Contract Prices for Road Construction as a Func-tion of Landform

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Abstract

In the context of the terrain conditionings, the volatility of unit prices of road construction in Europe and Poland was analyzed. On the basis of the price volatility index of twelve contracts concluded in 2016 by the Directorate of National Roads and Motorways (DDKiA), there was little variation in the average construction prices of 1 km of technical class S expressways on flat and undulating terrain, over a large area of Poland, above Wrocław and Lublin towards the north. However, also for the expressway, but in mountainous terrain in Małopolska, between Lubień and Chabówka, on three sections of S7, together with a length of 15.8 km, the coefficient of variation in unit prices was very large (5.7 times greater than in the flat and corrugated areas mentioned above). Among the reasons for this high price volatility, it was pointed out that it was necessary to adapt to difficult mountain conditions - through the use of specialized technical solutions, costly in implementation and other on almost every of these sections. Necessary were, among others over a 2-kilometer tunnel (many times more expensive than the other sections of the route), intensive reinforcement of escarpments with ground nails (with a total length of over 350 km) and foundation of embankments on gravel columns, as well as construction of numerous flyovers, viaducts and bridges with a total length of 5,752 km. Attention was also paid to the necessity of taking into account the proportion of the tunnel's length to the length of the remaining road section, as this is a condition of correct expenditure analysis.

Keywords: express roads, landform, road costs

Components of road construction costs

Roads besides absorbing a wide strip of land, even several dozen meters, eg under the motorway, contribute to pollution by exhaust fumes and noise of space within a radius of up to several kilometers. In addition, the area is artificially separated into separate parts. There is a need to move habitats and build passages for animals and other pro-environmental objects. As a result, according to [2] the value of elements of environmental protection, it constitutes about 18%, and sometimes it reaches even 35% of motorway construction costs, Figure 1.

The costs of population resettlement and land purchase account for about 15%, and in urban areas they can reach up to 30% of the total investment value (eg in the construction of M74 in Glasgow, in 2009). While the design costs range from 3% to 5%, currently expert opinions and consultancy usually amount to about 7%, and sometimes they reach 15% of the investment value. The construction itself usually costs about ¼ of the motorway value, while the administrative costs of such projects amount to around 30%.

Implementation conditions

Routes of roads depend on the conditions resulting from international agreements and performed functions in the general road network, as well as must be compliant with spatial development plans. However, the road design itself should meet the requirements of applicable law [4] and technical standards [3].

Roads, in particular, fulfill the basic requirements in terms of: safety of use, load-bearing capacity and stability, fire safety and other local hazards, environmental protection and protection against excessive noise, vibrations, air, water and soil pollution and provide conditions for using the road in accordance with its intended purpose, also by people with disabilities [3]. The route of the road should be properly inscribed in the surrounding area, with the most convenient crossing of obstacles, i.e. existing rivers and habitats and the existing development, as well as meet the conditions related to its maintenance and economics of the solution.

Among these many conditions, as a result, the road as an engineering object must be built in the existing terrain. Depending on the natural shape of the surface and the local conditions of foundation, the size of embankments and excavations, the need to reinforce slopes, the construction of bridges and viaducts and possibly the construction of tunnels are directly dependent. Naturally, the scope of these construction works directly affect the construction costs of individual roads.

Variability of road construction costs in europe

Analyzing, the costs of road construction in Europe, according to [16], Figure 2, in 1998 the lowest expenditures for completing the 1st kilometer of the motorway were in Spain. In flat and corrugated areas, they amounted to 1.9 million €, with a double the average cost of constructing motorways across the country of 3.8 million €. Much greater price differentiation was in Italy. In wavy areas, the lowest cost amounted to 7.5 million € for 1 km, and the average for the whole, including roads in the mountains and the need to build tunnels was 25 million €, ie 3.3 times higher. At the same time, in Switzerland, the cheapest section, at more affordable execution conditions, cost EUR 12.5 million per km. The cost was 5.4 times lower than the average price of motorways amounting to 67.5 million €. In Switzerland, due to extremely

