WARSAW UNIVERSITY OF TECHNOLOGY Index 351733
FACULTY OF CIVIL ENGINEERING
COMMITTEE FOR CIVIL AND WATER ENGINEERING
POLISH ACADEMY OF SCIENCES ISSN 1230-2945

DOI: 10.24425/ace.2025.156171

ARCHIVES OF CIVIL ENGINEERING

Vol. LXXI ISSUE 4 2025

pp. 299 – 313

Research paper

Contractor's risk premium in design & build construction contracts

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Abstract: The article is based on data about 349 orders for road construction in Poland. The unit prices (per one kilometer of roads) are compared, arising from the following two types of orders: design-bid-build (DBB) and design & build (D&B). As the exact list of construction works, as well as, the precise number of works is unknown before the contract is signed, the contractor's risk is higher. The probability of underpricing the offer in the case of D&B orders is higher than that of DBB orders. It is assumed that the contractors, to avoid the potential loss (if the offer is underpriced), raise the value of their offers more than in the case of DBB types of orders. This increase in offer price is usually named risk premium. The averaged unit prices of the roads of the same kind ordered as DBB are compared to D&B orders. To find the risk premium, to the values of DBB orders, the prices of the designs are added. This made the scope of the DBB and D&B orders the same i.e. able to compare. It is discovered that the average unit prices for DBB orders are higher than for D&B orders for four groups of orders, so the risk premium can't be calculated there. For the other two groups of orders, the risk premium is 19% and 49% of the total value of the DBB order i.e. value of the design plus the value of construction works ordered.

Keywords: design & build, offer price, public procurements, risk, road construction

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1. Introduction

Risk is an inherent part of a business activity of any kind. It also refers to the construction projects. Risk arises from the uncertainty of achieving the assumed goals. It can be defined as a probability of unfavorable conditions (i.e. materialization of risk factors) leading to disturbances in a construction project and then not achieving the assumed goals of a project [1]. The contractors, as well as, the clients like to lower the risk of every project to make the success of it more probable. The importance of managing the risk is so high that it became a separate section [2] of project management [3]. In the traditional method, the risk factors are identified and two-dimensionally assessed, by the probability of their occurrence and by the level of harmfulness to the project. This process is called qualitative risk assessment. Then, from hundreds of risk factors able to disturb a project, the decision maker chose several of them to verify e.g. with the Monte Carlo method, which combination of risk factors, if they occur, can make the highest damages in the assumed schedule and cost of the project [4]. This phase of risk analysis is named quantitative risk analysis. It was found that the lean management can be applied to risk analysis to make risk management simpler but almost equally successful [5], as well as, other modern methods, like in [7, 8]. The next decision of the project manager referred to each risk factor can be chosen from the following types of decisions:

- risk elimination,
- risk reduction,
- risk transferring,
- acceptance of risk,
- insurance.

Regardless the choice of risk limitation way, risk limitation requires additional cost to spend. In the case of acceptance of risk, not the planned cost arises, but the real cost recorded after completing the project can be much higher than the planned one. Considering the necessity of achieving the profit [6], a contractor has to provide a certain amount of money for their reaction to the identified risk associated with the contract to be executed. This amount is reflected in a bid price. In case of risk acceptance, the contractor if possible provides a reserve for unexpected events that may take place during the contract execution (as it was presented in [9]). The value of this reserve is also reflected in the bid price. Regardless of type the type of contractor's reaction to risk, it can be stated that the higher the risk, the higher the share of the reserve for risk in a bid price. The reserve for risk is understood as a sum of expenditures spent on risk lowering, insurance, and the reserve for covering the unexpected cost that may appear during the project execution (arising from risk acceptance). Considering also the elements of the contractor's cost [6, 10], the elements creating the contract sum i.e. contractor's bid price are presented in Fig. 1.

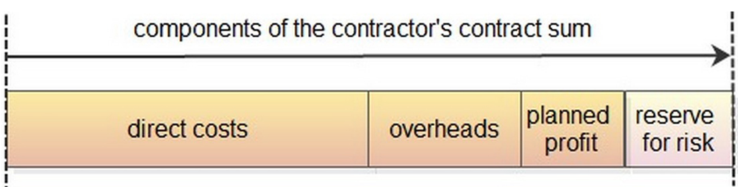

Fig. 1. The elements creating the contractor's bid price

The risk factors may concern the three critical areas of the project: time, budget (cost), and the project's scope. These elements are interdependent and they are also called project limits [11] as presented in Fig. 2.

