



## Research paper

# Analysis of direct rework costs in Ukrainian construction

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**Abstract:** The construction industry of Ukraine has a number of problems and barriers that hinder its development. The main problems affecting Ukraine are corruption, high level of opacity, inefficient use of resources and inefficient process management. Moreover, ineffective design and construction management reduce labor productivity and leads to reworks. Unfortunately, in Ukrainian construction industry most cases of rework have been accepted as a part of construction activities. Rework is one of the main factors in the growth of total costs and the excess of the schedule for the construction project. The problem of rework costs is important and needs to be studied more to alleviate these overruns in the future. However, rework data are usually quite difficult to obtain and most studies have been conducted in developed countries. It can be assumed that there is a greater probability of reworks and rework costs in developing countries than in the developed ones. Thus, the purpose of this article was to determine and systematize reworks factors, quantify amount of direct rework costs, determine the relationship between actual project costs, project duration variation and rework costs.

**Keywords:** rework, rework factors, rework costs, direct costs, construction

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## 1. Introduction

Construction is one of the most important industries for most countries and the entire economic effectiveness depends on it. This industry is important for the country economy since construction creates a large number of jobs and uses intermediate products and services (up to 40% of raw materials, chemical products, electrical and electronic equipment, etc.). The results of the construction industry can significantly affect overall economy development. The growth of construction is accompanied by: production of building materials and equipment, mechanical engineering, metallurgy and metalworking, petrochemicals, glass production, woodworking, transportation and energy.

This phenomenon is especially visible in developing countries such as Ukraine. Figure 1 shows correlation between Gross Domestic Product and Construction Production Index in Ukraine [1].

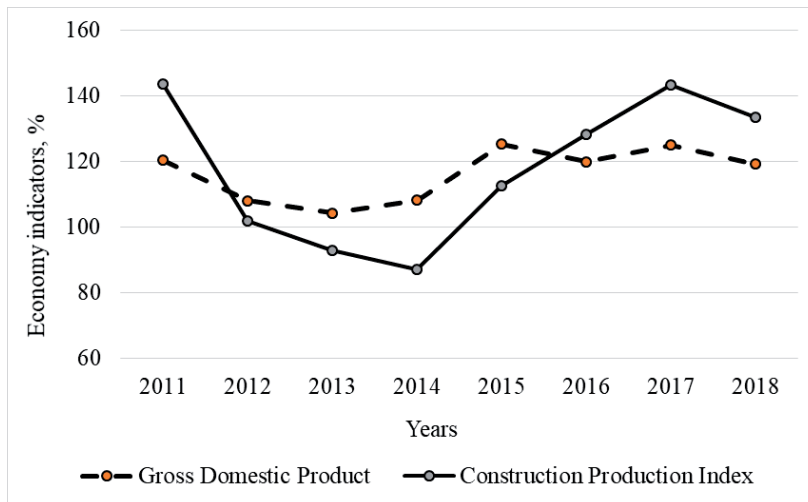


Fig 1. Ukrainian Gross Domestic Product and Construction Production Index in 2011-2018 [1]

Currently, the development of Ukrainian construction industry is hindered by a number of problems and barriers. Notwithstanding corruption and a high level of industry opacity, the key problems are the use of resources and process management inefficiently, in our view. Ineffective design and construction management reduces labor productivity and leads to reworks [2, 3]. The construction industry is one of the largest consumers of raw materials and related products, and is noted for its inefficient use and high

waste generation rates (up to 25% - 30%) including the ones due for reworks. Rework in construction is one of main reasons behind resources and time waste. Unfortunately, in Ukraine the most cases of rework have been accepted as a part of construction activities. This issue imposes a significant additional cost to the project. In the construction industry of Ukraine serious work on cost control, identifying the causes and consequences of reworks has not been carried out. One of the latest studies of causes of rework in construction projects in Ukraine determined the reasons and classification of rework factors (owner related, designer related and contractor related ones) [4]. The causes with the highest effects were "Design change" and "Lack of coordination". For the owner the "Lack of coordination and poor communication" as well as "Design change" had a very high impact on rework process implementation (37.5% and 31.3%, respectively). While, for the designer the "Incomplete design at the time of tender" and "Poor coordination of design" had the most significant impact on the occurrence of reworks (52.9% and 29.4 %, respectively). Moreover, for the contractors' respondents the "Design change initiated by contractor" was ranked in the first place of the list (very high effect 53.8%), while the "Poor planning and coordination of resources" was placed on sixth position in ranking (very high effect 23.1% and high effect 26.9%).