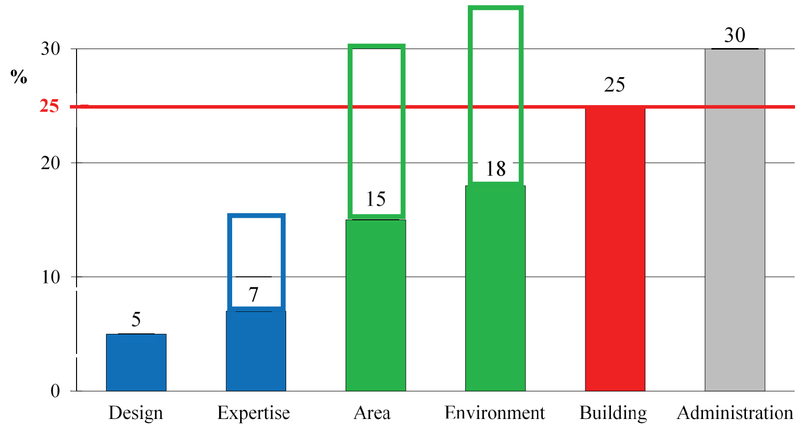

Fig. 1. Average share of components in the motorway construction costs [own elaboration based on 2]
Rys. 1. Średni udział składowych w kosztach budowy autostrad [opracowanie własne na podstawie 2]

complicated, high-altitude terrain conditions, it is necessary to drive roads in numerous, even multi-kilometer-long tunnels (eg in 2017, the network of road tunnels in Switzerland was the largest in Europe and was 421 kilometers long).

Therefore, even this brief comparison allows to notice that in difficult mountainous conditions the costs of road construction are even many times higher than in flat and undulating terrains.

Analyzed contracts for construction of roads in Poland

The total length of public roads in Poland in 2016 was about 420,000 km and there were over 35,000 bridge structures and tunnels with a total length of over 1,05 thousand km. According to plans (2016), the length of motorways in Poland, in 2020 will be about 7,800 km, including 2,000 km of highways and 5,800 km of expressways. There are currently 1991 km of highways and 5,813 km of expressways [9]. The progress of road construction on 13/04/2019, according to the data of the Directorate of National Roads and Motorways (DDKiA) [13], is shown in Figure 3.

The analysis covered 15 contracts for the construction of S-class express routes in Poland, which concluded DDKiA [13] in the first half of 2016. To assess the differences in road construction costs, the volatility coefficients of V were examined below.

Coefficient of variation

The assessment of the variation in the distribution of the examined feature, in this case the unitary costs of constructing S-class roads, can easily be carried out using the classic measure, ie the coefficient of variation. The coefficient of variation V, as a relative measure, is determined by the dependence:

$$V = s / x, x \neq 0, \quad (1)$$

where:
s – standard deviation from the sample,
x – the arithmetic mean of the sample.

According to Wawrzynek [7], if the value of the variation coefficient V expressed in% is in the range <0%, 20%> then the diversity of the population is small. At the V values belonging to the next interval (20%, 40%> is said about the average population differentiation, and the large variation is at the rate in the range (40%, 60%> and very large at V> 60%.

Contractual prices for technical class s roads

The surveyed contract prices of 15 contracts, which the Directorate of National Roads and Motorways [13] concluded in 2016 for the construction of S-class express routes (with two separate, two-lane roadways, load capacity 115 kN/axle, with emergency lanes, with viaducts and footbridges), passenger service areas, culverts and animal passes) are summarized in Table 1. One should notice a very large spread of average values of unit prices, from 14.27 million PLN to 322.93 million PLN for 1 km of the route.

The average price for all 15 analyzed contracts was x15 = 51.05 million PLN/km, and the standard deviation s15 = 75.91. Hence, the value of the coefficient of variation V15 = 149% was much higher than 60% - this means that the price differentiation was very large.

However, when analyzing 12 contracts for the construction of S-class roads in flat and wavy areas, i.e. in Poland, above Wrocław and Lublin towards to the north, the average cost of these routes was x12 = 22.8 million PLN/km, with the standard deviation s12 = 3.4, Figure 4. Due to the coefficient of variation V12 = 14.8%, smaller than 20%, as above it can be assumed that the price differential between these contracts was small.