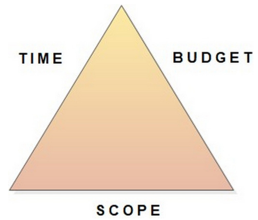

Fig. 2. The triangle of project limits [11]

A single risk factor usually affects two or three of these limits, even if it arises mainly from one of these three areas. For example, delays in the delivery of materials arises from time area, but it influences budget and time sides of the triangle [12]. Variation and change orders (arise from the scope of the project) affect the scope, time, and budget sides of the triangle [13,14]. Let's analyse the triangle of limits and risk issues regarding project delivery types. International Federation of Consulting Engineers (FIDIC fr. Fédération Internationale des Inginieurs-Conseils) [15] publishes standard forms of contracts for several types of project delivery. They distinguish among other types e.g. [16–18]) construction contract (so-called the red book) where a contractor executes construction works based on the design provided by a client, and Plant and Design-Build Contract (so-called the yellow book), where preparing a design and the construction works execution are subject of a single order. The construction contracts based on the red book are often named Design-Bid-Build (DBB), and based on the yellow book are named Design-and-Build (D&B) orders. The scopes of these two types of project deliveries are presented in Fig. 3.

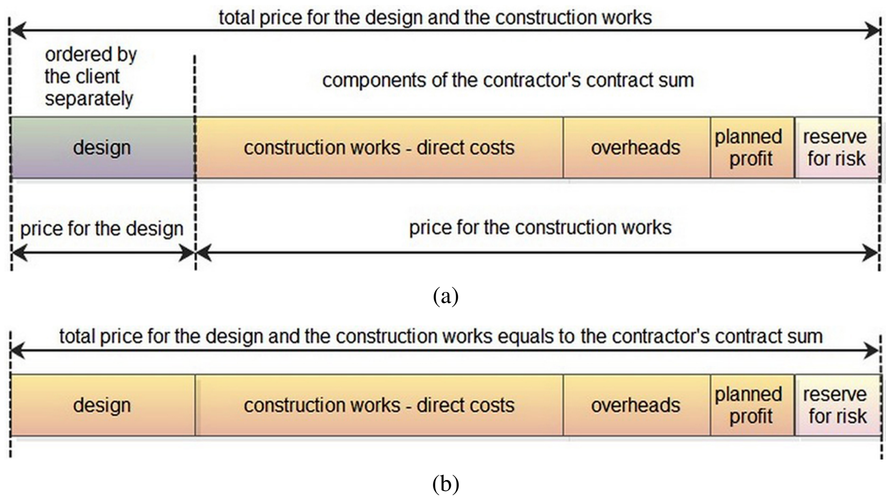

Fig. 3. The scope of the contract with its cost components: (a) for DBB order, (b) for D&B order

The differences between these two types of orders, and their advantages are widely discussed [18–20]. However, it is clear that for the D&B orders, there are more risk factors than in DBB orders [21] as the detailed scope of the project is uncertain – the design is the subject of a contract. It leads to the conclusion that the reserve for the risk assumed by the contractor should be higher than in the case of a DBB type of order. In trying to find the average difference in the reserve for risk between DBB and D&B orders, several orders have to be compared. The purpose of the study is to assess the risk premium for D&B orders.

2. Contractor's risk premium

2.1. The set of analysed orders

The dataset of the road construction orders prepared for the purpose of [22] served as a base. It is extended by the information concerning the value of the design (in the case of DBB order) and it is published in [23]. Each of the 349 orders is described there by:

- type of works: construction of a new road, or modernization of an existing one,
- type of road: highway, express road, national road (excl. express roads), voivodeship road, county road,
- location of the road by voivodeship (adm. region of Poland),
- type of order: D&B or DBB,
- price for design in PLN (only for DBB orders),
- price for works execution in PLN (only for DBB orders),
- total price in PLN,
- length of the section of the road in km,
- total price per 1 km.

The dates of these orders are Jul 1, 2014 to June 30, 2017.

2.2. Expected risk premium

Let's assume that a given contractor is asked to give the bid price for the same section of the road in two variants: excluding the design (DBB) and including preparation of the design (D&B). Assuming also that the contractor accepting (D&B) order would pay the same for the design as the client (in the DBB order) the risk premium could be presented as in Fig. 4.

As the D&B contract is more risky, the reserve for risk is expected higher than in DBB. With the other elements (presented in Fig. 4) unchanged, the risk premium can be defined as the difference between the value of the D&B order and the DBB order. Nevertheless, only one type of order can be chosen for the procedure of ordering a single section of the road (to build or to modernize). It was decided to compare the mean values of the unit prices (i.e. per 1 km of the road) for the very similar roads. The similarity of the roads in a single set is provided by the existence of the same type of works (e.g. only modernized), the same type of road (e.g. only express roads), and the same voivodeship of the location. The only difference between the two sets of compared unit prices is the type of order. For D&B orders the unit price is calculated