Rework can lead to a considerable addition of a project's time and cost overrun, especially, during a construction stage. Cost overrun is a regular situation in which the final cost of the project exceeds the initial estimates [5]. Implementation time, cost and quality are seen as main factors in measuring project success. Cost overrun is the main problem in project development and regular feature in construction industry especially for the developing countries [6]. The problem of cost overrun is important and needs to be studied thoroughly to alleviate these overruns in the future. For some projects, the overall rework costs may even exceed the estimated profit.

To represent the scale of the problem in the Ukrainian construction industry, the Authors analysed the amount of financing from the state and local budgets under the item "Capital construction". In 2018, capital works were carried out on the level of UAH 80.24 billion (\$3.21 billion) while at the beginning of 2019 the level of UAH 76.16 billion (\$3.05 billion) was achieved [1]. If we assume that direct rework costs amount to about 10% of the project cost, then reworks in construction financed from the state budget amounted to UAH 8.04 billion (\$0.321 billion) in 2018 and UAH 7.62 billion (\$0.305 billion) in 2019. Only construction costs from the state and local sources were counted, excluding private funds spent on construction. The attention to research of rework costs is due to the fact that this area is poorly studied in Ukrainian construction and, in our opinion, rework costs can be a significant part of the project

cost. In connection with the above, this article attempts to identify and systematize the rework factors, determine the relationship between actual project costs, project duration variation and quantify amount of rework costs in Ukrainian construction projects.

## 2. Rework costs in construction sector

Before assessing the rework costs in construction, it is necessary to determine what a rework is, and describe the difference between direct and indirect influences of reworks. Table 1 contains some definitions of rework found in existing literature.

Table 1. Definitions of rework

Authors	Definition
Alwi et al. [7]	Reworks is known as non-value adding symptoms that affect the productivity and performance in construction projects
Construction Industry Development Agency [8]	Doing something at least one extra time due to nonconformance to requirements
Ashford [9]	The process by which an item is made to conform to the original requirement by completion or correction
Love and Li [10]	The unnecessary effort of re-doing a process or activity that was incorrectly implemented the first time
Construction Industry Institute [11]	Activities that should be done many times and activities which result in undoing the work that is already performed

The general is, that rework becomes necessary either when an element of building works fails to meet customer requirements, or when the completed work does not conform to the contract documents. In either scenario, the product is altered to ensure conformity [12]. Varying interpretations and definitions of rework have led to a lack of uniformity in rework data collation and quantification [13].

Classifications of reworks are also quite diverse. Reworks can be divided depending on the source of their occurrence (errors, omissions, changes), depending on a degree of impact on a project (practically no impact, mild impact, serious impact, severe impact). The most popular is separation of reworks by causes. They were classified by project implementation stage, subject source of reworks and mixed classification.

One of the rework classifications is a division by impact on a project into direct and indirect. The direct impact of rework are additional: time, costs, materials and labor. The indirect impact of rework is the influence of an individual and organization performance [14]. On the individual level, indirect influence is manifested as: stress, fatigue, absenteeism, demotivation, poor morale. In fact, when a worker is subjected to reworks because of errors, changes or omissions, fatigue and stress are likely to emerge, increasing the likelihood of further reworks. On the organization level consequences of reworks include: reduced profit, loss of market share, lower reputation, low operational efficiency, increased turnover workforce, poor morale, lower productivity, quality degradation, litigation between participants of a project delivery.

Direct and indirect effects of reworks in construction lead to direct and indirect costs. Rework is one of the main factors in the growth of total costs and excess of the schedule for a construction project. However, rework data are usually quite difficult to obtain [15] and currently there is no uniform approach to collecting data on rework costs.