Prices for the construction of S7 sections road in mountainous terrain

In Małopolska, on the fragment of the S7 Kraków-Zakopane route between Lubień and Chabówka, 15.8 km long, Table 2, in difficult mountain terrain, with indispensable reinforcement of embankment and excavation slopes with retaining walls and anchors, and with the need to build many long overpasses, as well as a two-chamber tunnel, the execution of works is much more expensive than in the roads of the S class, but in flat areas.

For example, section I, 7.6 km long, Lubień - Naprawa will be built, on average, 68.6 million PLN/km, Figure 5. The most difficult, approximately 3-kilometer stretch II road, the Naprawa-Skomielna Biała will be completed at 322.9 million PLN/km, Figure 6. Episode III of this route, 5.2 km long,

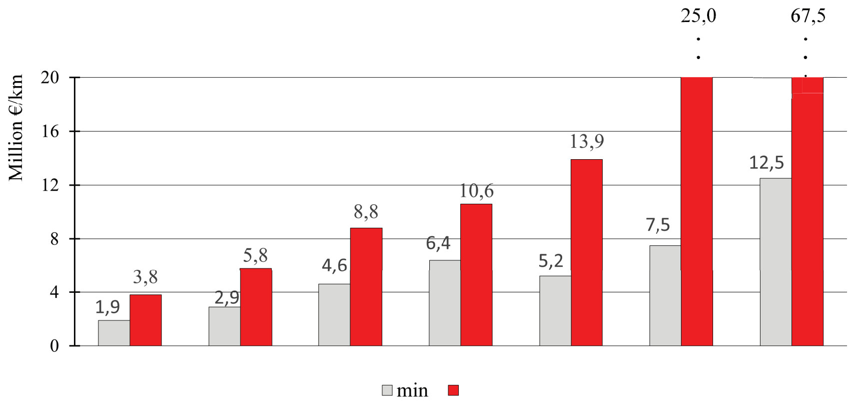

Fig. 2. Volatility of unit costs of motorway construction in selected European countries, in 1998 [own elaboration based on 16]
Rys. 2. Zmienność jednostkowych kosztów budowy autostrad w wybranych krajach Europy, w 1998 r. [opracowanie własne na podstawie 16]

Fig. 3. Road construction progress in Poland, 04/2019; roads are marked with colors:
green – existing, red – under construction, gray – planned [source: 9]

Rys. 3. Postęp budowy dróg w Polsce, 04/2019; drogi są oznaczone kolorami:
zielonym – istniejące, czerwonym – w budowie, szarym – planowane [źródło: 9]

Tab. 1. S-class expressway sections, for which in the first half of 2016, the Directorate for National Roads and Motorways concluded contracts for performance [own development based on 13]
Tab. 1. Odcinki dróg ekspresowych klasy S, dla których w pierwszej połowie 2016 r. Dyrekcja Dróg Krajowych i Autostrad zawarła umowy na wykonanie [opracowanie własne na podstawie 13]

Section of the road	Road	Length km	Price million PLN	Average million PLN/km
Radziejowice - Paszków	S8	21,5	306,9	14,27
Kościan Południe – Radomicko	S5	16	303,0	18,94
Wronczyn - Kościan	S5	19	360,0	18,95
Kołbiela - Garwolin	S17	13	290,0	22,31
Radomicko - Leszno	S5	19	440,0	23,16
Poznań – Wrocław	S5	19	443,0	23,32
Lubelska - Kołbiela	S17	15,2	370,5	24,38
Leszno - Kaczkowa	S5	9,5	232,6	24,48
Wyszków - Białystok	S8	16	404,5	25,28
Wyszków – Poręba	S8	13	334,7	25,75
Lubelska - Kołbiela cd.	S17	8,7	225,5	25,92
Ostrowia M. – prov. border podlaskie	S8	9,4	250,0	26,60
Lubień - Naprawa	S7	7,6	521,4	68,60
Naprawa – Skomielna Biała	S7	3	968,8	322,93
Skomielna Biała – Rabka Zdrój	S7	6,1	615,0	100,82