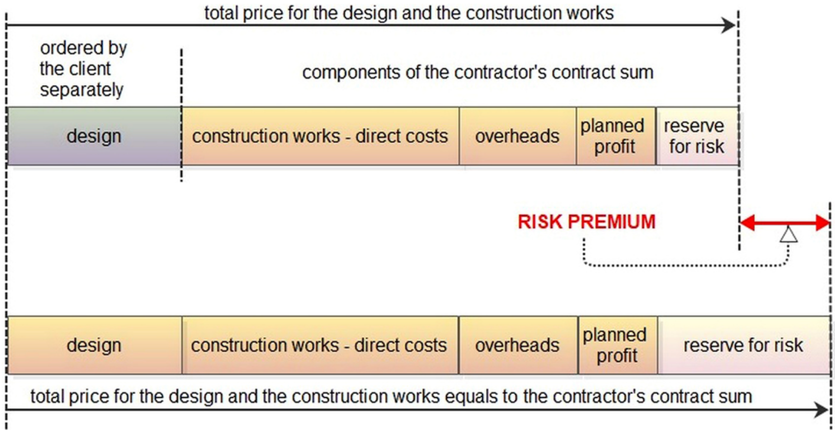

Fig. 4. The increase of the reserve for risk creates the risk premium

based on the value of order divided by the length of the section of the road. In DBB orders, the price for the design (paid by the client) and the contractor's contract value are summed and then divided by the length of the section of the road to achieve the unit price. For the selected two groups of contracts that differ only in the type order the average relative risk premium $\overline{r}$ can be calculated as follows:

$$\overline{r} = \frac{\overline{db} - \overline{b}}{\overline{b}} \cdot b100\% \tag{2.1}$$

where: $\overline{db}$ is the average unit price calculated for D&B orders, $\overline{b}$ is the average unit price calculated based on the value of sums of design and construction works orders.

The analyses of the database [23] are summarized in Table 1. There are only 6 pairs of possible comparisons between D&B and DBB orders (marked from C1 to C6 in the table). It was assumed that to compare means of sets, there should be at least 3 elements in each of the compared sets.

Table 1. Possible to compare groups of orders based on [23]

Label of the comparison	**Voivodeship**	**Type of works**	**Type of road**	**Number of orders type D&B**	**Number of orders type DBB**
C1	masovia	new constr.	express road	19	9
C2	masovia	new constr.	national road	6	4
C3	masovia	new constr.	voivodeship road	8	9
C4	masovia	modernization	voivodeship road	9	17
C5	lesser poland	new constr.	express road	3	5
C6	lower silesia	modernization	voivodship road	3	3

Four of these comparisons are based on orders in Masovia (C1 to C4), one in Lesser Poland (C5), and one in Lower Silesia (C6). Four of these order groups are for building new roads (C1, C2, C3, C6), and two for modernisation (C4 and C6). Two of the comparisons refer to the express roads (C1 and C5), three refer to the voivodeship roads (C3, C4, and C6), and one refers to the national roads (C2).

2.3. Risk premium calculation

The descriptive statistics of the 12 samples (subsets of unit prices) are presented in Table 2.

Table 2. Descriptive statistics of the samples

Label of sample	Mean	Standard deviation	Minimum	Maximum	Number of elements in the sample
C1 D&B	46 908 330	58 539 156	13 426 924	265 703 564	19
C1 DBB	31 461 937	21 569 822	10 889 609	72 600 758	9
C2 D&B	25 957 751	19 196 281	7 897 464	62 105 834	6
C2 DBB	21 816 655	10 352 673	8 410 195	32 312 787	4
C3 D&B	6 271 243	3 234 409	3 576 796	11 773 939	8
C3 DBB	12 086 447	10 823 442	3 810 348	30 054 847	9
C4 D&B	5 288 665	4 997 168	1 575 674	17 571 429	9
C4 DBB	7 268 417	7 751 466	1 193 440	30 395 655	17
C5 D&B	87 451 372	123191021	6252958	229199681	3
C5 DBB	123 546 967	125 307 561	23 778 468	334 113 300	5
C6 D&B	2 483 102	589 692	1 903 144	3 082 069	3
C6 DBB	6 426 491	9 294 969	1 040 139	17 159 372	3

Then, the 6 comparisons of mean unit prices can be done. Results are presented in Table 3.

Table 3. Calculation of risk premium

Label of the comparison	Mean of DBB	Mean of D&B	Difference of means (D&B – DBB)	D&B as a percentage of DBB	Relative increase/ /decrease in %
C1	31 461 937	46 908 330	15 446 393	149.1	49.1
C2	21 816 655	25 957 751	4 141 096	119.0	19.0
C3	12 086 447	6 271 243	–5 815 204	51.9	–48.1
C4	7 268 417	5 288 665	–1 979 752	72.8	–27.2
C5	123 546 967	87 451 372	–36 095 595	70.8	–29.2
C6	6 426 491	2 483 102	–3 943 389	38.6	–61.4

It can be observed that the risk premium exists only in comparisons C1 and C2. In the remaining four comparisons, the average unit price is lower for D&B orders than for DDB. Therefore the difference can't be named the risk premium. The means – as a part of a box-plot – together with all unit prices are presented in Fig. 5 (for C1 comparison) and Fig. 6 (for C4 comparison).