Love et al. [16] after analyzing 260 projects reported that rework costs are 11.07% of the original contract value. Burati et al. analyzed 9 major projects and concluded that an average of 12.4% of the contract cost was spent on rework [17]. Josephson and Hammarlund [18] state that the rework costs for residential, industrial and commercial construction sites vary from 2.3% to 9.4% of the contract value, and Fayek et al. found that this value ranges from 2% to 12% [19]. In infrastructure projects, the rework costs were 10.29% [20] and 16.5% of the contract value [21].

The results of the analyzes of direct rework costs in construction are given in Table 2. It can be seen that the range of rework costs is very large; from 1.3% to 16.5%. These variations result from differences in definitions, in data collection methods applied, and whether rework is calculated as a part of a project or contract value.

Table 2. Direct rework costs

Author	% of project cost
Construction Industry Development Agency [22]	10
Love et al. [23]	2.4-3.15
Josephson i Hammarlund [18]	2.3-9.4
Josephson et al. [24]	7.1
Burati et al. [17]	12.4
Abdul-Rahman [25]	2.5-5
Marosszeky [26]	5.5

Meshksar [27]	1.3- 3.30
Oyewobi et al. [28]	5.29
Simpeh [29]	9.94
Fayek et. al [19]	2-12
Forcada [21]	16.5
Love et al. [20]	10.29
Love et al. [16]	11.07
Average	7.84

The number of studies over indirect rework costs is limited, since they are not directly measurable. Barber et al. [30] found that when indirect costs are considered, the total cost of rework can be as high as 23% of a contract value. Love [31] found that indirect rework costs could have a multiplier effect of up to five times the direct cost.

Most studies in Table 2 were conducted in developed countries. It can be assumed that there is a greater probability of reworks, and hence cost overruns, in developing countries than in the developed ones. Some authors [32, 33, 34] pointed out that rework costs are more severe in developing countries where these overruns sometimes exceed 100% of the anticipated cost of a project.

### 3. Research method

The aim of the research method identifies and classifies factors that influence reworks and calculates the rework costs in construction projects. When selecting data, an attempt was made to maximize accuracy and minimize subjectivity. Of all the potential factors for increasing rework costs, only available and quantifiable ones were used. The study was conducted in the first half of 2018. Over the period from 2012 to 2017, 8 implemented construction projects were analyzed. Of the 8 projects, 5 were school construction projects (in Table 3 numbers 1, 3, 4, 6, 7), 2 kindergartens (in Table 3 numbers 2, 8) and 1 sport complex (in Table 3 number 5). The customer and investor in the projects were local governments. In Ukraine, when implementing construction projects at the expense of public procurement investor/customer functions are performed by an authorized local authority (Department of Construction and Architecture of Regional State Administration).

During the realization of the study, the following project documentation was analyzed:

- architectural, structural and MEP projects;
- initial estimate, final estimate, local estimate of additional works;
- acts of additional works;
- initial sheet of the volume of performed works; final sheet of the volume of performed works.

If reworks arose during the implementation of the construction project, then they should be displayed in the Act of additional works and in the Local estimate of additional works.

In addition, reworks are visible when comparing the final and initial sheets of the volume of performed works.

The study encountered the following difficulties:

1. In Ukraine, there is practically no system for accounting and control of reworks.
2. In the sheets of the volume of performed works, only quantitative data are indicated, data on the cost of work are in the estimates. During the period that was analyzed, in construction there was an increase in wages (tariff rates) which automatically increased the costs in the final estimate.
3. All documentation on the construction project is conducted in paper format. In this regard, it is impossible to use electronic format tools such as RFI (Request for Information) and COR (Change of Order). RFI is used when a project's documentation lacks information that is required to proceed with any given scope of work. COR means a document which describes a change in the scope of work, including a detailed description, drawings and specifications, and a request for changes to costs or time. Using these tools can track reworks in the project and their costs.

To overcome these difficulties, interviews were conducted with the project supervision inspectors to better understand the specifics and problems that arose during the implementation of the projects, as well as to help analyze the information received from the Acts for additional work.

## 4. Results and discussion

As a result of the analysis of construction projects the following data were obtained:

- rework factors,
- planned and actual project costs,
- planned and actual project duration,

- direct rework costs.

