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The relationship between railway gauges and topographic features on the example of the Hungarian Bükk Mountains

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Abstract: In our research we looked for the answer whether there is a proveble relationship between the topographic features and the gauges in the Bükk Mountains and in it's neighbourhood. The Bükk is characterized by diverse topography and extensive railway network.

In the Bükk Mountains and in its direct surroundings a railway network with four different gauges were built in the last nearly one and a half centuries. These railways clambered up from the hills of the mountain margin pedimentation along the deep canyon-like valleys to the 800-850 m high Nagy-fennsík.

Keywords: narrow-gauge railways, digital topographic model

1. Introduction

We find an exceptionally wide spectrum of the railway gauges in the Bükk Mountains and in its direct surroundings, from the 600 millimetre railroads until the 1435 millimetre gauges. The gauge of a railway depends on 3 different aspects in the area. The first one, and maybe the most important is the available source of funds. The second aspect is the quantity and the frequency of the deliverable merchandises, while the third aspect is the terrain.

2. Material and Methods

This paper examines the possibilities given by the different land features, and tries to look for a relationship between the railway gauges and the topographic features. The field observation of the topographic features was complemented with analysis of a digital terrain model. We examined how, and in what kind of researches can this DTM be used.

3. Results and Discussion

A. Bükk Mountains

The Bükk Mountains are the southernmost member of the North-Western Carpathians, and also this is the largest part of the North-Hungarian Mountain Range, and it has the highest average altitude. Although the altitude of the mountains do not reach the 1000 metres (Istállós-kő, 959 m), but some 50 of its peaks rise above 900 m. The eastern border of the Bükk is the Sajó river, and on the west the Tarna valley borders it. The Hevesaranyos–Mikófalvi basin separates it from the Ózd–Pétervásárai hills in the northwest. The strongly uplifted central part of the Bükk lowers in the north to the Bükk-Hát and in the south to the Bükkalja, and towards the Heves–Borsodi plains [1].

The geological structure of the Bükk is one of the most diverse in Hungary. Most of its rocks are sediments with a sea origin − mainly limestone, clay and shale, radiolarit, dolomite and sandstone. These rocks were formed cca. 310-330 million years ago, from the second half of Carbon period until the end of the Jurassic period. Between the sediment layers in the middle-late Triassic as a result of an undersea volcanic activity porfirit (metaandezite) and diabase (metabazalte) are formed. The mountain’s complicated, folded – overfolded, imbricate structured, thrust sheeted structure were formed at least in two sections between the Late-Jurassic and the Early-Eocen. In the first half of the Tertiary, in the early and middle Eocen the mountain was situated on the margin of the tropical and the warm-temperate zone, in a wet, warm, littoral environment, where the geomorphic evolution was directed by chemical weathering and erosion of the watercourses. Due to these erosive processes the relative height of the structural-geomorphological units formed by tectonic movements in the Cretaceous (synclines, anticlines, uplifted-overthrusted nappes) gradually decreased, and the Bükk was planed into a peneplain separated by wide, flat walleys. The separation of it’s big regions: the Bükk plateau, the South-Bükk, and the North-Bükk started at the end of the Pliocene. [2].

B. Railroads in the Bükk area

Several railways were built on the territory of the Bükk Mountains in the last one and a half centuries. Being connected to the national railway system the Füzesabony-Miskolc-Putnok, and the Putnok-Eger-Füzesabony railway -

founded on the front of the 1900 years- the railway embraces the mountain range [3].

The area enclosed by the above mentioned railways is not equal exactly with the territory of the Bükk. In this paper we've examined only those railroads that include the valleys reaching into the mountain. At the beginning of the XX. century were the narrow gauge railroads used in Nagyvisnyó, Szilvásvárad, Felsőtárkány, Lillafüred [4], Miskolc and on the Bükk Plateau. We've examined the relationship between these railways and the topographic features. In these days we cannot find a line that works on its total length anymore, only the lines at Szilvásvárad, Felsőtárkány and Lillafüred are still used on some stages (Figure 1.) [5-6].