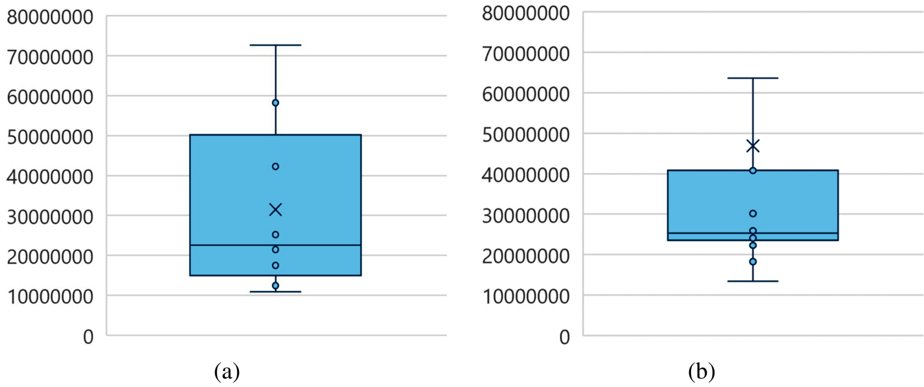

Fig. 5. Box-plots for the C1 comparison samples: (a) DBB orders, (b) D&B orders (outliers are excluded in b)

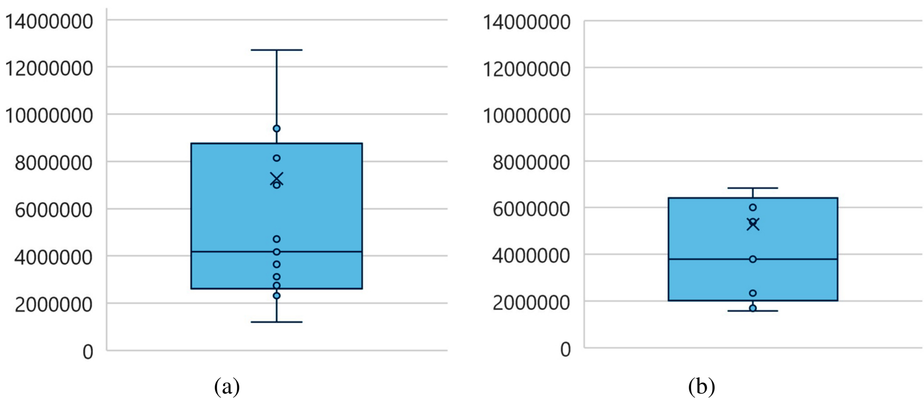

Fig. 6. Box-plots for the C4 comparison samples: (a) DBB orders, (b) D&B orders

3. Discussion

3.1. Unit prices of DBB vs D&B

Even if the database has information about 349 orders, there are 160 possible comparisons (2 types of works, 5 types of roads, 16 voivodeships), so an average 2.18 of orders per sample. Therefore, only 6 comparisons are possible to calculate (see Table 1). There were no D&B orders for modernisation of the county roads in any voivodeship. If a sample in a given voivodeship has less than 3 elements, it is excluded from the analysis i.e. it can't be compared. Statistical importance of the mean calculated based only on 2 values is low (as economic values are considered – that is unit prices). Secondly, to verify the normal character of data, Shapiro–Wilk's test [24] is assumed to be done. This test is recommended for the samples with low number of elements, however the minimum number of elements is 3.

The average risk premium calculated for the new express roads in Masovia is very high (49.1%). For the new national roads – also in Masovia – it is equal to 19.5%. Nevertheless, four out of six results of the comparison (C3 to C4) are negative. It means that the mean value of the unit price is lower if the D&B type of order is applied (see Fig. 5). It is suspected, that having the possibility to decide about the design (as in D&B orders), contractors are able to optimize the design and the construction works, lowering their costs. Then, even if the reserve for risk is higher, the total cost (for D&B) is lower than for DBB. It is presented in Fig. 7.