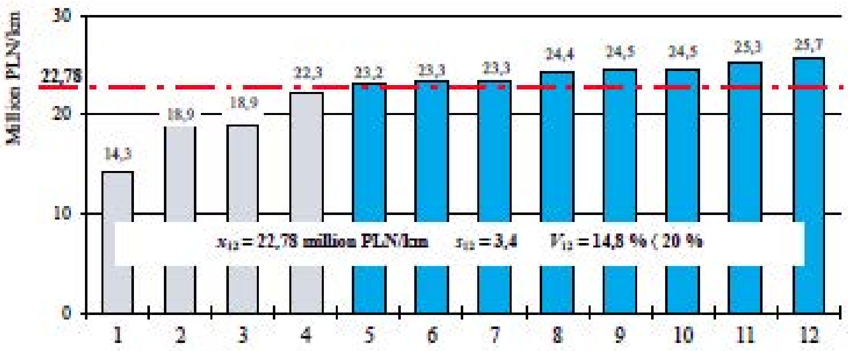

Fig. 4. Unit prices for S-class road construction contracts in Poland, on flat and undulating areas, contained in the first half of 2016 [own elaboration, based on 13]

Rys. 4. Ceny jednostkowe kontraktów na budowę dróg klasy technicznej S w Polsce, na terenach płaskich i falistych, zawarte w pierwszej połowie 2016 r. [opracowanie własne, na podstawie 13]

Skomielna Biała - Chabówka together with the GP dk47 route Rabka Zdrój - Chabówka length of 0.9 km will be on average, after 100.8 million PLN/km, Figure 7. The average price of these sections of the S7 road was x3 = 164.1 million PLN/km, and the standard deviation s3 = 3 4, Figure 8. Thus, the coefficient of price variation for these road sections was V3 = 84.4% and was significantly higher than 60%, which means that the volatility of contract values is very large, Figure 8, [7, 8].

The main reasons for these large unit price divergences were the different technical solutions necessary to apply in individual local conditions of each of these sections. These implementation restrictions can be divided into three groups:

- great diversity of the landform,
- variability of foundation conditions,
- uneven intensity of occurrence of accompanying road facilities.

Variables landform of the mountain terrain, among others caused the necessity of building a two-chamber tunnel under the Luboń Mały mountain, 2,06 km long, with a unit cost of about 3.8 times higher than the rest of the road Naprawa - Skomielna Biała [9]. At the same time, the tunnel was not implemented either on the first episode of Lubień-Naprawa or on the third Skomielna - Chabówka. Also, the landform has required the construction of numerous flyovers constituting 24%, 33% and more than 40% of the lengths of sections I, II and III, respectively. The construction of 12 bridge structures and 6 small ones with a total length of 2045 m is planned for section 1. On the second section (as above, beyond the tunnel) there was one viaduct with a length of 311 m, and on the third section of 17 viaducts and flyovers, and 4 small bridges with a total length of 3396 m (including ~ 2.3 km of the road on the viaducts, the largest 999 m long, with a 140 m span and the height of the support with load bearing structure 49.4 m and 4 smaller for the road link with lengths of 356.00 m to 446.00 m).

In addition to the varied terrain, there was a large variability of foundation conditions resulting from the various properties of the Carpathian flysch. For example, in section I, there was strong reinforcement of slopes using the total, up more than 350 km ground nails, while in the third section there was a need to make embankments on gravel columns closed with a aggregate mattress, [6].

In addition, the uneven intensity of occurrence of associated road objects on individual parts of the route was the result of both the location of such facilities and the route of roads in the existing communication network, as well as the very diversified mountain terrain and relatively smalls lengths of the analyzed routes. As a result, road junctions were located only on the Skomielna - Chabówka section. The first one in Skomielna Biała for the connection of roads S7 and dk28 (for the direction Wadowice - Nowy Sącz) and the second one in Zabornia for the fork S7 on dk47 (towards the direction of Chyżne and Zakopane). Also in this episode was the most favorable location of the express road maintenance base. Similar objects did not appear on sections I and II. In addition, the construction of passenger service areas (ILO) was unevenly planned: two in the I section in Lubień and Krzeczów and one in Zbójecka Góra on the III section (there was no ILO at the second section).