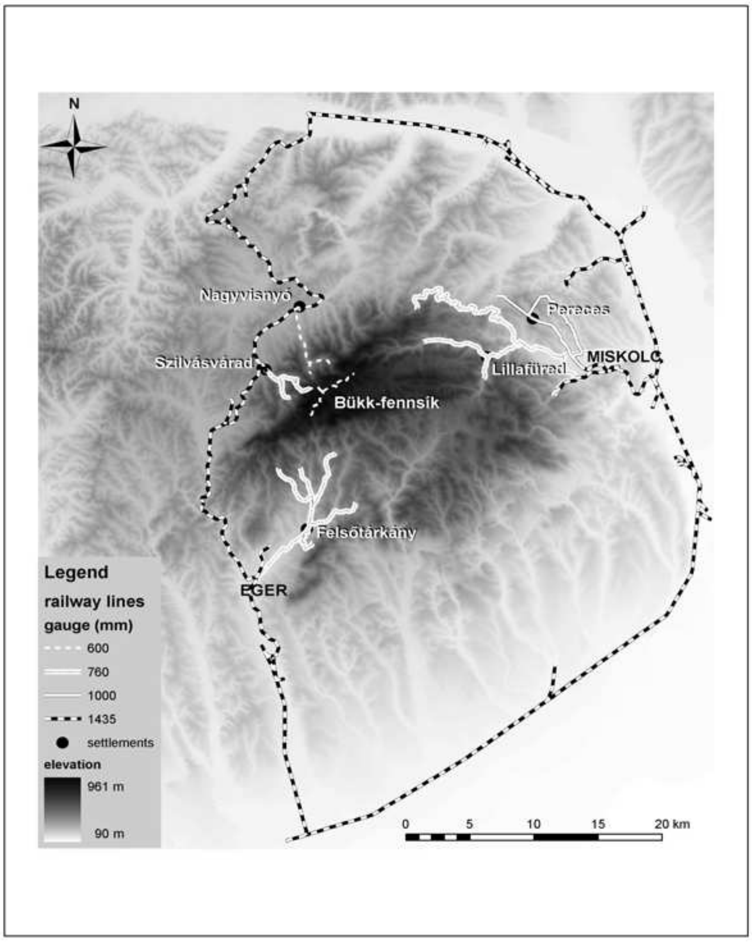

Figure 1.: The important railways of the Bükk and its neighbourhood

These railroads supplied the needs of the industry in the time of their building. Primarily the trees exploited from the forests, and the products of mines in the valleys were transported on these railways to the nearby villages, cities. Their building was not only determined by the quantity of the deliverable goods, but the the relief parameters were also important in the choice of the gauges.

The Diósgyőr - Pereces - Lyukóbánya 1000 mm wide railroad had the largest performance and the largest traffic [7], and this railway moved in the valley with the smallest elevation. It was necessary to build some structures, like the country's longest railway tunnel [8] on this line, which raised the costs. Due to these conditions, the railway lines of the Bükk Mountain range were built with narrow gauge.

Although these lines were perfectly suitable for the exploitation of the resources of the Bükk, nearly all of them were closed. The closures started at the 1960-70's, when the socialist government opted for the development of the road transport and the public roads, as a major goal. Due to this politics the Hungarian narrow gauge railways one after the other were abandoned [9-10].

C. Relief parameters and gauge

For the analysis of the relationship between the gauge and the topographic features we made field examinations, and we analysed the 10 metre resolution digital elevation model of the Bükk. We defined the most important parameters of the surface directly around to the rails with the help of the DEM: altitude above sea level, slope angle, relief energy by hectare and square kilometre, slope shape (curvature).

A close relationship can be seen between the gauges of the railways and the average altitude of their surroundings: the gauge is in inverse proportion to the altitude (1. table). Among the examined lines the railroad of the Nagy-fennsík with a smallest gauge (600 mm) runs on the highest average altitude (864 m), while the line with the widest gauge (1435 mm) is situated on the lowest part of the mountain(166 m) (1. table). Of course this widest railway also climbes up to relatively higher (~390 m) sections, but the length of these sections compared to the total length of the line is insignificant. It's remunerative to build more expensive constructions, like tunnels and ~10 m depth railway cuttings on these short sections to drive through the wide gauge lines. These objects are not part of the the digital elevation model, therefore in the area of these constructions the altitude of the DEM's surface is higher than the elevation of the railway. The deflections on the examined area are some 10 metres: at the tunnel nearby Szarvaskő 42 meters, and at the Nekézseny railway cutting 20 meters.