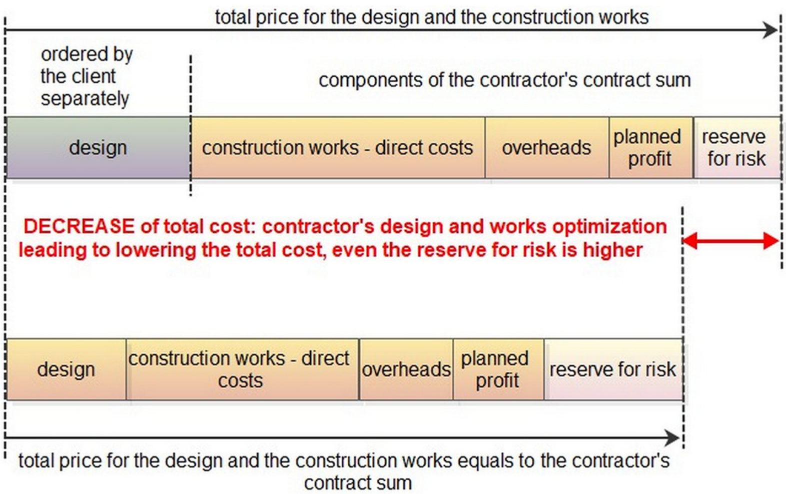

Fig. 7. The effect of suspected contractors' optimization in D&B orders

3.2. Statistic verification

It is decided to verify the statistical importance of the difference between the mean unit prices for DBB and D&B orders with ANOVA [25, 26]. There are two alternative hypotheses in ANOVA: H_0– the means of all samples are equal, and H_1 the mean of at least one sample is different from the means of other samples. The comparisons of just two samples are considered in the article (DBB and D&B). These hypotheses are tested with the following procedure based on [24, 27]:

- calculating means $\overline{x_i}$ for each of k samples (for $i = 1, 2, \ldots, k$)
- calculating the mean for all samples $\widetilde{x_i}$ (global mean) with the following formula (3.1):

$$\widetilde{x} = \frac{1}{n} \sum_{i=1}^{k_i} \sum_{j=1}^{n_i} x_{ij} \tag{3.1}$$

where:

(3.2)
$$n = \sum_{i=1}^{k} n_i$$

n_i is a number of elements in i-th sample, x_{ij} is a value of j-th element in i-th sample,

– calculating SS_{btw} i.e. sum of squared deviations of means (of each sample) from the global mean with the following formula (3.3):

(3.3)
$$SS_{\text{btw}} = \sum_{i=1}^{k} (\widetilde{x} - \overline{x_i})^2 \cdot n_i$$

– calculating SS_{tot} i.e. sum of squared deviations of x_{ij} (all values from all samples) from the mean of each sample with the following formula (3.4):

(3.4)
$$SS_{\text{tot}} = \sum_{i=1}^{k} \sum_{j=1}^{n_i} (x_{ij} - \overline{x_i})^2$$

– calculating variances two variances: variance between samples named MS_{btw} and variance within the samples named MS_{tot}, with the following formulas (3.5) and (3.6):

(3.5)
$$MS_{\text{btw}} = \frac{SS_{\text{btw}}}{df_{\text{btw}}}$$

(3.6)
$$MS_{\text{tot}} = \frac{SS_{\text{tot}}}{df_{\text{tot}}}$$

where degrees of freedom (df_{btw} and df_{tot}) are as follows:

(3.7)
$$df_{\text{btw}} = k - 1$$

(3.8)
$$df_{\text{tot}} = n - k$$

– calculating the statistics F with the following formula (3.9):

(3.9)
$$F = \frac{MS_{\text{btw}}}{MS_{\text{tot}}}$$

– reading the F_α value from the Fisher's tables. F_α depends on: the assumed confidence level α, df_{btw}, and df_{tot}.

If $F > F_\alpha$ there is no reason to reject the hypothesis H_0, so it can be stated that the means of samples are equal. Statistica software returns p value. If $p > \alpha$ there is no reason to reject the hypothesis H_0. The condition $F > F_\alpha$ is met, if and only if the condition $p > \alpha$ is met. However, to apply ANOVA, four assumptions must be met:

– independence of random variables for each sample,
– measurability of variables,
– normality of distribution of random variables in each of the compared samples,
– variance homogeneity in all compared samples.

Independence of each unit price is provided, as well as, measurability of them. In Shapiro–Wilk's test for normal distribution of the sample W statistics defined as

$$W = \frac{\left[\sum_{i=1}^{n/2} a_{n,i}\left(x_{n-i+1} - x_{(i)}\right)\right]^2}{\sum_{i=1}^{n}(x_i - \overline{x})^2} \tag{3.10}$$

where: x_i – non-ordered values in the sample, $x_{(i)}$ – values in the sample ordered increasingly, $\overline{x}$ – mean value, n – number of values in the sample, $[n/2]$ – total part of the half of the number of unit prices in a sample, $a_{n,i}$ – tabularized coefficient dependent on n is compared to theoretical W_{th} that depends on n and the assumed confidence level α. If the $W > W_{\text{th}}$ there is no reason to reject hypothesis H_0 (normal distribution is confirmed). In Statistica software statistics W is calculated and presented together with the value of p. If $p > \alpha$ then also $W > W_{\text{th}}$. Then homogeneity of variances (of the compared samples) can be verified with Levene's test [28–30]. The statistics W for this test is calculated based on formula (3.11).

