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Research paper

Planning the time and cost of implementing construction projects using an example of residential buildings

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Abstract: The constant increase in the population of cities affects the development of housing. Investors, in their activities related to the profit from the sale of flats, focus on the completion of residential buildings, which must be timely and in accordance with the budget assumptions. Therefore, there is a problem concerning the correct planning of the costs and duration of an investment. The aim of the conducted research was to determine the shape and course of the cost curves for construction projects related to the construction of residential buildings. Based on the analysis of the authors' own studies carried out in a homogeneous research group of 11 residence buildings, an original attempt was made to determine the area of the curve, which indicates the area of correct planning of cumulative costs and the forecasting of their deviations in the financial outlays of construction projects. By knowing the planned cost and duration of a construction project, and by using the proposed 6th degree polynomial, it is possible to determine the planned monthly work and expenditure amounts, and thus correctly plan the investment costs over time. It was proven that the planned work and expenditure advancement of the housing construction sector is greater in the first stage of its implementation when compared to the actual state. The determined 6th degree polynomials describe the regularity that shows that for half of the planned duration of works, the planned work and expenditure advancement is approx. 46%, while the actual advancement is approx. 35%.

Keywords: management of construction projects, time, cost, residential buildings

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1. Introduction

Residential buildings have always been the most popular form of architecture. Due to their prevalence, they shape the image of cities and give them their general character [1]. Their operation should therefore be in accordance with their intended purpose, and also with maintaining their appropriate technical [2] and aesthetic condition [3].

The constant increase in the population of cities affects the development of housing [4]. New building structures, mostly residential ones, are still being built [5]. The Polish real estate market is growing every year [6]. Data published by the Central Statistical Office in Poland indicate that in 2019 over 207,000 apartments with a total area of over 18 million m^2 were completed. When calculating proportionally to the number of inhabitants, Poland ranks third in Europe in terms of the number of built flats [7]. It is also worth noting that the data of the Central Statistical Office show that residential construction in Poland has been characterized by high growth rates in the last five years [8].

A large number of residential investments in this construction sector in 2019 brought a record value of construction and assembly production, which amounted to over PLN 19.5 billion, including PLN 16.5 billion for investments related to the construction of multi-apartment buildings and collective accommodation. Over 63% of completed apartments are intended for sale or rent, which means that they were built by development companies. Due to the fact that a construction developer operating in the private sector is focused on profit from selling or renting apartments, it is important to correctly plan the investment costs and effectively monitor the implementation and incurred financial outlays. There are many methods for estimating/forecasting costs related to the implementation of construction works, but they are very often complicated and require a decision-maker to define various and often difficult to define variables, which are in fact random events [9, 10]. Therefore, simple methods/models are sought in order to determine, with a high probability, the costs of construction works.

The aim of the research was to determine the shape and course of the cost curves for construction projects related to the construction of residential buildings. Based on the analysis of the authors' own studies, which were conducted in a homogeneous research group of 11 collective residential buildings, an original attempt was made to determine the area of the curve, and also to indicate the area of correct planning of cumulative costs in construction investments.

2. Literature review

The implementation of each construction project takes place according to specific time and cost parameters, and also in accordance with the established technical and quality requirements [11, 12]. The timely implementation of construction projects and the reduction of their completion time affect the economic efficiency of an investment [13]. A company's financial liquidity is also influenced by the correct planning of costs and financial flows in the implementation planning phase [14].

Therefore, an important element in planning construction projects is the correct planning of the course of implementation in terms of their time and cost, in particular the correct development of the Investor's work and expenditure schedule (with specific dates of commencement and completion of the investment, appropriate connections between tasks, a specific duration of individual tasks, and their costs of implementation) [15]. It is only a solid schedule of works, namely a reasonable work and expenditure schedule that can increase work efficiency and enable contractors to properly execute a contract at the lowest cost [16]. Of course, verification of the correctness of planned costs and investment time only takes place "post factum", i.e. at the end of the investment. Therefore, methods and tools that support planning are being sought.

In literature, there are many methods that are used to monitor construction projects. For example, the Earned Value Method is a commonly used and verified method in construction management practice [17, 18]. The Earned Value Method (EVM) allows the progress of a project's implementation to be controlled with regards to its scope, cost and duration [19]. The assumption of this method is to compare the planned progress of design works (planned scope) in the context of time (schedule) and cost (budget) to the actual implementation [20]. The method uses several indicators, such as: planned value (PV) – also known as the budgeted cost of work scheduled (BCWS), earned value (EV) – also referred to as the budgeted cost of work performed (BCWP), actual cost (AC) – also known as the actual cost of work performed (ACWP); appropriately determined deviations: schedule variance (SV), cost variance (CV); indexes: schedule performance index (SPI), cost performance index (CPI); values: estimated at completion (EAC) and estimated time at completion (ETTC), and also others [21, 22].