Commentary on the costs of road construction with tunnels

Unit costs for the construction of a section of road in the tunnel are usually many times greater than the construction of road sections in the open area, [1]. In the case of such relatively difficult to compare road construction costs of various sizes of tunnel sections, attention should be paid to the proportions of p - length of tunnels in relation to the entire analyzed routes. When checking the average construction costs of roads with different proportions p, calculations can be made in accordance with the proposed relationship:

$$k_p = k_t\, p + k_d\,(1\text{-}p)$$

where:

k_p – average cost of 1 km of the route for the assumed proportions p, million PLN/km (million €/km),

p – the value a proportions of the tunnel's length – l_t km, relative to the length of the analyzed road section – l_d km, $p = l_t / l_d$,

k_t , k_d – construction costs of 1 km, respectively, of the tunnel and the remaining part of the section of the road outside the tunnel, million PLN/km (million €/km).

Tab. 2. Characteristics of the S7 expressway on the Lubień-Chabówka section [own elaboration, based on 13]
Tab. 2. Charakterystyka drogi ekspresowej S7 na odcinku Lubień – Chabówka [opracowanie własne, na podstawie 13]

	Expressway S7, section Lubień - Chabówka, length 15.830 km, value of contracts PLN 2105 million		
Sections	I. Lubień - Naprawa	II. Naprawa – Skomielna Biała	III. Skomielna Biała – Chabówka (Rabka Zdrój– Chabówka)
Contractors	IDS-BUD S.A. ul. Grzybowska 87, 00-844 Warsaw ALTIS-HOLDING Corporation, ul. Kaczałowa 5w, 03146 Kiev, Ukraine	**Astaldi S.p.A. Via Giulio Vincenzo Bona 65, 00156** Rome, Italy	Salini Impregilo S.p.A. Via dei Missaglia 97, 20142 Milan, Italy
Contract dates	29.06.2016 r.	29.02.2016 r.	31.03.2016 r.
Cycles, months	22	54	22
Lengths, km	7,59	3,05 (including the tunnel)	5,19 (and 0.877 km GP dk47)
Gross values, PLN	521 519 095,35	**968 835 650, 11**	615 068 976,27
Tunnel, km	-	• 2,058 (near the Luboń Mały mountain)	-
Road junctions and facilities	-	-	• Skomielna Biała S7-dk28 (directions: Wadowice i Nowy Sącz, • Zabornia S7-dk47(directions: Nowy Targ i Chyżne) • Place of service for travelers
Place of service for travelers	• Lubień, • Krzeczów	-	• Zbójecka Góra
Viaducts and flyovers	• 24% of the road length, • total length 2045 m, • 12 objects and 6 small ones	• 33% of the length of the road (outside the tunnel) • length 311 m, • 1 object (box construction, traditional method, stationary scaffolding)	• 40.3% of the road length, • total length of 3396 m (~ 2.3 km of road on overpasses) • 17 objects and 4 small ones (reinforced concrete, beam and box construction, one and two-chamber, compressed, largest: 999 m long, including 140 m span, height of the support together with the supporting structure 49.4 m; 4 smaller for ramps, lengths 356.00 m to 446.00
Placing	• large diameter foundation piles	• large diameter foundation piles	• large diameter foundation piles, caissons, gravel columns with a mattress of broken aggregate, directly with the exchange of ground

For example, in Slovenia (where, according to [17] in 2012, the average cost of building motorways amounted to 7.3 million €/km and was 22% lower than the average price in Europe) implementation of the route with length l_{dS} = 4.5 km, with the długości l_{dS} = 1.5 km tunnel it amounted to 59 million €/km, i.e. it was 6.3 times higher than the European average and at the same time 8-times higher than the average motorway cost in this country.

The section of the S7 expressway - Skomielna Biała (dual carriageway with a two-chamber tunnel, [1, 14]) length l_{dP} = 3.05 km, with a tunnel l_{tP} = 2.057 km, according to the tender result will cost an average of 79.4 million €/km (34.6% more expensive than the average section of the route with a tunnel in Slovenia).