The rework factors were divided into four groups.

1) Discrepancy in documents that leads to direct clashes.

Discrepancies between sheets and disciplines and, as a result, direct conflicts between systems accounted for a large part of the problems. The inconsistencies can be divided into two groups:

- within one discipline (in structure, architecture and in MEP).
- between disciplines (between structure and architecture, between structure and MEP, between architecture and MEP).

There were numerous conflicts and collisions often encountered in the analyzed projects: closing door with column, conflicts between the door and the plumbing, a window was not in the middle of the stairs, wall shear, demolition of beams, lack of technical holes in monolithic reinforced concrete, reassignment of electrical networks due to conflict with water pipes, change in water supply scheme due to a change in the source of water supply at the entrance to the building, reassignment of the duct due to conflict with the sewer pipe, use of different types building materials in different disciplines (brick in architecture project and reinforced concrete in the structure project). These discrepancies were often detected by project supervision inspectors during the construction phase, which led to costly changes in the projects.

2) Errors and omissions at the design stage.

Errors and omissions in design varied in range in terms of the degree of impact on the project. For example, simple omissions of information in the figures (missing identifier numbers, lines, dimensions and details) lead to small delays in the project schedule, but omissions of building structures elements lead to massive delays and additional costs. Figure 2 is an example of omission of two reinforced concrete monolithic columns KM20.



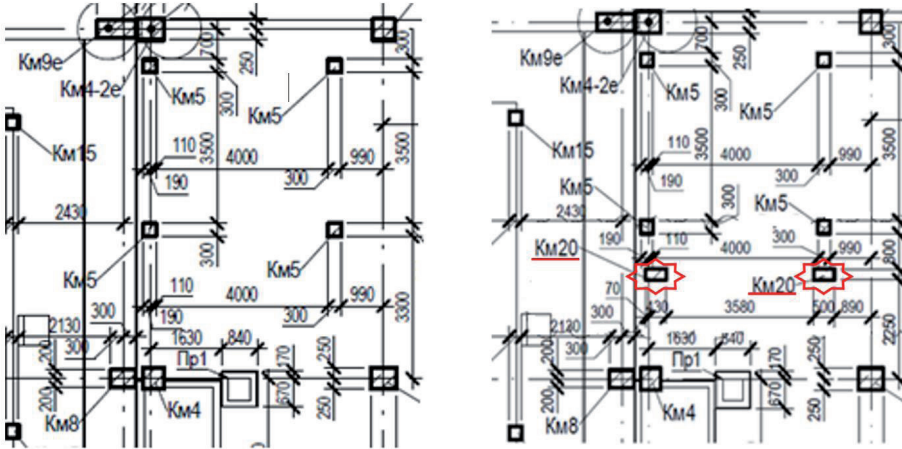


Fig 2. Example of omissions of two reinforced concrete monolithic columns KM20

At the same time, such omissions as insufficient study of the soil under the building, not taking into account fire standards and errors in the design calculation lead to significant increase in direct costs. Figure 3 is an example of one error in the design calculation in sport complex construction project (project 5), which led to reworks costs of UAH 9.14 million (9% of project costs). The designer made an error in calculating the amplification of metal shelves of columns. The existing support table of the crossbar did not provide for the structure strength and reliability.

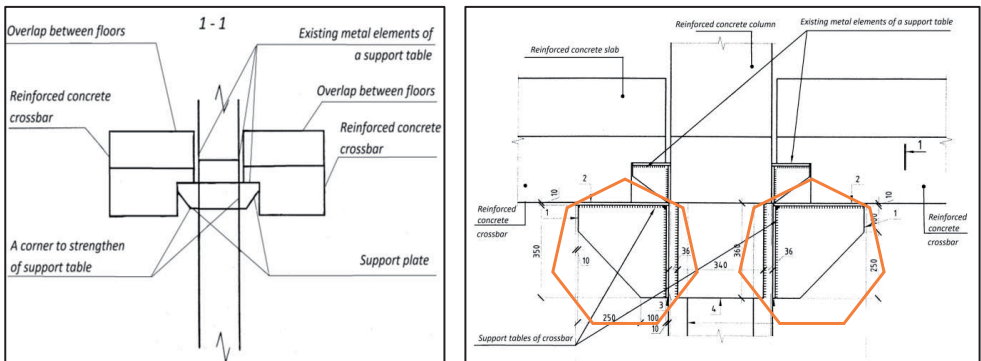


Fig 3. Example of error in calculating the amplification of metal shelves of columns