The main problem when applying the Earned Value Method is the difficulty to correctly determine or estimate the earned value (EV, BCWP). The earned value, also known as the budgeted cost of work performed, is a measure of actual work progress, i.e. the cost of all the work progress that was achieved within the project or its part, and which is calculated until the date of the report, and expressed with regards to planned costs. This indicator allows for the determination of how much the actual work would cost according to the plan. An important issue is the correct determination of the actual advancement of works in relation to the plan (schedule) [23]. Precise determination of this value is difficult and problematic, because most often in engineering practice, the actual advancement of the performed works is achieved by the Investor's Supervision Inspector or Bank Investment Supervision estimating the percentage progress of works. The subjective assessment of the progress of works is based on the experience of the building inspectors. For many construction projects, the advancement of works defined in this way is the basis for the amount of construction works performed in a given settlement period. The amount of works performed, which is approved by the Investor's Supervision Inspector and the Contractor, is the basis for invoicing the works. Therefore, very often the earned value (EV, BCWP) equals the value of the actual costs of the works performed (AC, ACWP). This means that EV = AC, and accordingly, the cumulative cost curves coincide.

The estimated earned costs and duration are not reliable in the first period of the project, but only stabilise in the second period in which, depending on the scenario adopted for further work, they take real values with high accuracy. In addition, all indicators are calculated in currency units, also deviation from the schedule, making it difficult to analyse and evaluate the results. Where the implementation of the project exceeds the deadline, the method shall show an irregularity which means it indicates that the project has been carried out as planned. These difficulties have contributed to the development of models and methods for more reliable forecasting of the total cost and deadline of projects, e.g. by introducing a hybrid methodology based on working packages and logical analysis of time [24], hybrid artificial intelligence [25] or by taking into account the impact of unplanned time and cost variances on the cash flow of the construction project [26].

Another, but equally effective tool for measuring the utilization of the financial outlays of a construction project is the presentation of planned cash flows on a timeline using a cumulative cost curve [27]. The cumulative cost curve shows the progress of the investment project from the commencement of construction works until their completion. The cumulative cost is the sum of the costs incurred by all resources assigned to a given task. Graphically, the cumulative cost curve is flattened in the initial and final stages of the construction project, while in the middle part it is steep, i.e. inclined at a large angle to the time axis. It resembles the shape of the letter “S”, and therefore the name of the cumulative cost curve is the “S curve” [28].

Both presented techniques (the Earned Value Method, the cumulative cost curve), in their basic application, are used to monitor and control the course of construction works. It should be noted, however, that the subject of the research is not the monitoring of the implementation of works, but the planning stage, which precedes the execution stage. Nevertheless, in order to develop a model for planning the course of the cumulative cost curve, which reflects reality, it is necessary to collect the required numerical data that contains all the information that is relevant from the point of view of research. Moreover, the data set must contain a statistically large number of measurements in order to constitute a certain pattern and reference point for the generalization of the examined issue.

3. Research methodology

In order to solve the set research goal, a proprietary research methodology consisting of 5 stages was developed.

3.1. Acquiring data for research

In order to achieve the set goal of the research, it is necessary to obtain reliable and real data concerning completed construction projects in the analysed homogeneous research group. The basic data that characterizes the course of each investment project include:

- the basic work and expenditure schedule, which includes a budget that is planned by a Contractor of the construction works, and which was contracted in the construction works contract, i.e. the cost of the investment and the duration of the investment project, and
- information about the actual course of the construction process, i.e. information provided by the Contractor of construction works about the works performed in a given settlement period. The information is provided at fixed intervals (e.g. once a month) to the Investor, Investor’s Supervision Inspector and/or Banking Investment Supervision.

Based on the basic work and expenditure schedule, it is possible to graphically present the planned course of the cumulative cost curve, while on the basis of the monthly summary of the amount of works performed, which includes the percentage advancement and the value of works carried out in a given settlement period, it is possible to recreate the course of the implementation of works and to also develop the shape of the curve of the actual cumulative costs.

As part of the conducted research, data was collected concerning 30 construction projects belonging to 8 research groups, which correspond to 8 different investment sectors, i.e. 510 reports prepared by the Bank Investment Supervision participating in the course of the analysed construction projects. All the collected data presented in Table 1 refer to investments implemented in Poland in the years 2006–2020.