$$W = \frac{n-k}{k-1} \cdot \frac{\sum_{i=1}^{k} n_i(\overline{z}_i - \widetilde{z})^2}{\sum_{i=1}^{k}\sum_{j=1}^{n_i}(z_{ij} - \overline{z}_i)^2} \tag{3.11}$$

where: n is the total number of cases in all samples, k is a number of different samples to which the sample cases belong, n_i is a number of cases in i-th samples, and

$$z_{ij} = \left|x_{ij} - \overline{x_{i2}}\right| \tag{3.12}$$

where: x_{ij} is a j-th value in i-th sample, $\overline{x_i}$ is mean value in i-th sample, $\overline{z}_i$ is a mean value of z_{ij} in i-th sample given by the formula:

$$\overline{z}_i = \frac{1}{n_i}\sum_{j=1}^{n_i} z_{ij} \tag{3.13}$$

$\widetilde{z}$ is a mean of all z_{ij} given by the formula:

$$\widetilde{z} = \frac{1}{n}\sum_{i=1}^{k}\sum_{j=1}^{n_i} z_{ij} \tag{3.14}$$

Similarly to ANOVA statistics W is approximately F distributed, and it is compared to F value read from Fisher's tables based on confidence level α, and degrees of freedom i.e. $k-1$ and $n-k$. The Levene test rejects the null hypothesis (variances of all samples are equal) if $W > F_{\text{value}}$ (i.e. when returned from Statistica software $p < \alpha$).

Table 4. Results of Shapiro–Wilk’s tests

Sample	**Number of elements in the sample**	***W***	***p***
C2 D&B	6	0.826475	0.100319
C2 DBB	4	0.969816	0.840342
C5 D&B	3	0.818812	0.160247
C5 DBB	5	0.823216	0.123602

Table 5. Results of Levene’s tets

Samples	$\mathbf{SS_{btw}}$	$\mathbf{df_{btw}}$	$\mathbf{MS_{btw}}$	$\mathbf{SS_{tot}}$	$\mathbf{df_{tot}}$	$\mathbf{MS_{tot}}$	***F***	***P***
C2 DBB vs C2 D&B	8.38E+13	1	8.38E+13	7.87E+14	8	9.84E+13	0.851063	0.383231
C5 DBB vs C5 D&B	1.98E+14	1	1.98E+14	3.09E+16	6	5.15E+15	0.038419	0.851075

Table 6. Results of ANOVA for C2 and C5

Samples	$\mathbf{SS_{btw}}$	$\mathbf{df_{btw}}$	$\mathbf{MS_{btw}}$	$\mathbf{SS_{tot}}$	$\mathbf{df_{tot}}$	$\mathbf{MS_{tot}}$	***F***	***P***
C2 DBB vs C2 D&B	4.12E+13	1	4.12E+13	2.16E+15	8	2.71E+14	0.15215	0.706669
C5 DBB vs C5 D&B	2.44E+15	1	2.44E+15	9.32E+16	6	1.55E+16	0.157337	0.705343

Only two comparisons (C2 and C5) have passed Shapiro–Wilk’s test and Levene’s test at the confidence level $\alpha = 0.05$. The result of them are presented in Table 4 and Table 5.

The ANOVA test has confirmed that the means in the samples of comparison C2 are equal, and the means in the samples of comparison C5 are equal. The results are presented in Table 6.

It can be concluded that even the differences between the mean unit prices seem to be significant (see Table 3), they can not be confirmed by ANOVA test (for C1, C3, C4, C5), or ANOVA results shows that the means of two samples (DDB and D&B) are equal (at the confidence level 0.05). Based on [24] it can be said that the lack of the statistically important difference between mean values of samples DBB and D&B is visible, as the significant part of the left and right boxes are overlapped as presented in Fig. 8.