### 3) Errors and omissions on the construction stage.

Errors and omissions during the construction phase are primarily associated with poor performance of work and the use of low-quality materials. Examples of the consequences of poor work when performing reinforced concrete structures: formwork displacement and deformation during concrete laying, production of concrete constructions inaccurate dimensions, lack of / insufficient reinforcement.

### 4) Poor / insufficient cooperation between project participants.

This type is the most difficult to identify, since some reasons that are included in the first three groups can be also included here. Collisions and clashes between disciplines might not exist if the project was developed at an early stage of implementation by the entire project team. For example, in projects that were analyzed, such situations often occurred when the designer suggested using non-modern building materials and inefficient working methods.

Also, an example in school construction project (project 1) of not effective cooperation between project participants was a case of replacing a solid fuel boiler after an installation of the entire heating system. The reason for the replacement was that the information about the fuel that should be used in the boiler had been received from the customer shortly before putting the facility into operation.

The figure 4 shows the percentage ratio of rework costs factors in each of 8 projects and their average value. The highest average value is a factor "Discrepancy in documents that lead to direct clashes" at 46%. Also, this factor was a maximum in 6 out of 8 projects. The second most important factor is "Errors and omissions on the design stage" at 22%. In the third place is the factor "Poor/insufficient cooperation between project participants" at 17%. In some projects, this factor was very weighty and fundamental to the generation of rework costs. In sport complex construction project (project 5) the factor "Errors and omissions on the design stage" was at 41% and in school construction project (project 1) the factor "Poor/insufficient cooperation between project participants" was at 40%. Factor "Errors and omissions on the construction stage" has an average value of 15% and has the least dispersion (9-22%).

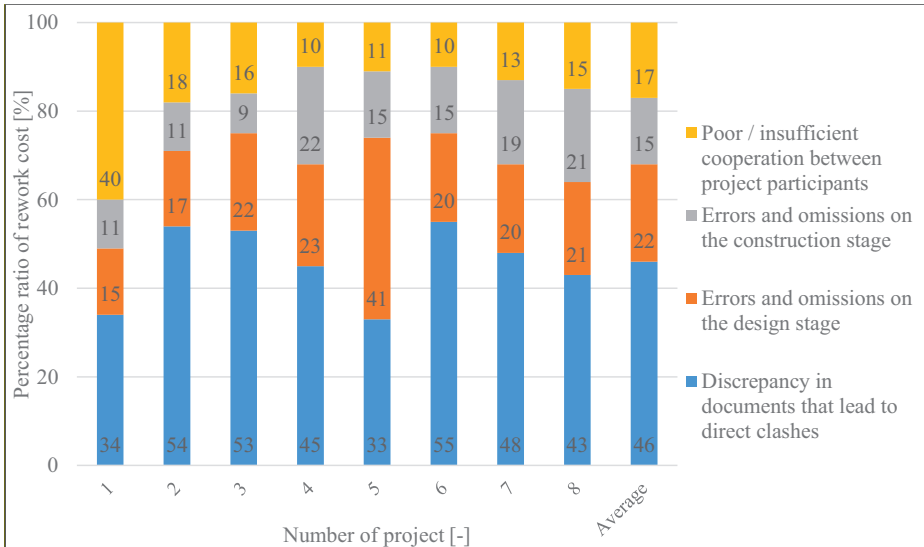


Fig 4. Percentage ratio of rework costs factors

Table 3 shows the numerical results of the analysis of construction projects, namely planned, actual and variation project costs, direct rework costs, planned, actual and variation project duration. The average value of direct rework costs is 11.1% of planned project costs.