Table 1. Summary of the number of analysed construction projects and obtained reports

Group	Investment number	Number of measurements	
A. Residential buildings	**A.1**	**16**	**188**
	A.2	**16**	
	A.3	**16**	
	A.4	**8**	
	A.5	**15**	
	A.6	**15**	
	A.7	**22**	
	A.8	**18**	
	A.9	**22**	
	A.10	**22**	
	A.11	**18**	
B. Office buildings	B.1	30	80
	B.2	27	
	B.3	23	
C. Hotel buildings	C.1	34	57
	C.2	6	
	C.3	17	
D. Commercial and Leisure Centres	D.1	15	121
	D.2	13	
	D.3	11	
	D.4	24	
	D.5	17	
	D.6	6	
	D.7	16	
	D.8	19	
E. Logistic Centres	E.1	8	16
	E.2	8	
F. Health Centres	F.1	13	13
G. Production Plants	G.1	25	25
H. Airport Developments	H.1	10	10
TOTAL		**510**	

3.2. Development of the data base

On the basis of information collected in stage 1, it is possible to prepare a collective data summary for each analysed construction project in the form of a two-dimensional table. In the table, each successive row contains data concerning the subsequent reporting period. Each dataset contains the following values:

- the budgeted cost of work scheduled – $BCWS_i$ – determined for each individual examined period $i \in (1, \ldots, n)$, where n is the number of settlement periods on the basis of the Investor's work and expenditure schedule. This value is expressed in the calculation currency adopted for the given investment, e.g. PLN,
- the cumulative value of the budgeted cost of work scheduled (C_{BCWS_i}) – obtained by summing up all the values of the budgeted cost of work scheduled from the whole analysed period according to formula $C_{BCWS} = \sum_{i=1}^{n} BCWS_i$. This value is expressed in the calculation currency adopted for the given investment, e.g. PLN,
- the actual cost of work performed ($ACWP_i$) – determined for each individual examined period $i \in (1, \ldots, m)$, where m is the number of settlement periods on the basis of the amount of expenditure performed; This value is expressed for the given investment in the adopted calculation currency, e.g. PLN,
- the cumulative value of the actual cost of work performed (C_{ACWP}) – obtained by summing up all the values of the actual costs of the work performed for the entire analysed period based on the formula $C_{ACWP} = \sum_{i=1}^{n} ACWP_i$. This value is expressed in the currency adopted for the building investment, e.g. PLN.

3.3. Processing the collected data

Each project is characterized by a different duration and cost of implementation. In order to be able to compare the collected data for different construction projects, it is necessary to properly process the collected data. For this purpose, for each individual analysed construction project, it is necessary to determine the following auxiliary unitless values:

- in relation to the budgeted cost of work scheduled ($BCWS$):
  - the unitless value of the budgeted cost of work scheduled V_{BCWS} for each single period i calculated from formula $V_{BCWS} = \dfrac{BCWS_i}{C_{BCWS}}$;
  - the unitless value of the planned time of work scheduled V_{PD} for each individual examined period i calculated from formula $V_{PD} = \dfrac{PD_i}{C_{PD}}$, where: C_{PD} – the planned duration of the building investment, PD_i – the examined subsequent planned implementation period $i \in (1, \ldots, n)$, where is the number of settlement periods based on the basic work and expenditure schedule;
- in relation to the actual cost of the work performed (V_{ACWP}):
  - the unitless value of the actual cost of the work performed V_{ACWP} for each single examined period i, which was calculated from formula $V_{ACWP} = \dfrac{ACWP_i}{C_{ACWP}}$;

- the unitless value of the actual time of the work performed V_{AD} for each individual examined period i, which was calculated from formula $V_{AD} = \dfrac{AD_i}{C_{AD}}$, where: C_{AD} – the actual duration of the building investment, AD_i – the examined subsequent actual implementation period $i \in (1, \ldots, m)$, where m is the number of settlement periods based on the amount of expenditure performed;

– the ratio of the actual cost of the work performed (V_{ACWP}) to the value of the cumulative budgeted cost of the work scheduled (C_{BCWS}), which was calculated from formula: $V_{ACWP/BCWS} = \dfrac{ACWP_i}{C_{BCWS}}$;

– the ratio of the actual duration of the building investment C_{AD} to the planned time of the work scheduled $V_{AD/PD} = \dfrac{AD_i}{C_{PD}}$.

3.4. Plotting the cumulative cost curves

Using the unitless values determined in stage 3, it is possible for each construction project to plot cumulative cost curves within the scope of:

– the budgeted costs of the work scheduled – V_{BCWS} in relation to V_{PD},

– the actual costs of the work performed – V_{ACWP} in relation to V_{AD},

– the deviations between the budgeted costs of the work scheduled and the actual costs of the work performed – $V_{ACWP/BCWS}$ in relation to $V_{AD/PD}$.

3.5. Determination of the area of cost curves

Using the cumulative cost curves developed in stage 4, it is possible to graphically define the area in which the analysed curves are located. In turn, on the basis of the areas of the curves, it is possible to analytically determine the course of the curves that have the best adjustment to the function. In order to describe the course of the curves, a polynomial regression and a trend function were used. The correlation coefficient R and the coefficient of determination R^2 were used as a measure of the adjustment of the trend function to the real values. The coefficient of determination takes values from 0 to 1. The adjustment of the model is better when the value of R^2 is closer to one. Therefore, if the correlation coefficient takes values within the range of:

– $0.00 < R < 0.33$ – there is a weak and insignificant correlative relationship and the model does not sufficiently describe the studied phenomenon,

– $0.34 < R < 0.66$ – there is an average correlative relationship and the model sufficiently describes the studied phenomenon,

– $0.67 < R < 0.90$ – there is a strong correlative relationship and the model describes the studied phenomenon well,

– $0.91 < R < 1.00$ – there is a very strong correlative relationship and the model describes the studied phenomenon very well.