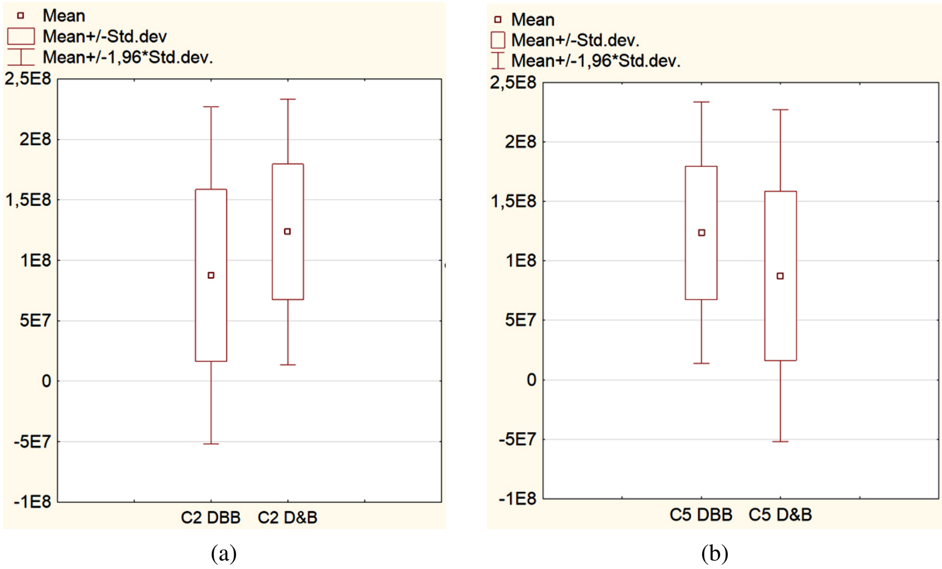

Fig. 8. The comparison of confidence intervals for C2 (a) and C5 (b) for DBB and D&B samples

4. Conclusions

The risk premium i.e. the increase in the mean unit price (per 1 km of the road) – in the case of D&B orders, compared to DBB orders – is defined in the article. The theoretical increase i.e. risk premium, is confirmed only for the new express roads and the new national (but not express) roads in Masovia. According to the increased risk of D&B orders (compared to the risk DBB orders), the unit price – so, also the total price – can be 49.1% higher (for new express roads in Masovia) and 19.0% higher (for new national roads in Masovia) if D&B order is applied, instead of DBB order.

Another important finding is that for four comparisons – out of six possible to analyse – the mean unit prices are lower for D&B orders. The decrease varies from –27.2% (for new voivodeship roads in Masovia) to – 61.4% (for the modernization of voivodeship road in Lower Silesia). The lower unit price in the case of D&B order is not in contradiction with the risk premium existence. It can be concluded that the contractors – in the case of D&B orders – are able to optimise the design which makes the construction works much cheaper (and the analysed unit prices lower). It is hard not to agree with the statement that the higher the risk, the higher the reserve for risk should be assumed. Even, if the reserve for risk is higher in D&B orders – for the four analysed cases i.e. C3 to C6 – the cost of the design and construction works (due to contractors' optimization) is much lower than it would be expected in DBB orders.

Nevertheless, the ANOVA test does not confirm that the mean unit price is different for the two samples analysed in C2. The same is true for C5 comparison i.e. ANOVA confirmed the equality of mean unit prices in the samples anaylsed there. For the other four comparisons (C1, C3, C4, and C6) normality of data (calculated separately for each sample) is not confirmed, so the ANOVA couldn't be applied. It could happen if the unit prices for a given sample vary a lot. It is assumed for the article that, if it is the same type of works, the same type of road, the same voivodeship, and the same type of order, the unit prices should not vary a lot. In fact, each road section has a different number of crossings, junctions, bridges, flyovers, etc. These elements are included in the total price and make it vary a lot.

There are two possible ways to get to the more general, statistically proven results. The median values of the unit prices can be compared (for DBB and D&B) orders. The alternative approach is to analyse the unit prices of typical elements of the road construction, but applying this method can be limited by the difficult access to the source of data.

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Premia za ryzyko wykonawcy w kontraktach budowlanych typu projektuj i buduj

Słowa kluczowe: budowa dróg, ceny ofertowe, projektuj i buduj, ryzyko, zamówienia publiczne

Streszczenie:

Zlecenia obejmujące swoim zakresem jednocześnie projekt i wykonanie odcinka drogi są w Polsce co raz częstszym typem zleceń wykorzystywanym przez zamawiających. Jedną z przyczyn, dla których ten typ zleceń jest stosowany, jest zapewne duża liczba sporów z wykonawcami dotyczącymi przyczyn powstawania wad ujawniających się w okresie gwarancyjnym. Zwiększa to zakres odpowiedzialności podmiotu, który przyjmuje zlecenie na zaprojektowanie i wybudowanie odcinka drogi. W przypadku, gdy w okresie gwarancyjnym ujawnią się wady przedmiotu zlecenia, wykonawca – w przypadku zlecenia typu projektuj i buduj – nie ma możliwości uniknięcia odpowiedzialności ze względu na błędy projektowe wskazywane jako przyczynę wad. Projekt jest w zakresie wykonawcy zlecenia. Konsekwencją rozszerzenia zakresu zlecenia o projektowanie jest także zwiększenie zakresu niepewności dotyczącego ograniczeń przedsięwzięcia inwestycyjnego. Każde budowlane przedsięwzięcie inwestycyjne ma trzy podstawowe ograniczenia: budżet przedsięwzięcia, czas jego wykonania oraz zakres prac do wykonania. Wykonawca, który przyjął zlecenie na wybudowanie obiektu (nie obejmujące projektowania) otrzymuje od zamawiającego dokumentację projektową. Zakres zlecenia jest więc pewny – opisany dokumentacją. Oceniając szanse na powodzenie danego przedsięwzięcia wykonawca analizuje, z jaką pewnością jest w stanie dotrzymać planowanego terminu zakończenia budowy oraz z jaką pewnością jego koszty zamkną