Table 3. The numerical results of construction projects analysis

Project	Project costs, mln.UAH			Direct rework costs		Project duration, months		
	planned	actual	variation	mln.UAH	%	planned	actual	variation
1	45.1	59.4	14.3	8.5	18.8	18	32	14
2	30.5	40.8	10.3	2.1	6.9	12	21	9
3	56.9	75.9	19	4.3	7.6	20	30	10
4	40.1	60	19.9	5.7	14.2	15	30	15
5	101.5	120.3	18.8	17.4	17.1	24	42	18
6	57.2	80.4	23.2	4.9	8.6	20	31	11
7	48.6	65.7	17.1	4.1	8.4	18	29	11
8	34.1	42.8	8.7	2.5	7.3	12	22	10
Average					11.1			

To check for the existence of relationships between indicators (Table 3), the Pearson correlation coefficient ( $R$ ) was calculated in Table 4.

Table 4. Pearson correlation coefficient of project indicators

Indicators/Factors	Pearson correlation coefficient R [-]			
	Actual project costs	Rework costs	Project duration variation	Variation project costs
Actual project costs	x	0.86	0.69	0.66
Rework costs	0.86	x	0.90	0.34
Project duration variation	0.69	0.90	x	0.39
Variation project costs	0.66	0.34	0.39	x

Since this study purpose was to analyze rework costs, the correlation of the pairs “Rework costs -> Actual project costs”, “Rework costs -> Project duration variation” is of the greatest interest. In the first case, the correlation coefficient is 0.86, in the second 0.90. The low value of correlation between “Rework costs” and “Variation project costs” (0.34) may be due to the fact that not only rework costs had an impact on the change in variation project costs. During the period that was analyzed, in construction there was an increase in wages (tariff rates) which increased variation project costs

According to the Chaddock’s scale, if the correlation coefficient is in the range from 0.7 to 0.9, then the strength of the relationship between the indicators is high. Thus, it can be argued that impact of rework costs to the change in project costs and project duration is significant in the Ukrainian construction industry.

#### 4. Conclusions

Ukrainian construction industry has a number of problems and barriers that hinder its development. Ineffective design and construction management reduces labor productivity and leads to reworks. Unfortunately, in construction industry of Ukraine, serious work on cost control, identifying the causes and consequences of reworks has not been carried out.

The study analyzed 8 construction projects implemented over the period from 2012 to 2017 in Ukraine. The average value of rework costs is 11.1% of planned project costs, which is significantly higher than average value in table 2 (7.84%). This difference between the values of rework costs may be due to the fact that most of the studies were conducted in highly developed countries (Australia, Spain, Denmark, Sweden, New Zealand). In these countries, one can observe a higher level of construction project management in general and control of rework costs in particular. The rework factors were divided into

four groups: discrepancy in documents that lead to direct clashes; errors and omissions at the design stage; errors and omissions at the construction stage; poor/insufficient cooperation between project participants. Afterwards, the Authors calculated the ratio of rework costs factors in each of 8 projects and their average value. The highest average value is in "Discrepancy in documents that lead to direct clashes" factor with 46%. Also, this factor was maximum in 6 out of 8 projects. The second most important factor is "Errors and omissions on the design stage" at 22%. In the third place is the factor "Poor/insufficient cooperation between project participants" at 17%. In some projects, these factors were very weighty and fundamental to the generation of rework costs. Factor "Errors and omissions at the construction stage" has an average value of 15%.

To check for the existence of relationships between the indicators, the Pearson correlation coefficient was calculated for the pairs "Rework costs -> Actual project costs" ( $R=0.86$ ), "Rework costs -> Project duration variation" ( $R=0.90$ ). This means the strength of the relationship between the indicators is high according to Chaddock's scale. Thus, it can be stated that in the Ukrainian construction industry there are links between rework costs, project costs and project duration.

The average value of rework costs calculated by us is a general indicator that shows the level of costs for a specific projects sample and cannot be an indicator for the entire construction industry. However, based on the value of this indicator, it is possible to measure likely level of negative impact of reworks on construction project result and measures to minimize it.

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### **Analiza kosztów bezpośrednich robót naprawczych w projektach budowlanych na Ukrainie**

Słowa kluczowe: roboty naprawcze, czynniki robót naprawczych, koszty robót naprawczych, koszty bezpośrednie, projekt budowlany.