The designated areas and the curves of the best adjustment enable the area for the appropriate planning of construction projects to be determined.

4. Research results

The article analyses data concerning buildings that belong to the category of residential buildings. 11 facilities were examined, and the data for the analysis came from 188 reports of the Bank Investment Supervision. The tasks of the Bank Investment Supervision (BIS) include: preliminary reporting (verification of the documentation provided by the Investor, with all permits and administrative decisions, as well as the planned budget), monthly reporting (constant monitoring of the investment implementation, monitoring of the investment execution status), and final reporting (final investment implementation). All the collected data concern investments implemented in Poland in the period of 2006–2020.

Table 2 presents a fragment of the collected data of the analysed construction projects, while Table 3 presents the unitless values calculated in accordance with the proposed research methodology (step 3) for one exemplary construction project – A1.

Table 2. Data characterizing the analysed construction projects (part of the summary)

Building investment	$BCWS_1$	$BCWS_2$	...	C_{BCWS}	$ACWP_1$	$ACWP_2$	...	C_{ACWP}
A1	1,025,000.00	2,125,000.00		17,002,557.00	1,055,000.00	3,205,000.00		17,002,557.00
A2	315,000.00	800,000.00		12,580,200.00	319,537.08	1,377,531.90		12,580,200.00
...								

Figures 1–3 show the obtained areas of the cumulative cost curves and the curves that best describe the analysed ranges. Figure 1 shows the areas of the cost curves with regards to the planned costs of the work scheduled (in short: plan vs. plan). Figure 2 shows the area of the cost curves with regards to the actual costs of the work performed (in short: reality vs. reality).

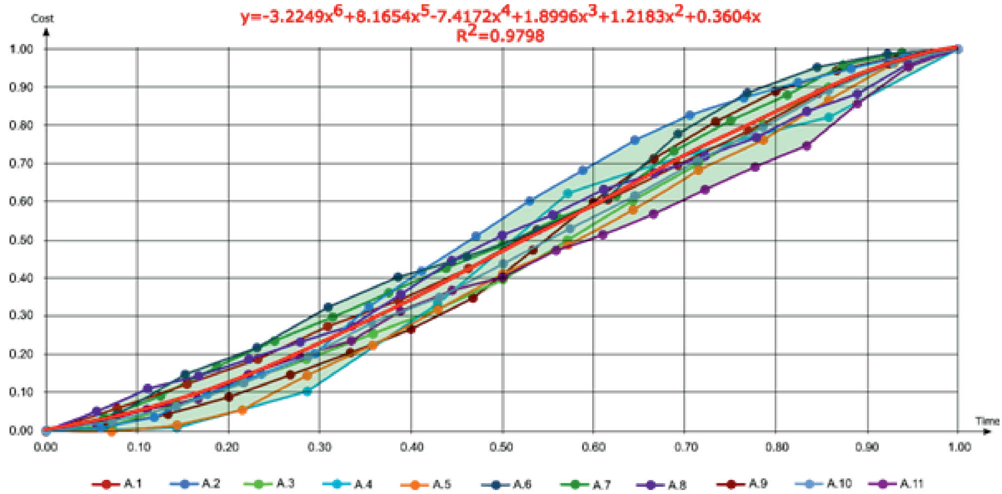

Fig. 1. The area of the cost curves with regards to the budgeted costs of the work scheduled

Table 3. Summary of the determined values for the exemplary construction project A.1