się w planowanej wysokości tj. dokonuje analizy ryzyka dotyczącego czasu oraz kosztów. W przypadku, gdy nie ma pewności co do rodzajów robót, które będą wykonywane, ani co do ilości prac, które muszą być wykonane dla wykonania całości zlecenia, maleje pewność dotrzymania umownego terminu ukończenia zlecenia, a także maleje pewność nieprzekroczenia planowanych kosztów. Innymi słowy dla wykonawcy takiego zlecenia rośnie jego ryzyko. Dla nieprzerwanego, wieloletniego działania przedsiębiorstwa niezbędne jest osiąganie zysku. Należy się spodziewać, że zwiększona niepewność kosztów przedsięwzięć zlecanych w trybie projektuj i buduj powoduje zwiększanie cen ofertowych wykonawców. Chcąc uniknąć ujemnego wyniku (straty) podwyższają oni ceny ofertowe tak, by ewentualny zwiększony zakres robót budowlanych czy ich ilość – w przypadku materializacji czynników ryzyka – nie spowodował straty. W artykule przedstawiono wyniki analiz dotyczących budowy 349 odcinków dróg w Polsce, dla których wybór najlepszej oferty miał miejsce pomiędzy 1 lipca 2014 roku a 30 czerwca 2017 r. Dane opublikowano w [23]. Większość z nich, tj. 226 była zlecona w trybie buduj, tzn. wykonanie projektu było zlecone wcześniej przez zamawiającego, a ceny tych zleceń także włączono do zakresu analiz. Zleceń typu projektu i buduj poddanych analizie było 123. Analizowano ceny jednostkowe (za 1 km drogi danego typu). Porównywano ceny jednostkowe zleceń typu projektuj i buduj do cen jednostkowych wynikających z sumy cen za zaprojektowanie i wybudowanie odcinków dróg. Analizy podzielono na następujące pięć rodzajów dróg: autostrady, drogi ekspresowe, drogi krajowe (niebędące ani autostradami, ani drogami ekspresowymi), drogi wojewódzkie (niebędące drogami ekspresowymi) praz drogi powiatowe. Analiz dokonano odrębnie dla nowobudowanych dróg oraz odrębnie dla kontraktów dotyczących modernizacji istniejących dróg. W artykule zdefiniowano premię za ryzyko. Wartość premii za ryzyko – obliczonej dla ceny jednostkowej na 1 km drogi – wynosi 49,1% w przypadku C1 oraz 19,0% w przypadku C2. W pozostałych przypadkach porównań tj. C3 do C6, średnia cena za 1 km drogi była niższa w przypadku zleceń typu projektuj i buduj, niż dla zleceń typu buduj, co oznacza optymalizację kosztów całego przedsięwzięcia przez wykonawców zleceń typu projektu i buduj oraz brak możliwości oszacowania premii za ryzyko. W artykule wykorzystano analizę wariancji (ANOVA), by potwierdzić (lub zaprzeczyć), że średnie pomiędzy dwoma porównywanymi zbiorami cen jednostkowych (jeden dla zleceń typu buduj; drugi projektuj i buduj) są równe. Tylko próby z dwóch porównań (C2 i C5) spełniły cztery warunki zastosowania analizy wariancji. W przypadku porównań C1, C3, C4 i C6 wyniki w próbach nie miały charakteru rozkładu normalnego, co potwierdzono testami Shapiro–Wilka. Co więcej, wynik z ANOVA przeprowadzonej dla C2 oraz C5 wykazał, że nie można odrzucić hipotezy zerowej (o równości średnich w badanych próbkach). Oznacza to, trzeba przyjąć, że pomimo obliczonej różnicy średnich cen jednostkowych pomiędzy zleceniami buduj oraz projektuj i buduj, średnie te nie różnią się znacząco na założonym w obliczeniach poziomie istotności α równym 0,05. Brak statystycznego potwierdzenia istotności różnic średnich będzie przedmiotem dalszych badań. Warto jednak podkreślić, że dla dwóch typów zleceń wyznaczono procentową wielkość premii za ryzyko wykonawcy. Po wtóre, w C5, gdzie średnia cena 1 km drogi dla zleceń typu projektuj i buduj jest niższa niż dla zleceń typu buduj, można stwierdzić, że wykonawcy zleceń typu projektuj i buduj potrafią tak optymalizować projekt i obniżyć koszty wykonawstwa, że pomimo wyższej rezerwy na ryzyko (bo ryzyko zleceń projektuj i buduj jest wyższe niż w zleceniach typu buduj), średnia cena jednostkowa 1 km drogi jest niższa.

Received: 2024-06-05, Revised: 2024-07-30