After considering the same proportion of tunnel length to the remaining road section pS = 0.3333, as on the road route

Fig. 5. The viaduct on the I section Lubień-Naprawa (402 m long) [source: 10]
Rys. 5. Wiadukt na odcinku I Lubień-Naprawa (402 m długości) [źródło: 10]

Fig. 5. Loading and transportation of excavated material from the tunnel [surce: 11]
Rys. 5. Załadunek i wywóz urobku z tunelu [źródło: 11]

Fig. 6. A fragment of the longest flyover on the Skomielna Biała–Chabówka section III (992 m long; largest: span the span 140 m, height of the support together with the supporting structure 49.4 m) [source: 12]
Rys. 6. Fragment najdłuższego wiaduktu na III odcinku Skomielna Biała – Chabówka (992 m długości; największe: rozpiętość przęsła 140 m, wysokość podpory wraz z konstrukcją nośną 49,4 m) [źródło: 12]

in Slovenia and with S7 costs on average, k_{tP} = 104.5 million €/km tunnel and k_{dP} = 27.5 million €/km for the remaining section of the road, calculated in accordance with the relation (2), the average cost of 1 km of this route S7 would be k_{pP} = 53.1 million €/km, ie it is 9.9% less than at the motorway in Slovenia, figure 3.

In the case of a 4.7 km section of the S69 Szare-Laliki road (single-station, with a one-chamber tunnel, [5, 15]), the construction cost was on average € 20.9 million €/km. After conversion according to the same proportion of tunnel length, to the remaining road section, for pS = 1/3, as in Slovenia, the average cost is k_{pL} = 27.5 million €/km.

Therefore, in order to better reflect the actual high expenditure on tunnels in the unit cost analysis, attention should be paid to the proportions of p – length of tunnels in relation to the entire test sections.

Summation

Road construction interferes very much with the natural environment

A large area of land is taken and divided into separate parts. There is pollution of the surrounding area with fumes and noise. As a result, in Europe the value of environmental protection elements constitutes about 18% (sometimes even 35%) of the construction costs of motorways. Purchase land and resettlement costs account for approximately 15% (in cities, up to 30%). The construction costs are usually around 25% and administrative costs about 30% of the value of highways. Design costs representing about 3% to 5% of the total costs of projects are unfavorably low.

The level of unit costs of road construction remains in direct dependence on the terrain conditions occurring on their routes

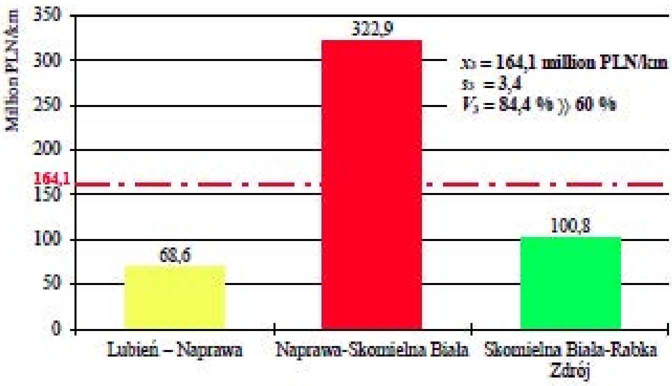

Fig. 7. Unit prices of contracts for the construction of S7 road sections between Lubień and Skomielna Biała [own elaboration, based on 14]
Rys. 7. Ceny jednostkowe kontraktów na budowę odcinków dróg S7 między Lubniem a Skomielną Białą [opracowanie własne, na podstawie 14]

In Europe, for example in 1998, the lowest expenditures for making the one kilometer of highways were in Spain. In the whole country, in large part on flat and undulating terrain, road construction costs amounted to an average of € 3.8 million per 1 km. In Italy, in the majority of wavy areas, the lowest cost was 7.5 million €/km. With the average cost for the whole country, with a higher share of roads in the mountains and the need for tunnels construction was costs were 3.3 times higher and amounted to 25 million € per km. In Switzerland however, the cheapest section cost more than 5.4 times less (in more accessible field conditions) than the average cost of motorways there, which amounted to as much as 67.5 million €/km. There, too, due to the extremely difficult alpine implementation conditions, it was necessary to drive roads on numerous overpasses and in multi-kilometer tunnels.