Period	The cumulative value of the budgeted cost of work scheduled	The cumulative value of the actual cost of work performed	The unitless value of the budgeted cost of work scheduled	The unitless value of the planned time of work scheduled	The unitless value of the actual cost of work performed	The unitless value of the actual time of work performed	The ratio of the actual cost of work performed to the cumulative value of the budgeted cost of work scheduled	The ratio of the actual duration of the construction project to the planned time of work scheduled
i	$BCWS_i$	$ACWP_i$	V_{BCWS}	V_{PD}	V_{ACWP}	V_{AD}	$V_{ACWP/BCWS}$	$V_{AD/PD}$
1	1,025,000.00	1,055,000.00	0.06	0.08	0.06	0.06	0.06	0.08
2	2,125,000.00	2,305,000.00	0.12	0.15	0.14	0.13	0.14	0.15
3	3,255,000.00	3,305,000.00	0.19	0.23	0.19	0.19	0.19	0.23
4	4,705,000.00	4,153,000.00	0.28	0.31	0.24	0.25	0.24	0.31
5	5,855,000.00	5,211,400.00	0.34	0.38	0.31	0.31	0.31	0.38
6	7,295,000.00	6,329,000.00	0.43	0.46	0.37	0.38	0.37	0.46
7	8,938,000.00	7,231,000.00	0.53	0.54	0.43	0.44	0.43	0.54
8	10,300,200.00	8,248,600.00	0.61	0.62	0.49	0.50	0.49	0.62
9	11,869,200.00	9,367,300.00	0.70	0.69	0.55	0.56	0.55	0.69
10	13,418,200.00	10,370,100.00	0.79	0.77	0.61	0.63	0.61	0.77
11	15,078,565.00	11,211,600.00	0.89	0.85	0.66	0.69	0.66	0.85
12	16,430,065.00	12,312,600.00	0.97	0.92	0.72	0.75	0.72	0.92
13	17,002,557.00	13,989,600.00	1.00	1.00	0.82	0.81	0.82	1.00
14		15,772,449.00			0.93	0.88	0.93	1.08
15		16,326,659.00			0.96	0.94	0.96	1.15
16		17,002,557.00			1.00	1.00	1.00	1.23

In turn, Figure 3 shows the area of the cost curves with regards to the deviations between the budgeted costs of the work scheduled and the actual costs of the work performed (in short: plan vs. reality). In addition, in the background of Figure 3, there is an area designated for the budgeted costs of the work scheduled (Figure 1), which enabled the planned values to be compared with the actual ones.

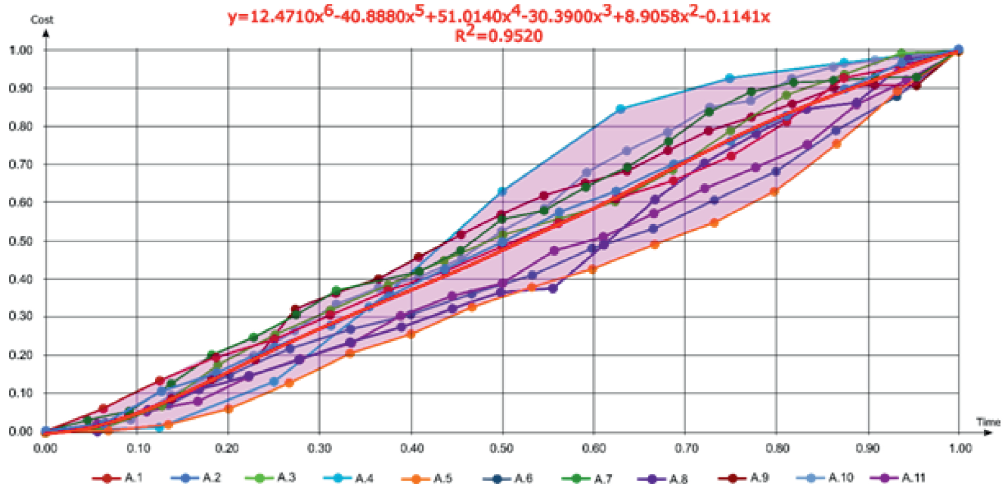

Fig. 2. The area of the cost curves with regards to the actual costs of the work performed

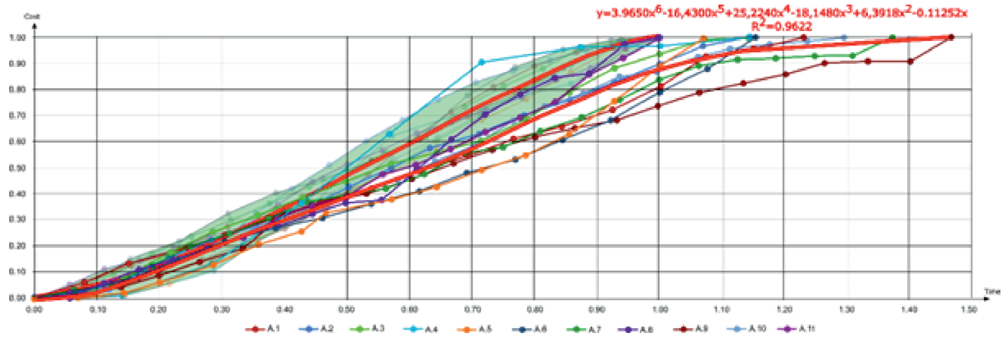

Fig. 3. The areas of the cost curves with regards to the deviations between the budgeted costs of the work scheduled and the actual costs of the work performed in the context of the budgeted costs of the work scheduled

For each analysed area of the cost curves, a trend function was determined. A high value of the correlation coefficient was obtained for the 6th order polynomial. The 6th order polynomial describes the course of the curves with an accuracy of over 95%. The correlation coefficient reached values close to 0.98, which means that there is a very strong correlative relationship and that the model very well describes the analysed phenomenon, which is the course of the cumulative cost curves.