Table 1: Some relevant data of the examined railways in the Bükk area

Railway	gauge (mm)	lenght (km)	average elevation (m)	Lowest elevation (m)
Nagyvasút	1435	246	166	95
Pereces	1000	19	197	158
Lillafüred	760	18	267	170
Mahóca	760	18,2	316	216
Szilvásvárad	760	7,7	448	359
Felsőtárkány	760	13,3	246	185
Sikló	760	0,7	716	606
Fennsík	600	7,7	864	804
Nagyvisnyó	600	7,3	372	274

Similar relationship can be observed between the lowest altitude of the railway lines above sea level and the gauge: when the lowest section of the line is high, it was built with a narrower gauge (1. table). The reason of this is, that it was possible to build the narrower gauge lines a with a smaller material costs (easier rails, smaller ties, easier engine), therefore it was cheaper to transport the stocks onto the site. It's important, that these railways are in a foresty mountain range, which is situated far from the major traffic roads of the neighbourhood areas.

Examining the slope angles of the surface close to the raillines, it is verifiable that in the surroundings of the 600 -760 mm gauges the average gradient of the slopes is higher, than in the area of the 1000 - 1435 mm railroads (2. table). Examining the maximums of the slope gradients astonishingly large values can be seen. The reason of this is that the Bükk is characterized by gorge-like valleys with steep slopes, and generally narrow, waterlogged, occasionally inundated valley bottoms. Therefore the lines running along these valley bottoms often lead in the valley sides. As the earthworks, comprising the creation of the railway cuttings are exceptionally energy and cost efforts were made to build as narrow railway lines as possible and still sufficient.

The rate of relief energy (relative relief) indicates the dissection of the surface. Just as well in the case of the slope angle, the examination of the relief energy indicates, that the average value of the relative relief in case of the railroads with a smaller gauge is lower, than in case of the bigger gauge tracks (2. table). That means that on more dissected terrain tracks with narrower gauge were built. This is true in the case of the line on the Nagy-fennsík, where the average slope of the surface is small, but on the other hand, because of the proximity of the plateau edge the morphology of the plateau is relatively dissected.

The slopes are characterized not only by their steepness, but their shape as well. Concave, straight and convex slope sections can be distinguished upon their curvature. Using an elevation model the curvature value with a grade direction, with a strike-direction and both directions can be defined. Along the narrowest lines of the area, at Lillafüred and Nagyvisnyó the high average curvature value indicates, that these railroads were established often on convex slopes (2. table). So another relationship can be presupposed between the shape of the slopes and the gauge of the railway lines running on them. The high slope angles, the high relief energies and the convex valley sides indicate, that in the rising mountain range the incised valleys, valley sections are the most typical ones.

Table 2: Some relevant data of the examined railways in the Bükk area

Railway	Average slope of the surroundings (°)	Average relief (m/km^2)	Average relief (m/ha)	Average curvature
Nagyvasút	3,2	47,5	6,4	0,05
Pereces	6,1	88,3	12,1	0,11
Lillafüred	12,6	186,8	26,4	0,27
Mahóca	11,8	162,3	23,3	0,02
Szilvásvárad	20,4	247	38,1	0,14
Felsőtárkány	6,3	122,8	14,6	0,28
Sikló	22,6	345,2	41,1	0,24
Fennsík	15,4	153,6	30,6	0,03
Nagyvisnyó	9,2	179	21,6	0,51

4. Conclusion

In our examinations we found a strong relationship between the railway gauges and the major parameters of the surface: the altitude above sea level, the slope angle, dissection of surface (relief energy), and slope shape.

In the valleys with narrow, deep, valley bottom, where it is often necessary to build the track in convex valley sides, the narrow gauge railway lines are typical, just as well, on the plain characterized Nagy-fennsík, where the narrow gauge railroad could be built at a lower price because of the high average altitude.

The aim is the minimisation of the expenses in both cases. In the case of the valleys with the reduction of the earthworks, and in case of the Nagy-fennsík with the reduction of the quantity of stocks and transportation expenses.

The researches made by using a digital elevation model led to results in harmony with the examinations on the field. It's verifiable, that with a suitable resolution and accuracy, digital elevation models can be applied well in these researches. All these bring up the opportunity of the researches made by this model being applicable with a suitable result on other similar areas as well.

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