#### **Streszczenie:**

Przemysł budowlany Ukrainy ma wiele problemów i barier, które utrudniają jego rozwój. Główne problemy dotyczące Ukrainę to korupcja, nieefektywne wykorzystanie zasobów i zarządzanie procesami, które również przyczyniają się do zmniejszenia wydajności pracy i potrzeby prowadzenia robót naprawczych. Niestety, w Ukrainie na rynku budowlanym istnieje przyzwolenie na powstawanie dodatkowych prac w trakcie lub po zakończeniu prac nad danym przedsięwzięciem. Roboty naprawcze są jednym z głównych czynników wzrostu całkowitych kosztów i przekroczeń harmonogramów projektów budowlanych. Problem kosztów robót naprawczych jest bardzo istotny i należy go bardziej zbadać, aby móc zapanować nad tymi kosztami w przyszłości. Na podstawie publikowanych danych przyjmuje się, że średnia wartość kosztów tych robót wynosi ok. 11 % pierwotnej wartości zamówienia. Jednakże, dostęp do danych dotyczących prac naprawczych jest ograniczony, a większość badań na ten temat przeprowadzono w krajach rozwiniętych. Można założyć, że istnieje większe prawdopodobieństwo przeróbek i kosztów przeróbek w krajach rozwijających się niż w krajach rozwiniętych ze względu na braki regulacji lub respektowania przepisów. W związku z powyższym, celem niniejszego artykułu było określenie i usystematyzowanie czynników związanych z robotami naprawczymi, ilościowe określenie bezpośrednich kosztów tych robót, określenie związku między rzeczywistymi kosztami projektu, zmiennością czasu trwania projektu i kosztami robót naprawczych. W badaniu przeanalizowano osiem projektów budowlanych zrealizowanych w okresie od 2012 do 2017 roku na Ukrainie. Czynniki robót naprawczych zostały podzielone na cztery następujące grupy: rozbieżność w dokumentach prowadząca do bezpośrednich kolizji; błędy i pominięcia na etapie projektowania; błędy i pominięcia na etapie budowy; słaba / niewystarczająca współpraca między uczestnikami projektu. Następnie, Autorzy obliczyli wartości czynników kosztów robót naprawczych w każdym z ośmiu projektów i ich średnią wartość. Najwyższą średnią wartością wynoszącą 46% charakteryzował się czynnik „Rozbieżność w dokumentach prowadzących do bezpośrednich kolizji”. Ponadto, był on na pierwszym miejscu w rankingu dla sześciu z ośmiu analizowanych projektów. Drugim najważniejszym czynnikiem był „Błędy i pominięcia na etapie projektowania”, którego wartość była na poziomie 22%. Na trzecim miejscu przy osiągnięciu 17% znalazł się czynnik „Słaba / niewystarczająca współpraca między uczestnikami projektu”. W większości inwestycji, czynniki te były bardzo ważne i miały zasadnicze znaczenie dla generowania kosztów robót naprawczych. Natomiast, czynnik „Błędy i pominięcia na etapie budowy” miał średnią wartość 15%. Ponadto, w celu sprawdzenia istnienia powiązań między czynnikami, obliczono współczynnik korelacji Pearsona R dla par „Koszty robót naprawczych -> Rzeczywiste koszty projektu” oraz „Koszty robót naprawczych -> Zmienność czasu trwania projektu”, który wyniósł odpowiednio 0,86 i 0,90. Wartości współczynników wskazują, że siła związku między czynnikami jest wysoka zgodnie ze skalą Chaddocka. Można zatem stwierdzić, że w przedsięwzięciach budowlanych w Ukrainie istnieje wpływ kosztów robót naprawczych na zmiany kosztów projektu i czas jego trwania. Obliczona przez nas średnia wartość kosztów robót naprawczych jest ogólnym wskaźnikiem, który wskazuje na poziom tych kosztów dla konkretnego zestawu projektów i nie może być wskaźnikiem dla całej branży. Jednak na podstawie tego wskaźnika można ocenić ewentualny poziom negatywnego wpływu zmian na wyniki projektu budowlanego i prognozować działania mające na celu jego zmniejszenie.

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