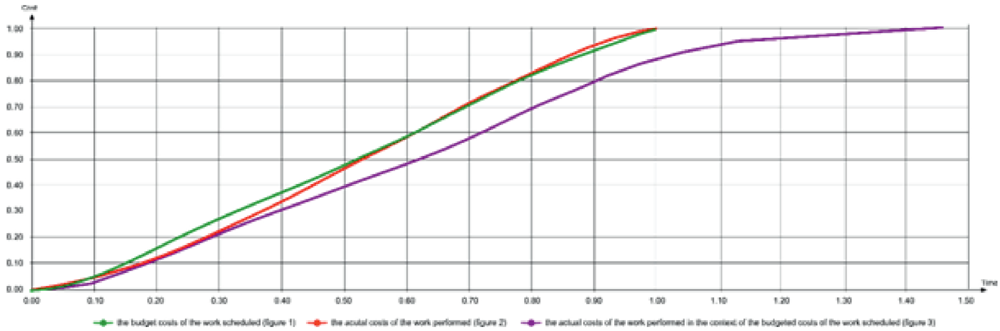

Fig. 4. Best fit curves for the construction projects analysed related to the construction of Residential Buildings

The analysis of the obtained cumulative cost curve areas shows that:

– the determined waveforms of the curves with the best adjustment of the curve to the function fit into the 6th degree polynomial with high accuracy. The values of the coefficients of determination R^2 and correlation R for the analyzed data are close to one. This means that there is a very strong correlative relationship and that the model very well describes the studied phenomenon, which is the course of the cumulative cost curves;
– for the area of the budgeted cost curve, the 6th degree polynomial describes the course of the real cost curve with an accuracy of over 98% and a level of correlation close to 1;
– for the area of the actual cost curve, the 6th order polynomial describes the course of the actual cost curve with an accuracy of over 97% and a level of correlation close to 1.

A comparative analysis of the obtained areas of the cumulative cost curves and the curves with the best adjustment to the analysed construction projects, which are related to the construction of residential buildings, showed that:

– the budgeted costs resulting from the basic work and expenditure schedule slightly differ from the actual costs incurred during the implementation. Only 4 projects exceeded the budgeted costs by 2–4%, while the costs for the remaining 7 projects were within the planned budget,
– the planned completion time resulting from the basic work and expenditure schedule differs significantly from the actual duration of the investment. Only 2 investments were completed on schedule, while the remaining 9 investments were completed after the scheduled time. The actual completion time from the planned time was longer by 14% to 47% when compared to the planned completion date of the investment. The average value of the investment duration was equal to 1.15±0.15.
– in the classic approach to cost planning, it is assumed that the implementation will take place much faster than in reality, as shown in Figure 3. According to the cost curves, the planned work and expenditure advancement in the first stage of the implementation is much greater than in reality (the curve of the budgeted costs of the work scheduled is above the actual curve of the work performed). According to the obtained 6th degree polynomials, for half of the planned duration of works, the planned work and expenditure advancement is approx. 46%, while the actual advancement is approx. 35%;

– the obtained areas of the cost curves for the budgeted costs of the work scheduled and the actual costs of the work performed in relation to the actual cost show that costs are generated at a much faster pace than planned in the second stage of the implementation of works.

5. Discussion of the results and limitations

The method of planning the course of the cumulative cost curve in construction projects (which was proposed in the article) using the cumulative cost curve (S-curve) fits well in the area of research related to the planning, monitoring and management of construction projects. The technique of the S-curve is commonly used for control. However, the traditional method of estimating cost curves based on the schedule is not always accurate, and therefore many alternative empirical models have been suggested as an alternative, e.g. using a polynomial function to generalize S-curves [29–31], methods of simulation [32,33], or methods of artificial intelligence [34, 35]. The analysis of the literature shows that the S-curve models proposed to date usually differ from reality and are too complicated, and thus not practical in the planning and management of construction projects. The article presents, according to the author, the simplest possible model for determining the course of the curve of the cumulative costs of construction works. The proposed model is practical and easy to apply, because it was developed as a result of the authors' own measurements of the incremental value of the amount of work and expenditure performed. The measurements were included in the cyclical coherent auditing reports of the Bank Investment Supervision, which were verified by the Financing Bank and the Investor's Supervision.

On the basis of the obtained results, it has been proved that the planned work and expenditure advancement of a housing construction is greater in the first stage of its implementation when compared to the actual state. The designated 6th degree polynomials describe the regularity that for half of the planned duration of works, the planned work and expenditure advancement is approx. 46%, while the actual advancement is approx. 35%. The obtained areas of the cost curves for the budgeted costs of the work scheduled and the actual costs of the work performed indicate that the costs are generated faster than planned in the second stage of construction works.

