematical dependencies of the numbers of displayed settlement objects between the TM scales

$$y = a_0 + bx + cx^2 + dx^3 + \dots \quad (1)$$

where

y = number of objects displayed on the derived map (smaller scale map);

x = number of objects displayed on the original map (larger scale map);

a,b,c,...= polynomial parameters that can be determined e.g. by the least squares method using the measured values x_i, y_i of the number of displayed objects (buildings, corners of buildings and blocks) on the original and derived map. In practice, the number of measured values usually exceeds the number of measurements necessary to determine all parameters of the polynomial. The measured and displayed values showed that in most cases a polynomial of degree 1, i.e. a linear function, is sufficient to determine the functional dependence of the display of the numbers of objects in the settlements on the derived TM. However, with larger sets of measurements in settlements, there are cases when the same values of the number of displayed objects of settlements on the original map correspond to multiple values of the number of displayed objects for these settlements on the derived map or different values on the original map correspond to the same values on the derived map. Such a relationship between two randomly varying quantities of the number of objects in settlements in a statistical set of measurements

is based on a correlation between the measures, which can be expressed in terms of a linear relationship by:

$$y_i = y_p + b_{yx}(x_i - x_p) \quad (2)$$

$$x_i = x_p + b_{xy}(y_i - y_p) \quad (3)$$

$$b_{xy} = \frac{\sum x_i y_i - n x_p y_p}{\sum x_i^2 - n x_p^2} \quad (4)$$

$$b_{yx} = \frac{\sum x_i y_i - n x_p y_p}{\sum y_i^2 - n y_p^2} \quad (5)$$

$$r = \sqrt{b_{yx} \cdot b_{xy}} \quad (6)$$

where

y_i = numbers of tracked objects of individual settlements on derived maps;

x_i = the number of tracked objects of each settlement on the original maps;

y_p = average values of the frequency of tracked objects from all settlements on the derived maps;

x_p = average values of the frequency of tracked objects from all settlements on the original maps;

b_{yx}, b_{xy} = directive regression lines;

r = correlation coefficient.

3. Results of mathematical and statistical analysis of measured values

From a total of 169 urban and rural settlements selected and evaluated, nearly 100,000 data were examined, including building counts, building blocks and building corners. On the basis of mathematical and statistical analysis on the topographic maps of the Czech Republic, the above correlation functions were determined and mostly very close relationships between the numbers of depicted settlement objects on the derived and original maps (the values of the correlation coefficients were usually greater than 0.85) were demonstrated - see Rybansky (1982, 1994, 1995, 1999), Javorský (1992). In total, 507 (169x3) correlations were calculated (for buildings, blocks and corners). The resulting graphs were then aggregated from these correlations. The overall levels of generalization of the selected settlement objects can be seen in the following graphs (see Fig. 13-18).