In Poland, similarly, on the basis of the analysis of contracts for the construction of S-class express routes, which concluded DDKiA [13] in the first half of 2016, it was found that found that, in areas of flat and corrugated have 12 sections of such S-class roads (with two separate, two-lane roadways, with emergency lanes, with viaducts, overpasses and footbridges, passenger service areas, culverts and passageways for animals) in the part of Poland, above Wroclaw and Lublin towards the north, they are they are characterized by low prices and low volatility. They the average price was x_{12} = 22.8 million PLN/km, with the standard deviation s_{12} = 3.4, and the coefficient of variation V_{12} = 14.8%, was less than 20% (which means that the coefficient of variation *V* of these contracts was small).

In Malopolska, the three contracts, for the sections of the S7 Kraków-Zakopane road, between Lubień and Chabówka, 15.8 km long (in difficult mountainous terrain, with the necessary strengthening of slopes with retaining walls and with anchoring and with the need to build many long overpasses, as well as a two-chamber tunnel) the performance of works was 7.2 times more expensive than in the previously analyzed 12 roads, also technical class S, but in flat and corrugated areas. The average price of these three sections of S7 was x_3 = 164.1 million PLN/km, standard deviation s_3 = 3.4, and the coefficient of variation V_3 = 84.4% (it was much larger than 60%, which means that the differentiation of the value of contracts was very big).

The main reasons for these several times higher contract prices were difficult conditions for road construction in mountainous terrain. In particular, large variations in the shape of the surface of the mountain terrain and the variability of foundation conditions (on the Carpathian flysch) and indirectly also related to the landform an uneven intensity of occurrence of road objects almost every time required individual technical solutions and consequently completely differents construction costs.

The landform on the first section of the S7 Repair - Skomielna Biała required the most expensive construction of a two-chamber tunnel with a length of 2.06 km, under the Luboń Mały mountain, with a unit cost of about 3.8 times higher than the rest of the section (one kilometer long, with a 311-meter long overpass). On the other sections, 1st Lubień-Naprawa (7.59 km long) and Skomielna III - Chabówka (5.19 km plus 0.877 km) there were several overpasses and viaducts.They accounted for 24% and over 40%, respectively, in relation to the length of all these sections. On the third section, these objects together were 3,396 km long, including the road on the flyovers – 2.3 km long, In the III section, these objects together were 3,396 km long, with the longest section: of 0.999 km, with a span of 140 m and a total height of 49.4 m).

Variable conditions of the Carpathian flysch were the cause that when performing drill hole on the part of the tunnel there was a need to pre-support the ceiling of ancestor with a steel pipes jacket and strengthen the forehead ancestor using workable anchors, made of fiberglass rods. On the first section of the road, there was a need to strong reinforcement of slopes where was using together, up more than 350 km ground nails, while in the third section there was a need to make embankments on gravel columns closed with aggregate mattress.

An uneven intensity of occurrence of accompanying road facilities on particular parts of the route resulted from both the principles of the location of such facilities and the course of existing roads, as well as from the very diversified terrain. Therefore, it was necessary to build two road interchanges in Skomielna Biała and Zabornia.

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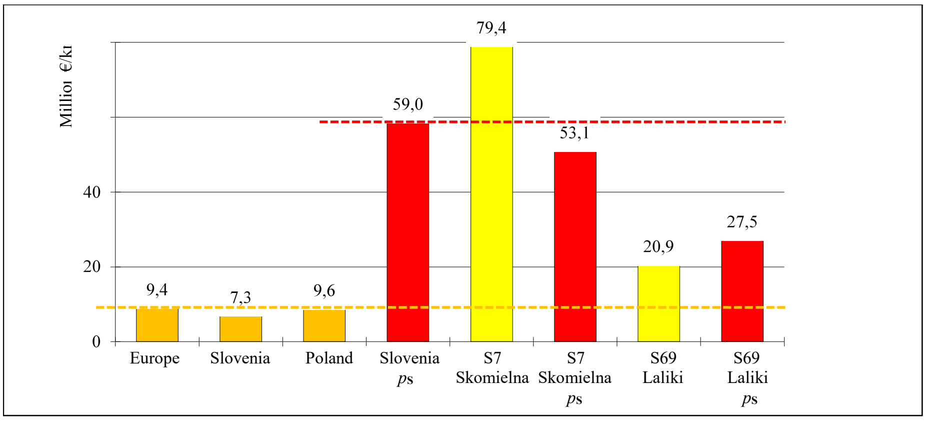