The conducted research has several important limitations that are worth mentioning. Firstly, in the conducted research, each analysed investment is unique and unrepeatable due to its specificity, difficulties, uncertainties and risks. Each analysed construction project was located in a different location and was implemented by different contractors. The human factor plays a very important role in the analysed issues, however, due to the financial nature of the collected research material, the influence of this factor on the occurrence of deviations in time and cost was not studied.

Secondly, in many of the analysed cases, the collected data show overlapping values between the ACWP and the BCWP. The basic task that was difficult to perform was a reliable and comprehensive control of the progress of work. Therefore, only the values concerning the budgeted costs of the work scheduled (BCWS) and the actual costs of the work performed (ACWP) were analysed in the research.

Thirdly, only the actual direct costs related to the implementation of construction works within the shell & core, internal installations, external networks, and the finishing works of residential buildings up to the so-called developer state were subjected to the analysis. The analysis does not take into account additional costs resulting from the entire life cycle of a building object, e.g. operating costs, profit on sales, discount rates [36].

6. Summary

Appropriate planning of construction projects, in terms of the time and cost of implementation, is a key element of success. Completion of the implementation within the planned budget and time is desired by both Contractors and Investors. The method of shaping the cumulative cost curve (S-curve) proposed in the article is a helpful tool that can be used to plan financial flows.

Cumulative cost curve analysis is commonly used for project planning and control, but the traditional cost curve estimation method based solely on schedule is not always accurate. The analysis of more than a dozen cost curves carried out in the article shows that the previously proposed models of projected S curves tend to deviate from reality and are too complex and therefore not practical in the planning and management of construction projects.

Knowing the budgeted cost and duration of a construction project, and by using the proposed 6th degree polynomial, it is possible to determine the planned monthly work and expenditure amounts, and thus correctly plan the utilization of investment costs during the implementation of monitored buildings.

In the article, the analysis is limited to only collective housing buildings. It is advisable to continue research related to other construction objects, e.g. commercial and service facilities, etc. The proposed method is constantly being improved, and thanks to its development and modification it will be possible to create even simpler and more accurate methods of planning the costs of implementing various investment tasks in the construction industry with regards to their character/classification.

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Planowanie czasu i kosztu realizacji przedsięwzięć budowlanych na przykładzie budynków zbiorowego zamieszkania

Słowa kluczowe: zarządzanie przedsięwzięciami budowlanymi, czas, koszt, budynki zbiorowego zamieszkania

Streszczenie:

Nieustanny wzrost liczby ludności miast wpływa na rozwój budownictwa mieszkaniowego, głównie w sektorze developerskim. Inwestorzy w swoich działaniach, związanych z czerpaniem zysku ze sprzedaży mieszkań nastawieni są na terminową i zgodną z założeniami budżetowymi realizację budynków mieszkalnych. W związku z tym pojawia się problem prawidłowego zaplanowania kosztów i czasu trwania inwestycji i skutecznego monitorowania realizacji i ponoszonych nakładów finansowych.

Istnieje wiele metod do szacowania/prognozowania przepływów finansowych związanych z realizacją robót budowlanych, jednak bardzo często są one skomplikowane i wymagają od Inwestorów określenia różnych i często trudnych do określenia zmiennych o charakterze losowym.

Celem prowadzonych badań było określenie kształtu i przebiegu krzywych kosztowych dla przedsięwzięć budowlanych związanych z realizacją budynków zbiorowego zamieszkania. Na podstawie analizy przeprowadzonych badań własnych w jednorodnej grupie badawczej 11 budynków zbiorowego zamieszkania podjęta została autorska próba wyznaczenia pola krzywej, wskazująca obszar poprawnego planowania skumulowanych kosztów i przewidywania ich odchyleń nakładów finansowych przedsięwzięć budowlanych. Znając planowany koszt i czas trwania przedsięwzięcia budowlanego i korzystając z zaproponowanego wielomianu 6-go stopnia możliwe jest określenie planowanych miesięcznych przerobów rzeczowo-finansowych, a tym samym prawidłowe zaplanowanie w czasie kosztów inwestycyjnych.

Metodyka i przebieg badań

Aby osiągnąć postawiony cel badań niezbędne było pozyskanie rzetelnych i rzeczywistych danych dotyczących zrealizowanych przedsięwzięć budowlanych w analizowanej jednorodnej grupie badawczej. Do podstawowych danych charakteryzujących przebieg każdego przedsięwzięcia inwestycyjnego należą: bazowy harmonogram rzeczowo-finansowy, zawierający planowany przez wykonawcę prac budowlanych, zakontraktowany w umowie o roboty budowlane, budżet, tj. koszt inwestycji oraz czas trwania przedsięwzięcia inwestycyjnego, oraz informacje o rzeczywistym przebiegu procesu budowlanego, tzn.

informacje przekazywane przez wykonawcę prac budowlanych o zrealizowanych pracach w danym okresie rozliczeniowym, przekazywanych w ustalonych odstępach czasu (np. 1 raz w miesiącu), do inwestora, inspektora nadzoru inwestorskiego i/lub bankowego inspektora nadzoru.