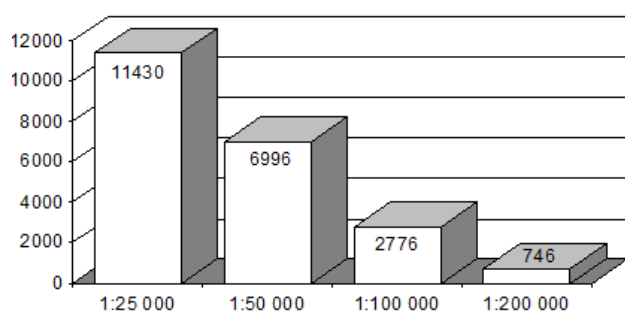


Figure 13. Generalization of the number of buildings in urban settlements

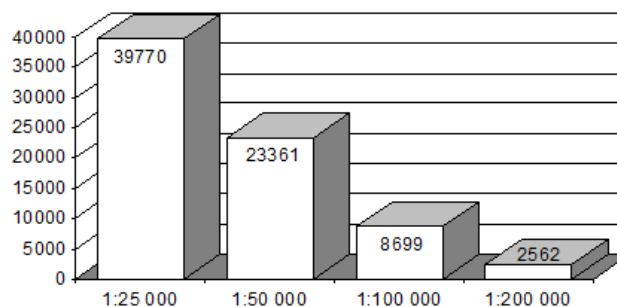


Figure 17. Generalization of the number of building corners in urban settlements

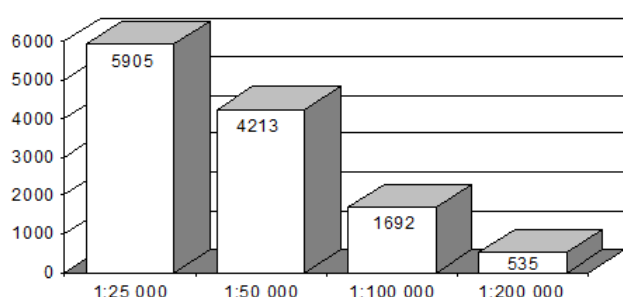


Figure 14. Generalization of the number of buildings in rural settlements

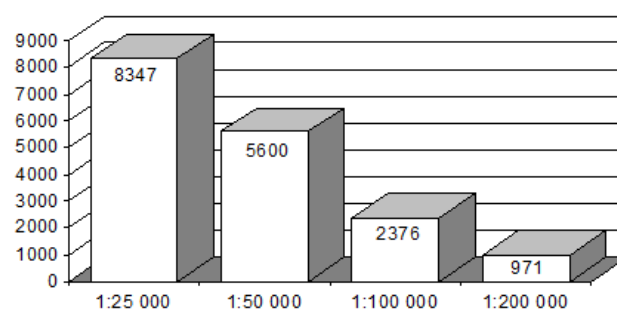


Figure 18. Generalization of the number of building corners in rural settlements

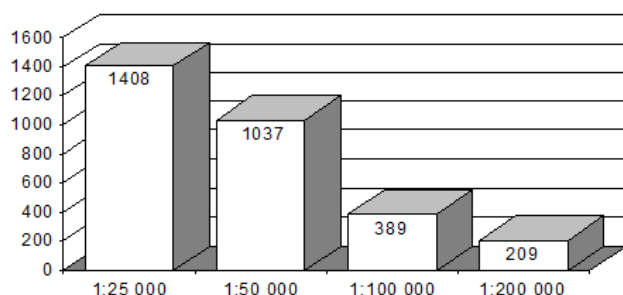


Figure 15. Generalization of the number of blocks in urban settlements

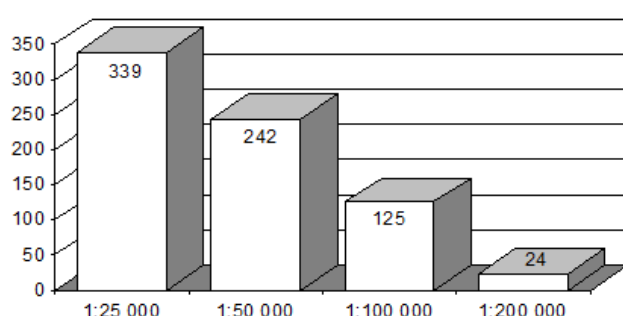


Figure 16. Generalization of the number of blocks for rural settlements

After analyzing the graph showing the generalizations of settlements on the topographic maps, the following findings emerge:

When generalizing the number of buildings in urban settlements, approximately 61.2% of buildings ($6996/11430 \times 100$) were displayed from the 1:25K map to the 1:50K map, 39.7% from the 1:50K map to the 1:100K map, and 26.9% from the 1:100K map to the 1:200K map.

When generalizing the number of buildings in rural settlements, approximately 71.3% of buildings ($4213/5905 \times 100$) were displayed from the 1:25K map to the 1:50K map, 40.2% from the 1:50K map to the 1:100K map, and 31.6% from the 1:100K map to the 1:200K map.

When generalizing the number of building blocks in urban settlements, approximately 73.7% of building blocks ($1037/1408 \times 100$) were displayed from the 1:25K map to the 1:50K map, 37.5% from the 1:50K map to the 1:100K map, and 53.7% of building blocks from the 1:100K map to the 1:200K map.

When generalizing the number of building blocks in rural settlements, approximately 71.4% of building blocks ($242/339 \times 100$) were displayed from the 1:25K map to the 1:50K map, 51.7% from the 1:50K map to the 1:100K map, and 19.2% of building blocks from the 1:100K map to the 1:200K map.

When generalizing the number of building corners in urban settlements, approximately 58.7% of building corners ($23361/39770 \times 100$) were displayed from the 1:25K map to the 1:50K map, 37.2% from the 1:50K map to the 1:100K map, and 29.5% from the 1:100K map to the 1:200K map.

When generalizing the number of building corners in rural settlements, approximately 67.1% of building corners (5600/8347*100) were displayed from the 1:25K map to the 1:50K map, 42.4% from the 1:50K map to the 1:100K map, and 40.9% of building corners from the 1:100K map to the 1:200K map.

4. Discussion

The results of a multi-year statistical survey, in which 169 urban and rural settlements were selected and evaluated, and nearly 100,000 data were examined, illustrate mathematical relationships that can be understood as the approach of hundreds of experienced editors in the production of derived maps. It should be noted that there were differences between the editors' approaches to generalization, but they were not fundamental, and this was reflected in the populating of the topographic maps with cartographic features. The topographic maps under consideration were produced by cartographers from different institutions, but the prescriptions for generalizing settlements were similar, as evidenced by maps from the border areas between different states. From this point of view, the generalization values found can be considered as beneficial, especially in the context of their application to automated technologies for the selection and generalization of map features in the production of derived maps.

5. Conclusion

By comparing the results of the generalization of the number of buildings, blocks and building corners in urban and rural settlements on topographic maps, the following conclusions can be drawn:

- In urban settlements, there is a greater degree of generalization of the number of buildings and building corners than in rural settlements;
- The display of building blocks shows a greater degree of generalization when moving from a 1:50K map to a 1:100K map for rural settlements. When switching from a 1:100K map to a 1:200K map, it is the other way around. This is due to a greater reduction of blocks based on the marker key.

From the point of view of correlation dependencies of the detected numbers of objects in settlements on the original topographic maps and derived topographic maps, as well as from the similarity of the results obtained by various persons who participated in the detection of these dependencies, it follows that the topographic maps of the Czech Republic, which are currently in the supply of the Czech Armed Forces, are a compact, unified map work created on the basis of a systematic editorial approach in the design and production part of map production.

Mostly very close dependence relations between neighboring scales, resulting from high values of tightness coefficients of correlations and small dispersions of measured values of large statistical sets, are a prerequisite for the fact that the above mentioned basic mathematical relations can be used both for the assessment of the current

topographic map work and for proposals for its further development.

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