Fig. 3. Unit average costs of the analyzed roads and after considering the proportion pS = 1:3 (of the tunnel's length in relation to the total length of the road section) [own elaboration]

Rys. 3. Średnie jednostkowe koszty analizowanych dróg oraz po uwzględnieniu proporcji pS = 1:3 (długości tunelu w stosunku do całkowitej długości odcinka drogi) [opracowanie własne]

of existing roads, as well as from the very diversified terrain. Therefore, it was necessary to build two road interchanges in Skomielna Biała and Zabornia and the of the express road maintenance base in the III section as well as constructions of passenger service areas (ILO): two in the I section in Lubień and Krzeczów and one in Zbójecka Góra on the III section.

Unit costs of roads with tunnels, due to the many times higher expenditure on tunnels, than the other sections of routes should take into account the proportions p of their mutual lengths. For example, the average cost of building motorways in Slovenia amounted to 7.3 million €/km, 22% lower than the European average, while a 4.5 km section of the route with 1.5 km tunnel cost 59 million €/km, i.e. it was 8 times more expensive. At the same time, the section of the S7 Naprawa - Skomielna Biała express road, 3.05 km long with a 2.057 km tunnel, will cost an average of 79.4 million €/km according to the result of the tender. However, when comparing unit costs, in order to express the actual expenditures for execution of works, the same proportion of *p* - lengths of tunnels to the analyzed road sections should be taken into account. Then, after taking into account considering the same proportion of p = 0.33 (the length of the tunnel to the length of the route, as in Slovenia), the unit price of this section of the S7 is much lower, being lower by 9.9% than in Slovenia and amounts to 53.1 million €/km.

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Ceny kontraktowe na budowę dróg jako funkcja ukształtowania terenu

W kontekście uwarunkowań ukształtowania terenu przeanalizowano zmienność cen jednostkowych budowy dróg w Europie i w Polsce. Na podstawie badań wartości współczynnika zmienności cen dwunastu kontraktów zawartych w 2016 roku przez Dyrekcję Dróg Krajowych i Autostrad (DDKiA) stwierdzono małe zróżnicowanie jednostkowych wartości budów dróg ekspresowych klasy technicznej S na terenach płaskich i falistych, na dużym obszarze Polski, powyżej Wrocławia i Lublina w kierunku północy. Natomiast, również dla drogi ekspresowej, lecz w terenie górzystym w Małopolsce, między Lubniem i Chabówką, na trzech odcinkach S7, razem długości 15,8 km, współczynnik zmienności cen jednostkowych był bardzo duży (5,7 razy większy, niż jw. na terenach płaskich i falistych). Pośród przyczyn tej dużej zmienności cen wskazano konieczność dostosowania do trudnych warunków górskich – specjalistycznych rozwiązań technicznych, kosztownych w realizacji, odmiennych na każdym z tych odcinków. Niezbędne były, m.in. ponad 2-kilometrowy tunel (wielokrotnie droższy od pozostałych odcinków trasy), intensywne wzmocnienia skarp gwoździami gruntowymi (o łącznej długości ponad 350 km) lub posadowienia nasypów na kolumnach żwirowych, jak też budowy licznych estakad, wiaduktów i mostów o sumarycznej długości 5,752 km. Zwrócono również uwagę na konieczność uwzględniania proporcji długości tunelu do długości pozostałego odcinka drogi, bowiem jest to warunek prawidłowej analizy nakładów.

Słowa kluczowe: drogi ekspresowe, ukształtowanie terenu, koszty dróg