W ramach prowadzonych badań zgromadzono dane dotyczące 30 przedsięwzięć budowlanych, należących do 8 grup badawczych, odpowiadającym 8 zróżnicowanym sektorom inwestycyjnym, tj. 510 raportów sporządzanych przez uczestniczących w przebiegu analizowanych przedsięwzięć budowlanych inspektorów nadzoru bankowego. Wszystkie zgromadzone dane przedstawione w tabeli 1 dotyczą inwestycji zrealizowanych w Polsce w okresie 2006–2020. Dla każdego analizowanego przedsięwzięcia budowlanego, możliwe było opracowanie zbiorczego zestawienia danych w formie tabeli dwuwymiarowej.

Każde przedsięwzięcie charakteryzuje się innym czasem trwania oraz kosztem realizacji. Aby możliwe było porównanie zgormadzonych danych dla różnych przedsięwzięć budowlanych, konieczne było odpowiednie przetworzenie zgromadzonych danych. W tym celu dla każdego pojedynczego analizowanego przedsięwzięcia budowlanego konieczne było wyznaczenie pomocniczych wartości niemianowanych.

Korzystając z wyznaczonych wartości niemianowanych możliwe było dla każdego przedsięwzięcia budowlanego wykreślenie krzywych kosztów skumulowanych w zakresie planowanych kosztów planowanej pracy, rzeczywistych kosztów wykonanej pracy, odchyleń między planowanymi kosztami planowanej pracy a rzeczywistymi kosztami wykonanej pracy.

Korzystając w krzywych kosztów skumulowanych możliwe było graficzne określenie przestrzeni, w której znajdują się analizowane krzywe. Na podstawie przestrzeni krzywych możliwe było analityczne wyznaczenie przebiegu krzywych o najlepszym dopasowaniu krzywej do funkcji. Aby opisać przebieg krzywych wykorzystano regresję wielomianową i funkcję trendu. Wyznaczone przestrzenie oraz krzywe najlepszego dopasowania pozwoliły na określenie przestrzeni prawidłowego planowania przedsięwzięć budowlanych.

Wnioski

Analiza otrzymanych przestrzeni krzywych kosztów skumulowanych wykazała, że:

– wyznaczone przebiegi krzywych o najlepszym dopasowaniu krzywej do funkcji z wysoką dokładnością wpisują się w wielomian 6-go stopnia. Wartości współczynników determinacji R^2 i korelacji R dla analizowanych danych są bliskie jedności;

– planowane koszty wynikające z bazowego harmonogramu rzeczowo-finansowego nieznacznie odbiegają od rzeczywistych kosztów ponoszonych w trakcie realizacji (2–4%);

– planowany czas realizacji wynikający z bazowego harmonogramu rzeczowo-finansowego znacznie odbiega od rzeczywistego czasu trwania inwestycji (14%–47%);

– wg krzywych kosztowych planowane zaawansowanie rzeczowe i finansowe jest dużo większe w pierwszym etapie realizacji w porównaniu do rzeczywistości, natomiast w drugim etapie realizacji prac koszty generowane są w duży szybszym tempie niż planowane.

Podsumowanie

Prawidłowe zaplanowanie przedsięwzięć budowlanych, w kontekście czasu i kosztu realizacji, stanowi kluczowy element sukcesu. Zakończenie realizacji w zaplanowanym budżecie i czasie jest pożądane zarówno przez wykonawców robót budowlanych jak i inwestorów. Pomocnym narzędziem, zastosowanym w artykule, do planowania przepływów finansowych, jest metoda kształtowania krzywej kosztów skumulowanych (krzywa „S”).

Znając planowany koszt i czas trwania przedsięwzięcia budowlanego i korzystając z zaproponowanego wielomianu 6-go stopnia możliwe jest określenie planowanych miesięcznych przerobów rzeczowo-finansowych, a tym samym prawidłowe zaplanowanie utylizacji kosztów inwestycyjnych w czasie realizacji monitorowanych obiektów budowlanych.

W artykule analiza ogranicza się tylko do budynków zbiorowego zamieszkania. Wskazane jest kontynuowanie badań związanych z innymi obiektami budowlanymi, np. obiektami handlowo-usługowymi, itp. Zaproponowana metoda jest stale udoskonalana i dzięki jej rozwojowi i modyfikacji możliwe będzie wypracowanie jeszcze prostszych i dokładniejszych metod planowania kosztów realizacji różnych zadań inwestycyjnych w budownictwie w zależności od ich charakteru/klasyfikacji.

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